II.—The Forests of England; and the Management of them in Bye-gone Times. Price 6s.

Ancient forests, chases, parks, warrens, and woods, are described; details are given of destructive treatment to which they have been subjected, and of legislation and literature relating to them previous to the present century.

EXTRACT FROM PREFACE.—'Contrast with this [the paucity of works in English on Forest Science], the richness of Continental languages in literature on such subjects. I have had sent to me lately *Ofversight of Svenska Skogsliteraturen, Bibliografiska Studieren of Axel Cnattingius*, a list of many books and papers on Forest Science published in Sweden; I have also had sent to me a work by Don José Jordana y Morera, Ingenero de Montes, under the title of *Apuntes Bibliographico Forestale*, a *catalogue raisonné* of 1126 printed books, MSS., &c., in Spanish, on subjects connected with Forest Science.

'I am at present preparing for the press a report on measures adopted in France, Germany, Hungary, and elsewhere, to arrest and utilise drift-sand by planting them with grasses and trees; and in *Der Europaeische Flug-sand und Seine Cultur, von Josef Wessely General Domaenen-Inspecktor, und Forst-Academie-Direktor*, published in Vienna in 1873, I find a list of upwards of 100 books and papers on that one department of the subject, of which 30, in Hungarian, Latin, and German, were published in Hungary alone.

'According to the statement of one gentleman, to whom application was made by a representative of the Government at the Cape, for information in regard to what suitable works on Forest Economy could be procured from Germany, the works on *Forst-Wissenchaft*, Forest Science, and *Forst-Wirthchaft*, Forest Economy, in the German language may be reckoned by cartloads. From what I know of the abundance of works in German, on subjects connected with Forestry, I am not surprised that such a report should have been given. And with the works in German may be reckoned the works in French.

'In Hermann Schmidt's *Fach Katalogue*, published in Prague last year (1876), there were given the titles, &c., of German works in *Forst und Jagd-Literatur*, published from 1870 to 1875 inclusive, to the 31st of October of the latter year, amounting in all to 650, exclusive of others given in an appendix, containing a selection of the works published prior to 1870. They are classified thus:—General Forest Economy, 93; Forest Botany, 60; Forest History and Statistics, 50; Forest Legislation and Game Laws, 56; Forest Mathematics, 25; Forest Tables and Measurements, &c., 148; Forest Technology, 6; Forest Zoology, 19; Peat and Bog Treatment, 14; Forest Calendars, 6; Forest and Game Periodicals, 27; Forest Union and Year Books, 13; Game, 91; Forest and Game in Bohemian, 44. In all, 652. Upwards of a hundred new works had been published annually. Amongst the works mentioned is a volume entitled *Die Literatur der letzten sieben Jahre* (1862-1872) *aus* *dem Gesammtgebiete der Land-und Forst-wirthschaft mit Einschluss der landw. Geweber u. der Jagd, in deutscher, französischer u englisher Sprache Herausg. v. d. Buchandl, v.* Gerold and Co., *in Wein,* 1873, a valuable catalogue filling 278 pages in large octavo.

'This volume is published as a small contribution to the literature of Britain, on subjects pertaining to Forest Science.

'It is after due consideration that the form given to the work—that of a compilation of what has been stated in works previously published—has been adopted.

III.—Forestry of Norway. Price 5s.

There are described in successive chapters the general features of the country. Details are given of the geographical distribution of forest trees, followed by discussions of conditions by which this has been determined—heat, moisture, soil, and exposure. The effects of glacial action on the contour of the country are noticed, with accounts of existing glaciers and snow-fields. And information is supplied in regard to forest exploitation and the transport of timber, in regard to the export timber trade, to public instruction in sylviculture, and to forest administration, and to ship-building and shipping.

EXTRACT FROM PREFACE.—'In the spring of 1877, while measures were being taken for the formation of an Arboretum in Edinburgh, I issued a pamplet entitled *The Schools of Forestry in Europe: a Plea for the Creation of a School of Forestry in connection with the Arboretum in Edinburgh.* After it was made known that arrangements were being carried out for the formation of an International Exhibition of forest products, and other objects of interest connected with forestry, in Edinburgh with a view to promoting the movement for the establishment of a National School of Forestry in Scotland, and with a view of furthering and stimulating a greater improvement in the scientific management of woods in Scotland, and the sister countries, which has manifested itself during recent years, the council of the East Lothian Naturalists' Club resolved on having a course of lectures or popular readings on some subject connected with forestry, which might enable the members and others better to profit by visits to the projected Exhibition, and which should be open to the public at a moderate charge. The conducting of these was devolved upon me, who happened to be vice-president of the club. The following treatise was compiled from information then in my possession, or within my reach, and it constituted the basis of these lectures.'

IV.—Finland: its Forests and Forest Management. Price 6s 6d.

In this volume is supplied information in regard to the lakes and rivers of Finland, known as *The Land of a Thousand Lakes*, and as *The Last-born Daughter of the Sea;* in regard to its physical geography, including notices of the contour of the country, its geological formations and indications of glacial action, its flora, fauna, and climate; and in regard to its forest economy, embracing a discussion of the advantages and disadvantages of *Svedjande*, the *Sartage* of France, and the *Koomaree* of India; and details of the development of Modern Forest Economy in Finland, with notices of its School of Forestry, of its forests and forest trees, of the disposal of its forest products, and of its legislation and literature in forestry are given.

Extract from Preface.—'I happened to spend the summer of 1879 in St. Petersburg, ministering in the British and American Chapel in that city, while the pastor sought relaxation for a few months at home. I was for years the minister of the congregation worshipping there, and I had subsequently repeatedly spent the summer among them in similar circumstances. I was at the time studying the Forestry of Europe; and I availed myself of opportunities afforded by my journey thither through Norway, Sweden, and Finland, by my stay in Russia, and by my return through Germany and France, to collect information bearing upon the enquiries in which I was engaged. On my return to Scotland I contributed to the *Journal of Forestry* a series of papers which were afterwards reprinted under the title *Glances at the Forests of Northern Europe*. In the preface to this pamphlet I stated that in Denmark may be studied the remains of forests in pre-historic times; in Norway, luxuriant forests managed by each proprietor as seemeth good in his own eyes; in Sweden, sustained systematic endeavours to regulate the management of forests in accordance with the latest deliverances of modern science; in Finland, *Sartage* disappearing before the most advanced forest economy of the day; and in Russia, *Jardinage* in the north, merging into more scientific management in Central Russia, and *Réboisement* in the south. This volume is a study of information which I then collected, together with information which I previously possessed, or have subsequently obtained, in regard to the Forests and Forestry of Finland.'

Translation of Extracts from Letters from Dr A. Blomqvist, Director of the Finnish National School of Forestry at Evois:—'On my return from Salmos three weeks ago I had the great pleasure to receive your volume on the Forests and Forest Management in Finland. I return you grateful thanks for the gift, and no less for publishing a description of the forestal condition of our country. It is with sentiments of true gratitude I learn that you had previously taken part in a work so important to our country as the preparation of a new edition of the New Testament in Finnish. Your descriptions of our natural scenery are most excellent and interesting. Personally I feel most interest in your accounts of *Koomaree.* I value it much. and not less so your concurrent final conclusion in regard to the effects of the exercise of it in Finland.'

Translation of Statement by M. De La Grye, in the *Revue des Eaux et Fôrets* of January 1884 :—'In an address delivered some weeks since at a banquet of exhibitors in the French section at Amsterdam, M. Herisson, Minister of Commerce, expressed an intention to publish a series of small books designed to make known to French merchants foreign lands in a commercial point of view. If the Minister of Commerce wishes to show to our merchants the resources possessed by Finland, he need not go far to seek information which may be useful to them, they will be found in a small volume which has just been published by Mr John Croumbie Brown.

'Mr Brown is one of those English ministers, who, travelling over the world in all directions [some at their own cost], seeking to spread the Word of the Lord in the form of Bibles translated into all languages, know how to utilise the leisure left to them at times while prosecuting this mission. Some occupy themselves with physical science, others with archæology, some with philology, many with commerce ; Mr Brown has made a special study of sylviculture. He has already published on this subject many works, from amongst which we may cite these : *Hydrology of South Africa ; The Forests of England ; The Schools of Forestry in Europe ; Rêboisement in France ; Pine Plantations on Sand Wastes in France.*

'His last book on Finland is the fruit of many journeys made in that country, which he visited for the first time in 1833, but whither he has returned frequently since that time. Mr Brown gives narratives of his voyages on the lakes which abound in Finland, and his excursions in the immense forests, the exploitation of which constitutes the principal industry of the country. The School of Forestry at Evois has furnished to him much precise information in regard to the organisation of the service, and the legislation and the statistics of forests, which, added to what he had procured by his own observation, has enabled him to make a very complete study of this country, poetically designated *The Land of a Thousand Lakes,* and which might also justly be called *The Kingdom of the Forest,* for there this reigns sovereign.'

V.—Forest Lands and Forestry of Northern Russia. Price 6s 6d.

Details are given of a trip from St. Petersburg to the forests around Petrozavodsk on Lake Onega, in the government of Olonetz; a description of the forests on that government by Mr Judrae, a forest official of high position, and of the forests of Archangel by Mr Hepworth Dixon, of Lapland, of the land of the Samoides and of Nova Zembla; of the exploitation of the forests by *Jardinage*, and of the evils of such exploitation; and of the export timber trade, and disposal of forest products. In connection with discussions of the physical geography of the region information is supplied in regard to the contour and general appearance of the country; its flora, its forests, and the palaeontological botany of the regions beyond, as viewed by Professor Heer and Count Saporta; its fauna, with notices of game, and with copious lists of coleoptera and lepidoptera, by Forst-Meister Gunther, of Petrozavodsk.

EXTRACT FROM PREFACE.—'In the spring of 1877 I published a *brochure* entitled *The Schools of Forestry in Europe: a Plea for the Creation of a School of Forestry in connection with the Arboretum in Edinburgh*, in which with details of the arrangements made for instruction in Forest Science in Schools of Forestry in Prussia, Saxony, Hanover, Hesse, Darmstadt, Wurtemburg, Bavaria, Austria, Poland, Russia, Finland, Sweden, France, Italy, and in Spain, and details of arrangements existing in Edinburgh for instruction in most of the subjects included amongst preliminary studies, I submitted for consideration the opinion, "that with the acquisition of this Arboretum, and with the existing arrangements for study in the University of Edinburgh, and in the Watt Institution and School of Arts, there are required only facilities for the study of what is known on the Continent as Forest Science to enable these Institutions conjointly, or any one of them, with the help of the other, to take a place amongst the most completely equipped Schools of Forestry in Europe, and to undertake the training of foresters for the discharge of such duties as are now required of them in India, in our Colonies, and at home."

'This year has seen world-wide arrangements for an International Exhibition of forest products and other objects of interest connected with forestry in Edinburgh, "In the interests of forestry, and to promote a movement for the establishment of a School of Forestry in Scotland, as well as with a view of furthering and stimulating a greater improvement in the scientific management of woods in Scotland and the sister countries which has manifested itself during recent years."

'The following is one of a series of volumes published with a view to introduce into English forestal literature detailed information on some of the points on which information is supplied to students at Schools of Forestry on the Continent; and to make better known the breadth of study which is embraced in what is known there as *Forstwissenscaft*, or Forest Science.'

VI.—French Forest Ordinance of 1669; with Historical Sketch of Previous Treatment of Forests in France. Price 4s.

The early history of forests in France is given, with details of devastations of these going on in the first half of the seventeenth century; with a translation of the Ordinance of 1669, which is the basis of modern forest economy; and notices of forest exploitation in *Jardinage*, in *La Methode à Tire et Aire*, and in *La Methode des Compartiments.*

Extract from Preface.—' "The Celebrated Forest Ordinance of 1669:" Such is the character and designation generally given at the present day to the Ordinance in question. It is known, by reputation at least, in every country on the Continent of Europe; but, so far as is known to me, it has never before been published in English dress. It may possibly be considered antiquated; but, on its first promulgation, it was welcomed, far beyond the bounds of France, as bringing life to the dead; and I know of no modern system of Forest Exploitation, based on modern Forest Science, in which I cannot trace its influence. In the most advanced of these—that for which we are indebted to Hartig and Cotta of Saxony—I see a development of it like to the development of the butterfly from what may be seen in the structure of the chrysalis; and thus am I encouraged to hope that it may prove suggestive of beneficial arrangements, even where it does not detail what it may be deemed desirable to adopt.

'In my translation I have followed an edition issued with Royal approval in 1753, with one verbal alteration to bring it into accordance with certain older approved editions, and with another verbal alteration to bring it into accordance with editions issued in 1699, 1723, 1734, and 1747.'

Translation of notice by M. De La Grye for July 1883 in the *Revue des Eaux et Fôrets:* 'England, which with her immense possessions in India, in Canada, and in the Cape of Good Hope, is beyond all question a State rich in forests, has never up to the present time given to this portion of her domains more than a very moderate share of her attention; but for some years past public opinion is becoming alarmed, in view of the immense devastations which have been committed in them, and the forest question coming forward spontaneously has become the subject of numerous publications: amongst which, after the excellent monthly collection, the *Journal of Forestry and Estate Management,* comes the Translation of the Ordinance of 1669, which has just been published by Mr John Croumbie Brown. This translation of a monument of jurisprudence, well known in France, but which has never before been reproduced in English, has furnished to Mr Brown an opportunity of giving a historical sketch of French Forest Legislation, and an exposition of the different methods of exploitation followed in our country. Drawn from the best sources, and commented on with talent, these documents form an elegant volume, which the author has made the more complete by binding with it a summary of the treatise he has published on the Forests of England.'

VII. –Pine Plantations on Sand Wastes in France. Price 7s.

In this are detailed the appearances presented by the Landes of the Gironde before and after culture, and the Landes of La Sologne; the legislation and literature of France in regard to the planting of the Landes with trees; the characteristics of the sand wastes; the natural history, culture, and exploitation of the maritime pine, and of the Scots fir; and the diseases and injurious influences to which the maritime pine is subject.

Extracts from Preface.—'The preparation of this volume for the press was undertaken in consequence of a statement in the *Standard and Mail*, a Capetown paper, of the 22d July 1876, to the effect that in the estimates submitted to Parliament £1000 had been put down for the Cape Flats, it was supposed with a view to its being employed in carrying out planting operations as a means of reclaiming the sandy tracts beyond Salt River.

'This volume was originally compiled in view of what seemed to be required at the Cape of Good Hope. It has been revised and printed now, as a contribution towards a renewed enterprise to arrest and utilise sand-wastes which stretch from Table Mountain to the Hottentot Holland Mountains; and additional information is forthcoming if it should be desired.'

VIII.—Reboisement in France; or, Records of the Replanting of the Alps, the Cevennes, and the Pyrenees, with Trees, Herbage, and Bush, with a view to arresting and preventing the destructive consequences of torrents. Price 12s.

In this are given a *résume* of Surell's study of Alpine torrents, of the literature of France relative to Alpine torrents, and of remedial measures which have been proposed for adoption to prevent the disastrous consequences following from them—translations of documents and enactments, showing what legislative and executive measures have been taken by the Government of France in connection with *réboisement* as a remedial application against destructive torrents—and details in regard to the past, present, and prospective aspects of the work.

Extract from Preface.—'In a treatise on the Hydrology of South Africa I have given details of destructive effects of torrential floods at the Cape of Good Hope and Natal, and referred to the measures adopted in France to prevent the occurrence of similar disastrous floods there. The attention of the Legislative Assembly at the Cape of Good Hope was, last year, called by one of the members of the Assembly to the importance of planting trees on unproductive Crown lands. On learning that this had been done I addressed to the editor of the *Cape Argus* a communication, of which the following is a copy:—

'"I have before me details of destructive effects of torrents which have occurred since I left the Colony in the beginning of 1867. Towards the close of that year there occurred one, the damage occasioned by which to roads and to house property at Port Elizabeth alone was estimated at from £25,000 to £30,000. Within a year thereafter a similar destructive torrent occurred at Natal, in regard to which it was stated that the damage done to public works alone was estimated at £50,000, while the loss to private persons was estimated variously from £50,000 to £100,000. In the following year, 1869, a torrent in the Western Province occasioned the fall of a railway bridge, which issued in loss of life and loss of property, and personal injuries, for one case alone of which the railway proprietors were prosecuted for damages amounting to £5000. In Beaufort West a deluge of rain washed down the dam, and the next year the town was flooded by the waters of the Gamko; and the next year, 1871, Victoria West was visited with a similar disaster. Such are the sums and the damages with which we have to deal in connection with this question, as it affects the case; and these are only the most remarkable torrents of the several years referred to. I have spoken of millions of francs being spent on *réboisement* in France, and some may be ready to cry out, 'Nothing like such an expenditure can be undertaken at the Cape!' Perhaps not; but the losses occasioned by the torrents seem to amount at present to about a million of francs *in the year*. This falls in a great measure on individuals, that would fall on the community; and the community in return would benefit by water retained to fertilize the earth, instead of being lost in the sea, and by firewood and timber being grown where now there is none. These are facts well deserving of consideration in the discussion of the expediency of planting Crown lands with trees."

'Towards the close of last year, 1874, still more disastrous effects were produced by torrential floods. According to the report given by one of the Colonial newspapers, the damages done could not be estimated at much less than £300,000. According to the report given by another, the damage done to public works alone was estimated at £350,000,—*eight millions, seven hundred and fifty thousand francs.* And my attention was called anew to the subject.

'On addressing myself to M. Faré, Director-General of the Administration of Forests in France, there was afforded to me every facility I could desire for extending and verifying the information I had previously collected in regard to the works of *réboisement* to which I have referred. Copies of additional documents were supplied to me, with copies of works sanctioned by the Administration, and arrangements were made for my visiting and inspecting, with every assistance required, the works begun and the works completed; and thus I have been enabled to submit a much more complete report than it would otherwise have been in my power to produce.

'While the compilation I have prepared owes its publication at this time to the occurrence of the inundations of last year at the Cape of Good Hope, the publication has been undertaken in the hope that in other countries besides South Africa the information may be turned to practical account.'

Translation of extract from letter to the author by M. ALEXANDRE SURELL, *Ingenieur des Ponts et Chausses*, chairman of the *Compagnie des Chemins des Fer du Midi et du Canal lateral à la Garonne*, and author of *Etude sur les Torrents des Hautes-Alps, Ouvrage Couronne par l'Academie des Sciences en* 1842 :—'You are rendering an eminent service to society in calling the attention of serious thinkers to the subject of *réboisements* and *gazonnements*. It is a vital question affecting our descendants, specially in southern climates, there are useful truths which have to be diffused there, and you have fulfilled this duty amongst your countrymen.

'In France public opinion, long indifferent, is now sufficiently enlightened on the question, and much has been done.

'I have been able to establish in the course of a recent journey that, throughout a great part of Switzerland, in Styria, in Carinthia, and in the Tyrol, the same phenomena which have issued in the desolation of our French Alps are beginning to produce the same effects. There have been recognised a number of extinct torrents which had originated in the destruction of the forests. If people go on sleeping, and the administration or the communes do nothing to arrest the evil, posterity will have a sad inheritance devolved upon it.

'You have given, with very great clearness, a *résumé* of what I have done in France, be it by my works, or be it by my workings, for the regeneration of our mountains.'

Translation of extract from letter by the late M. Ernest Cézanne, *Ingenieur des Ponts et Chausses, Représentant des Hautes Alpes à l'Assemblée Nationale*, and author of *Une Suite* to the work of M. Surell. 'The post brought to me yesterday your very interesting volume on *Réboisement.* I at once betook myself to the perusal of it; and I am surprised that a foreigner could digest so completely such a collection of our French documents drawn from so many diverse sources. The problem of *réboisement and the regeneration of the mountains* is one of the most interesting which man has to solve, but it requires time and money, and with the authorities and political assemblies, technical knowledge which is as yet but very sparingly possessed. It is by books so substantial as yours, sir, that public opinion can be prepared to face the importance of this great work.'

IX.—Hydrology of South Africa; or Details of the Former Hydrographic Condition of Cape of Good Hope, and of Causes of its Present Aridity, with Suggestions of Appropriate Remedies for this Aridity. Price 10s.

In this the desiccation of South Africa, from pre-Adamic times to the present day, is traced by indications supplied by geological formations, by the physical geography or the general contour of the country, and by arborescent productions in the interior, with results confirmatory of the opinion that the appropriate remedies are irrigation, arboriculture, and an improved forest economy: or the erection of dams to prevent the escape of a portion of the rainfall to the sea—the abandonment or restriction of the burning of the herbage and bush in connection with pastoral and agricultural operations—the conservation and extension of existing forests—and the adoption of measures similar to the *réboisement* and *gazonnement* carried out in France, with a view to prevent the formation of torrents, and the destruction of property occasioned by them.

M. Jules Clavé, of world-wide reputation as a student of Forest Science, wrote in the *Revue des Deux Mondes* of 1st May 1882:—

[*Translated.*] 'Since the first travels of Livingstone, the African continent, hitherto inaccessible, has been attacked on all points at once. By the north, and by the south, by the east, and by the west, hardy explorers have penetrated it, traversed it, and have dragged from it some of its secrets. Travellers have paid tribute and done their work in opening up a path; it is now for science and civilisation to do theirs, in studying the problems which present themselves for investigation; and in drawing in the current of general circulations the peoples and lands, which appear as if destined to stand outside; and in causing to contribute to the increase of social wealth the elements of production previously unknown. Thus are we led to receive with interest works which can throw a new light on the condition of regions which may have been known for a long time, and which make known the conditions of their prosperity. It is under this title that the work of the Rev. J. C. Brown on the *Hydrology of South Africa* appears deserving of notice; but it is so also from other points of view. Mr Brown, after a previous residence in the colony of the Cape, whither he had been sent in 1844 as a missionary and head of a religious congregation, returned thither in 1863 as Professor of Botany in the College of South Africa, and he remained there some years. In both of these positions he had occasion to travel through the colony in all directions, and had opportunities to collect most valuable information in regard to its physical geography. Mr Brown on going out to the Cape knew nothing of the works which had for their object to determine the influence of forests on the climate, on the quantity of rain, and on the river-courses in Europe; he had never heard mention of the work of M. Surell on the torrents of the Alps, or of that of M. Mathieu on forest meteorology, nor of those of M. Domontzey, Costa de Bastelica, and so many others on the subject of *réboisement;* and yet in studying by himself, and without bias, the climatic condition of South Africa, he came to perceive that the disturbances in the regularity of the flow of rivers within the historic period should be attributed in a large measure to the destruction of forests; and he meets in agreement on this point the *savants* whose names have been mentioned. We have thought it might not be without interest to readers of the *Revue* to have in the lines of Mr Brown a collection of phenomena which, in their manifestation at any specified point are not less due to general causes, the effects of which may be to make themselves felt everywhere where there may be existent the same conditions than to aught else.' And there follows a lengthened article in illustration.

X.—Water Supply of South Africa, and Facilities for the Storage of it. Price 18s 6d.

In this volume are detailed meteorological observations on the humidity of the air and the rainfall, on clouds, and winds, and thunder-storms; sources from which is derived the supply of moisture which is at present available for agricultural operations in the Colony of the Cape of Good Hope and regions beyond, embracing the atmosphere, the rainfall, rivers, fountains, subterranean streams and reservoirs, and the sea; and the supply of water and facilities for the storage of it in each of the divisions of the colony

—in Basutoland, in the Orange River Free State, in Griqualand West, in the Transvaal Territory, in Zululand, at Natal, and in the Transkei Territory.

EXTRACT FROM PREFACE.—'Appended to the Report of the Colonial Botanist at the Cape of Good Hope for 1866 was an abstract of a Memoir prepared on the Hydrology of South Africa, which has since been embodied in a volume which has been published on that subject, and an abstract of a Memoir prepared on Irrigation and its application to agricultural operations in South Africa, which embraced a Report on the Water Supply of the Colony; its sources, its quantity, the modes of irrigation required in different circumstances, the facilities for the adoption of these in different districts, and the difficulties, physical and other, in the way of works of extensive irrigation being carried out there, and the means of accomplishing these which are at command.

'In the following volume is embodied that portion of the Memoir which related to the water supply, and the existing facilities for the storage of this, with reports relative to this which were subsequently received, and similar information in regard to lands beyond the Colony of the Cape of Good Hope, which it has been sought to connect with the Colony by federation, or otherwise; and the information relative to irrigation has been transferred to a Report on the Rivers of the Colony, and the means of controlling floods, of preventing inundations, of regulating the flow of rivers, and utilising the water by irrigation otherwise.

'In the series of volumes to which this belongs its place is immediately after that on the *Hydrology of South Africa,* which contains details of the former hydrographic condition of the Cape of Good Hope, and of causes of its present aridity, *with suggestions of appropriate remedies for this aridity;* and it has been prepared to show that, not in a vague and general use of the terms, but in strict accordance with the statement, the severe, protracted, and extensive droughts, and destructive floods and inundations, recorded in the former volume, find their counterpart in constantly alternating droughts and deluges in every district of the Colony,—and that, in every so-called division of it, notwithstanding the deluges, there were protracted sufferings from drought, and, notwithstanding the aridity, there is a supply of water at command, with existing facilities for the storage of the superabundant supply which at present proves productive of more evil than good.'

Statement by Reviewer in *European Mail*:—'Dr Brown is well known at the Cape, for in the exercise of his duties he travelled over the principal part of it, and much, if not indeed the substance, of the bulky volume before us, has been before the Cape public in the form of Reports to the local Government. As these reports have been commented upon over and over again by the local press there is little left for us to say beyond the fact that the author reiterates his opinion that the only panacea for the drought is to erect dams and other irrigation works for the storage of water when the rains come down. There can be no doubt that this is sage and wholesome advice, and the only question is, who is to sustain the expense? Not long ago, somewhere about the time that Dr Brown was prosecuting his labours, it will be remembered that General Wynard said that "Nature had furnished the cups if only science would take the trouble to make them secure." It is but to repeat an oft-told story that with a good supply of water South Africa would be one of the finest of nature's gardens, and would be capable of producing two crops a year, in addition to furnishing fodder for sheep and cattle. The question of the water supply for irrigation and other purposes has been staved off year after year, and nothing has been done. It is not too much to say, however, that the question must make itself felt, as it is one of the chief factors in the ultimate prosperity of South Africa. The author is evidently in love with his subject, and has contributed a mass of facts to Hydrology which will be useful to all countries of an arid character.'

XI.—Forests and Moisture; or Effects of Forests on Humidity of Climate. Price 10s.

In this are given details of phenomena of vegetation on which the meteorological effects of forests affecting the humidity of climate depend—of the effects of forests on the humidity of the atmosphere, and on the humidity of the ground, on marshes, on the moisture of a wide expanse of country, on the local rainfall, and on rivers—and of the correspondence between the distribution of the rainfall and of forests—the measure of correspondence between the distribution of the rainfall and that of forests—the distribution of the rainfall dependent on geographical position, or determined by the contour of a country—the distribution of forests affected by the distribution of the rainfall—and the local effects of forests on the distribution of the rainfall within the forest district.

Extracts from Preface.—'This volume is one of a series. In the first of the series—a volume entitled—published last year, *Hydrology of South Africa; or, Details of the Former Hydrographic Condition of the Cape of Good Hope and of Causes of its recent Aridity, with Suggestions of appropriate Remedies for this Aridity.*

'This volume, on the effects of forests on the humidity of the atmosphere and the ground, follows supplying illustrations of the reasonableness of the suggestion made in regard to the conservation and extension of forests as a subordinate means of arresting and counteracting the desiccation and aridity of the country.'

EXTRACTS FROM LETTERS to the author from the late Hon. George P. Marsh, Minister of the United States at Rome, and author of *The Earth as Modified by Human Action*:—'I am extremely obliged to you for a copy of your *Réboisement in France*, just received by post. I hope the work may have a wide circulation. . . . Few things are more needed in the economy of our time than the judicious administration of the forest, and your very valuable writings cannot fail to excite a powerful influence in the right direction. . . .

'I have received your interesting letter of the 5th inst., with the valuable MSS. which accompanied it. I will make excerpts from the latter, and return it to you soon. I hope the very important facts you mention concerning the effect of plantations on the island of Ascension will be duly verified.

. . . 'I put very little faith in *old* meteorological observations, and, for that matter, not much in *new*. So much depends on local circumstances, on the position of instruments, &c.—on *station*, in short, that it is only on the principle of the tendency of some to balance each other that we can trust to the registers of observers not *known* to be trained to scientific accuracy. Even in observatories of repute, meteorological instruments are seldom properly hung and guarded from disturbing causes. Beyond all, the observations on the absorption of heat and vapour at small distances from the ground show that thermometers are almost always hung too high to be of any value as indicating the temperature of the stratum of the atmosphere in which men live and plants grow, and in most tables, particularly old ones, we have no information as to whether the thermometer was hung five feet or fifty feet from the ground, or whether it was in any way protected from heat radiated from near objects.'

EXTRACT LETTER from the late Professor Henry, of the Smithsonian Institution, Washington:—'The subject of Forest Culture and its influence on rainfall is, just at this time, attracting much attention in the United States. At the last meeting of the American Association for the advancement of science a committee was appointed to memorialise Congress with reference to it. Several of the Western States Governments have enacted laws and offered premiums in regard to it. The United States Agricultural Department has collected statistics bearing on the question, and we have referred your letter to that establishment.

'The only contribution that the Smithsonian Institution has made to the subject is that of a series of rain-fall tables, comprising all the observations that have been made in regard to the rainfall in the United States since the settlement of the country; a copy of this we have sent to your address.

'It may be proper to state that we have commenced a new epoch, and have, since the publication of the tables in question, distributed several hundred rain gauges in addition to those previously used, and to those which have been provided by the Government in connection with the signal service.'

These notices and remarks are cited as indicative of the importance which is being attached to the subject discussed.

EXTRACT FROM LETTER to the author from Lieut.-Col. J. Campbell Walker, Conservator of Forests, Madras, then Conservator-in-Chief of Forests, New Zealand; author of *Report on State Forests and Forest Management in Germany and Austria*:—'I am in receipt of yours, along with the notices of your works on Forestry, by book post. I think very highly of the scope of the works, and feel sure that they and similar works will supply a want much felt by the Indian forest officers.

'It contains many important data which I should have vainly sought elsewhere, and it will be regarded by all competent judges as a real substantial contribution to a knowledge of the existing surface, and the changes which, from known or unknown causes, that surface is fast undergoing.'

FORESTS AND MOISTURE:

OR

EFFECTS OF FORESTS ON HUMIDITY OF CLIMATE.

By same Author.

Narrative of an Exploratory Tour to the Northeast of the Colony of Cape of Good Hope, by the Revs. T. Arbousset and F. Daumas, of the Paris Missionary Society. (A Translation.)

Hydrology of South Africa; or Details of the former Hydrographic condition of the Cape of Good Hope, and of causes of its present Aridity, with suggestions of appropriate remedies for this Aridity.

Reboisement in France; or Records of the replanting of the Alps, the Cevennes, and the Pyrenees with trees, herbage, and bush, with a view to arresting and preventing the destructive consequences and effects of torrents.

In the Press, and speedily will be Published,

Water Supply of South Africa: its sources, its quantity, the difficulties (physical and other) in the way of works of extensive irrigation being carried out at the Cape, and the means of accomplishing these which are at command, with notices of what has been done in connection with the storage of water and irrigation in other lands.

FORESTS AND MOISTURE;

OR

EFFECTS OF FORESTS

ON

HUMIDITY OF CLIMATE.

COMPILED BY

JOHN CROUMBIE BROWN, LL.D.,

Formerly Government Botanist at the Cape of Good Hope and Professor of Botany in the South African College, Capetown, Fellow of the Royal Geographical Society, Fellow of the Linnean Society, and Honorary Vice-President of the African Institute of Paris, etc.

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CONTENTS AND ARGUMENT.

PAGE.

INDEX TO AUTHORITIES CITED, xi

PREFACE, xiii

States circumstances in which the volume is published.

INTRODUCTION, - - - - - 1

States subjects to be discussed as being more particularly the effect of forests on the humidity of the climate, including the rainfall; but treating this only as accessary to other effects, and these such as may be produced by every blade of herbage according to its measure.

PART I.—PHENOMENA OF VEGETATION ON WHICH THE METEOROLOGICAL EFFECTS OF FORESTS AFFECTING THE HUMIDITY OF CLIMATE DEPEND, 3

CHAPTER I.—*Primary Phenomena of Vegetation*, 3

Primary phenomena of vegetation are expounded as seen in the Red Snow, the Yeast plant, Confervæ, and Algæ (p. 3), and thus is illustrated the absorption of moisture by *endosmose* (p. 5), which process is more fully detailed (p. 6). The liquid absorbed is traced from the rootlets to the leaves (p. 10); the rise of the sap is explained in accordance with the supposition of its being attributable to *endosmosic* action (p. 12). The difference between this and capillary attraction is explained (p. 13), and the difference between this and what is called *vis a tergo* (p. 15). The structure of the leaf is described (p. 17), and the process of the evaporation of the moisture by the stomates of the leaves is illustrated (p. 19).

CHAPTER II.—*On the Quantity of Moisture Evaporated through the Stomates of the Leaves*, 21

Facts illustrative of the quantity of moisture evaporated through the stomates of leaves are cited from Marsh and others, embracing observations on the oak by Marshal Vaillant (p. 21), and on the maple and the birch in America (p. 22).

CHAPTER III.—*Disputed and Secondary Phenomena of Vegetation*, 25

SECTION I.—*On the Absorption of Moisture by Leaves*, 25

It is alleged that there is a lack of evidence of moisture being absorbed by leaves in great quantity (p. 25).

SECTION II.—*On the Production of Water by Plants*, 26

A reference is made to quantities of water found in the Kaffir ironwood (p. 26), the pitcher plant and the teazle (p. 27), to water secreted by ants (p. 28) and by the cuckoo-spit (p. 29); and it is intimated that it is not unreasonable to suppose that water may be secreted by vegetables (p. 31).

SECTION III.—*On the Dropping of Water from the Leaves of certain Trees*, - 31

Reference is made to observations on a celebrated laurel in Fervo (p. 31), and it is suggested that the dropping of water from its leaves may be attributable to a copious deposit of dew (p. 32), and this is again referred to in explanation of similar phenomena observed in Madeira (p. 35) and in Europe (p. 37).

PART II.—EFFECTS OF FORESTS ON THE HUMIDITY OF THE CLIMATE, - - 38

CHAPTER I.—*Immediate Effects of Forests on the Humidity of the Atmosphere*, . 38

Reference is made to controverted views on this subject, and these are discussed (p. 38).

SECTION I.—*On the Humidity of Atmosphere in the vicinity of Trees, indicated by the dampness of houses overshadowed by Trees, or situated in close proximity to a Wood*, - 39

This is attributed to the moisture evaporated through the stomates of the leaves being absorbed or retained by the walls (p. 39).

SECTION II.—*On Clouds occasionally seen surmounting Woods while the Atmosphere around is comparatively clear*, 40

There is discussed a statement by Marsh in favour of the popular view that mountains attract clouds (p. 46); and phenomena seen on Table Mountain, at the Cape of Good Hope, are adduced to show that these, like the alleged attraction of clouds by forests, are attributable to a reduction in the temperature of the air (p. 48).

CHAPTER II.—*Effects of Forests on the Humidity of the Ground,* 51

SECTION I.—*On the Wetness of Roads where these are overshadowed by Trees,* - 51

While the profuse evaporation from the trees through the stomates of the leaves is not overlooked, the wetness of roads is traced to the effect of the shadow occasioned by the trees preventing evaporation from the overshadowed portion of the road (p. 51); in illustration of which effect of shade are adduced experiments and observations made at the Cape of Good Hope (p. 52), and observations on the effect of shade on ponds in England (p. 55).

SECTION II.—*On the Desiccation of Ground by Drying Winds being prevented by the Shelter afforded by clumps of Trees,* 55

Illustrations are given of the effect of shelter in arresting evaporation, and of the extent to which even bush may act as a windbrake (p. 56).

SECTION III.—*On the General Phenomena of Evaporation from Forests,* 57

There are given indications of evaporation being retarded by forests (p. 59), observations on the quantity of rain arrested by leaves made by Marshall Vaillant (p. 61) and by M. Mathieu (p. 62), observations by the latter on the different quantities of water evaporated in woods and in adjacent open land (p. 63), and notices of corresponding observations made by Risler (p. 64), with the conclusion from the whole that under the same measure of rainfall the soil of the forest retains notably more water than does uncovered ground (p. 65).

SECTION IV.—*On the Moisture being attracted from the Atmosphere, or otherwise retained in the Ground by Vegetable Mould,* - - 65

It is stated how it may be seen that there is a greater quantity of moisture in the soil of a forest than in the soil of open country (p. 65); illustrations are given of the process whereby such moisture is absorbed (p. 65); the difference between this and the deposit of dew is pointed out (p. 66); the property is stated to be possessed in a high degree by clay and by vegetable mould (p. 67); the latter is shown to be a product of forests, and a mode of determining the quantity of it in the soil is described (p. 70), and the humus is shown to be liable to decomposition when exposed to the rays of sun, unshaded by herbage and trees (p. 71).

CHAPTER III.—*Effects of Forests on Marshes*, - 73

SECTION I.—*On the Drying-up of Marshes on the Growth of Trees*, - - - 73

It is stated that what is evaporated through the stomates of the leaves is derived from the ground (p. 73). and that the quantity often exceeds many times that of the rainfall (p. 74); that to a great extent what the atmosphere thus gains the earth loses (p 79); and an illustration of the effect in drying up wet ground is given (p. 80).

SECTION II.—*On the occcasional appearance of Marshes on the destruction of Forests*, - - 81

Cases of the appearance of marshes on the destruction of forests are cited, which are attributed to the interruption of the withdrawal of excess of moisture from the soil by the trees (p. 81).

SECTION III.—*On the occasional Destruction of Forests by the Creation of Marshes*, - - 83

The destruction of forests by marshes is attributed to the damming-up of water outlets at a lower level (p. 83), and illustrative cases are given from Russia (p. 83), Canada (p. 85), and the United States of America (p. 88).

SECTION IV.—*On the Desiccating Effects produced on Marshes by Forests in prolonged periods*, 90

The gradual conversion of marshes into habitable and arable land is discussed (p. 90), and Ireland and Denmark are referred to in illustration (p. 91).

CHAPTER IV.—*On the Effects of Forests on the Moisture of a wide expanse of Country*, - - - 93

SECTION I.—*Cases in which the extensive destruction of Forests does not appear to have perceptibly affected the quantity of the Rainfall over a wide expanse of Country*, 94

The difference between *moisture* and rainfall is pointed out (p. 94); and illustrations of little eff ct having been produced on the quantity of rain falling over a wide expanse of country having been produced by an extensive destruction of forests are given from France (p. 95), and from the United States of North America (p. 98).

SECTION II.—*Cases in which the extensive destruction of Forests appears to have been followed by a marked desiccation of Land and aridity of Climate*, - - - 99

It is stated that the extensive destruction of grass and herbage and trees in South Africa has been followed by drought (p 104); and there are cited statements in regard to corresponding observations elsewhere by Marsh (p. 106); by Hooker (p. 108); by Schleiden and Fries (p. 108); Fraas (p. 109); Becquerel (p. 110); Laurent, &c. (p. 111); Humboldt (p. 112); Boussingault (p. 113); and Hough (p. 115).

SECTION III.—*Cases in which the Destruction of Trees have been followed by desiccation; and the planting of Trees has been followed by the restoration of humidity,* 117

St. Helena (p. 117) and the Mauritius (p. 124) are adduced as cases in which the destruction of trees has been followed by desiccation; and the replanting of trees with restoration of humidity. The Island of Ascension is brought forward as a case in which the absence of trees was accompanied by aridity, and the planting of trees was followed by humidity (p. 128); the measures adopted are detailed (p. 134); and the successful results are reported (p. 141).

SECTION IV.—*Cases illustrative of Effects of Forests on Humidity corresponding to such as have been adduced,* 144

Accounts are given of climatal changes on the Island of Madeira (p. 144); and reference is made to alleged changes in Alexandria and in Egypt (p. 146); South Africa (p. 148); South America, &c. (p. 149).

CHAPTER V.—*Local Effects of Forests on the Rainfall and on Rivers,* - - 150

SECTION I.—*On the production of Rain,* 151

The production of rain is traced to the deposit of moisture in excess of what can be retained at a reduced temperature by air by which it had been absorbed; and in view of this there is detailed the rise of the Trade Winds (p. 151), the course of currents of air from the polar to the equatorial regions, and their return thither depositing moisture absorbed while proceeding toward the equator (p. 152). Reference is made to the quantity which must have been so absorbed (p. 153). The production of clouds by eddies and whirlwinds is described (p. 156); and the production of rain as detailed by Sir John Herschel (p. 158).

SECTION II.—*The Effects of Forests on the quantity of the Local Rainfall,* - - - 159

There are brought forward the views of Boussingault and Becquerel that forests increase the local rainfall (p. 159). Observations by Mr Draper are again brought forward, but with them an illustration of the effect of forests by Coultas (p. 160); and statements of the views of Marsh and the observations of Mathieu in accordance with the views of Boussingault (p. 161); with remarks on the same by M. Cézanne (p. 162).

SECTION III.—*Effects of Forests and of the Destruction of Forests on Rivers and Streams,* 165

Cases are cited from America North and South (p. 166), from France (p. 167), from Germany and from the Cape of Good Hope (p. 172); illustrative of the flow of streams and rivers varying with the existence and destruction of forests. A *resumé* is given of a treatise by Herr Wex on the diminution of water in springs and rivers, with augmentation of floods (p. 175); with reports on the same by the Academy of Science of Vienna (p. 199), and by the Academy of Science of St. Petersburg (p. 203); and a *resumé* of observations reported by Dr Ernst Ebermayer (p. 204).

SECTION IV.—*Immediate Effects of Trees in Arresting the Flow and Escape of Rainfall,* 212

There are cited objections to the views of M. Becquerel in regard to the effects of trees advanced by Marshal Vaillant (p. 212); but with these, observations reported by M. Coute-Grand Champs, and M. d'Arboise de Jubainiville (p. 214), by Mr Marsh and by M. Jules Clave (p. 216), showing that trees have the effect of arresting the flow and escape of the rainfall; observations by Mr Marschand on the increased hydroscopicity, capillarity, and permeability of soil occasioned by the growth of trees (p. 217); and additional illustrations of the same supplied by Cézanne (p. 221), by d'Hericourt, and by Marsh (p. 223).

SECTION V.—*Secondary Effects of Trees in Arresting the Flow and Escape of the Rainfall, and thus Equalising to some extent the Flow of Rivers,* 225

The secondary effects of trees in arresting the flow and escape of the rainfall, and thus equalising to some extent the flow of rivers, are illustrated by reference to the effect of floods in washing away earth, and sometimes covering fertile land with infertile earth, in connection with which are cited statements by Marsh in regard to these effects (p. 226); and statements by Surell in regard to the prevention of them by the growth of trees (p. 237); statements by Cézanne in regard to natural arrest of torrents by forests (p. 242); and by Costa de Bastelica on the effect of trees in increasing the humidity of the soil and consequent drainage of water to subterranean reservoirs (p. 244); of Marchand on the occasion of storms in the Alps (p. 249); with a historical narration of the application of *reboisement* to arrest and prevent the effects of such storms (p. 251).

CHAPTER VI.—*On the correspondence between the distribution of the Rainfall and of Forests,* - - 255

There is stated the course to be followed in this discussion (p. 255).

SECTION I.—*On the Measure of Correspondence between the Distribution of the Rainfall and that of Forests,* 256

This is illustrated from statements by Dr Brandis in regard to India (p. 256), by Mr Maclaren in regard to America (p. 259), by a comparison of report on the rainfall in North America, issued by the Smithsonian Institution (p. 262), with the account of the forests of North America given by M. Marny (p. 264); and a statement in regard to the destruction of forests in South Africa (p. 269).

SECTION II.—*On the Distribution of the Rainfall dependent on Geographical Position, being determined by the Contour of a Country,* - 271

An illustration of the distribution of the rainfall being affected by the altitude of a country is given in the effects of a wind-wave which passed over Europe in September 1866 (p. 272); with an illustration of the same operation in the production of a "mackerel sky"; and of the Table Cloth on Table Mountain (p. 273). Which are followed by an exposition by Cézanne of his doctrine that it is determined in a great measure by the rapidity with which the atmospheric current rises (p. 274); and illustrations of this being the case supplied by Raulin (p. 280).

SECTION III.—*On the Distribution of Forests Affected by the Distribution of the Rainfall,* 283

There is cited a statement by Marsh relative to a tendency manifested by ligneous vegetables to secure the universal occupancy of land (p. 283). The operation of laws regulating the dispersion of vegetables is illustrated (p. 286); and the operation of these on the dispersion of trees is seen to depend in part upon the rainfall (p. 289).

SECTION IV.—*On the Local Effects of Forests on the Distribution of the Rainfall within the Forest District,* 293

The general effect of forests is shown to be to retard the flow of the rain-water precipitated (293), and so in prehistoric times to have converted torrents into peaceful streams (294), while the same effect is shown to be produced by them still (p. 295). There are cited observations adduced to prove that apparently they influence somewhat the quantity of the rainfall and the local distribution of it over the year (p. 299); and the reconciliation of conflicting observations and opinions (p. 302) is shown to be possible (p. 303).

CONCLUSION, - - 307

INDEX TO AUTHORITIES CITED.

Academy of Science of St. Petersburg, 203. Academy of Science of Vienna, 199, 299.

Baines, 69. Balfour, 4. Barnard, 129. Barrington, 128. Becquerel, 110, 212. Belgrand, 294. Bell, 137. Berghaus, 176, 180, 194. Blanqui, 120, 148. Bloget, 301. Blore, 52. Boussingault, 113, 148, 159. Brandis, 256. Breton, 248. Brown, 142. Bryand, 150. Burnet, 129.

Cantegril, 174. Cézanne, 21, 59, 65, 68, 94, 147, 157, 162, 221, 242, 274, 293, 303, 305. Chapman, 26. Chouseul-Graffier, 213. Clavé, 216, Chavery, 215. Conte-Grandchamps, 214. Costa de Bastelica, 244, 251. Cotle, 96. Coultas, 160.

D'Arboise de Jubainville, 214. Dallinger, 18. D'Hericourt, 223, Draper, 100, 111, 160. Drysdale, 18. Duponchel, 232. Dutrochet, 6.

Ebermayer, 204. Emerson, 23. Emsman, 117. Espy, 304.

Faber, 236. Fraas, 109. Fries, 108. Frisi, 231.

Gosse, 25. Graham, 35, 145. Gras, 248. Gray, 5, 9, 59. Grebanau, 177, 184. Guglielmini, 231.

Hagen, 177, 178, 183. Hales, 15. Hayes, 155. Henry, 98, 115, 262. Herschel, 32, 34, 49, 158, 282, 303. Home, 56, 145. Harker, 108, 112, 128. Hough, 100, 148. Humboldt, 34. Hummel, 169. Huxley, 18.

Irving, 154. Jamieson, 300, Janisch, 118. Job, 10. Johnstone, 37, 55. Johnstrus, 225.

Kieser, 4.

Labuissiere, 295. Laurent, 111. Lemoine, 221. Lenneps, 32. Leslie, 41, 43. Livingstone, 28. Lombardini, 233.

Maas, 177, 179. Max Graham, 113. Maclaren, 159. Macvicar, 71. Marschand, 167, 217, 249. Mardigny, 232. Marny, 264. Marsh, 21, 22, 45, 46, 57, 64, 74, 88, 90, 106, 115, 125, 144, 148, 161, 167, 171, 216, 223, 226, 283. Mathieu, 62, 64, 161. Maury, 156. Meguscher, 33. Meldrum, 134. Mitchell, 43. Moffat, 104, 173. Mohl, 19.

Orlebar, 55.

Perrot, 192. Pfaff, 21, 25. Piper, 169. Playfair, 124.

Renou, 302. Rogers, 126. Raulin, 95, 97, 279.

St. John, 127. Saussure, 34. Scheubler, 92. Schleiden, 21, 25. Scoresby, 153. Shott, 100. Siemni, 169. Steinmitz, 152. Surell, 174, 230, 237. Symons, 300.

Tennant, 30. Thomas, 164. Thomson, 272. Thornton, 124. Thurmann, 67.

Vaillant, 21, 61, 75, 212. Valles, 252. Van Reenan, 172. Vampell, 90, 291.

Wells, 32. Wex, 175. Williams, 23. Wiseman, 204. Wisner, 175.

PREFACE.

This volume is one of a series. In the first of the series—a volume published last year, entitled "Hydrology of South Africa; or, Details of the former Hydrographic condition of the Cape of Good Hope, and of causes of its present Aridity, with suggestions of appropriate remedies for this Aridity,"—it is stated that the desiccation of the country is attributable, primarily and mainly to the upheaval of the land and the consequent rapid draining off of the water with which it was covered and of the subsequent rainfall; and secondarily, to rapid evaporation occasioned by the temperature and latterly promoted by the destruction of forests and herbage and grass. There are adduced facts and testimony indicative of this having been the case; and in view of these the appropriate remedies for the prevailing aridity are stated to be—the erection of dams to prevent the escape of a portion of the rainfall to the sea,—the abandonment or restriction of the burning of the veldt,—the conservation and extension of existing forests,—and the adoption of measures similar to the *reboisement* and *gazonnement* carried out in France, with a view to prevent the formation of torrents and destruction of property occasioned by them.

There is now in the press, and shortly will be published, a continuation of that volume on the "Hydrology of South Africa," supplying illustrations of the practicability of applying the first of these remedies being a report on the water supply of South Africa: its sources, its quantity, the difficulties (physical and other) in the way of works of extensive irrigation being carried out at the Cape, and the means of accomplishing these which are at command, with notices of what has been done in connection with the storage of water and irrigation in other lands.

This volume, on the effects of forests on the humidity of the atmosphere and of the ground, follows in the series, supplying illustrations of the reasonableness of the suggestion made in regard to the conservation and extension of forests, as a subordinate means of arresting and counteracting the desiccation and aridity of the country.

And early in the present year was published a volume entitled "Reboisement in France: or, Records of the replanting of the Alps, the Cévennes, and the Pyrenees with trees, herbage, and bush, with a view to arresting and preventing the destructive consequence and effects of torrents."

Should encouragement offer, the publication of this volume will be followed by the publication of a volume on the effects of forests on the temperature of a country, and the correlation of humidity and temperature in meteorological phenomena; a volume on the chemistry of vegetation, and the effects thereby produced on the salubrity of a climate; and a compilation of official documents, showing what arguments for the conservation and extension of forests have been submitted to the consideration of legislative and scientific bodies in different countries, in view of the meteorological effects of forests,—and what measures have been adopted in view of these to secure more extensively for the benefit of man the meteorological benefits which may be thus produced.

HADDINGTON, *December 1876.*

EFFECTS OF FORESTS

ON THE

HUMIDITY OF THE CLIMATE.

INTRODUCTION.

The following treatise on Meteorological Effects of Forests relates mainly to the effects of these on the humidity of the atmosphere and of the soil. Besides these there are effects produced by forests on the temperature and the salubrity of a country, and all of these are correlated—each of them affecting the others, and the others, each.

It is a matter of common observation that houses in the close proximity of trees are often damp; it is also frequently observed that both in summer and winter the temperature in a wood is different from what it is in the open country; and it is becoming generally known that vegetation so affects the constitution of the atmosphere as to keep the air fit for the support of man and beast. Phenomena connected with each of these effects, and different phases of these, will incidentally come under our notice; and their correlation may be attended to; but the discussion of these does not come within the scope of this treatise.

No effects are attributed by me to forests which are not produced, or might not be produced, by any and every blade of herbage or of grass according to its measure. The difference is considered to be only a question of degree. As the hue of a single hair, or a thread of spun glass, may be imperceptible to many observers to whom the hue of a mass of the same hair or glass may be apparent at once, so the meteorological effect of a tiny leaf or a tiny moss, scarcely perceptible by a hurried glance, or those of a single tree, may be inappreciable because infinitesimally small, but the effects produced by a forest with its countless trees, boughs, and leaves be most manifest; and then, with these effects known, we may with advantage proceed to the closer study of any one of them, or of phenomena connected with them in such of the less complicated vegetable structures as supply facilities for the study of these phenomena free from complications which are met with in such masses of vegetation as are met with in forests; and by reasoning from the lesser to the greater, as well as from the greater to the less, we may attain to what are at once clearer and more comprehensive views of the truth on the subject. This is what I propose to do in the sequel.

To prevent misapprehension I may call attention to the circumstance that in treating of humidity it is not the rainfall alone of which I speak. I attribute not a little of the prevalent popular opinions in regard to the effects of forests, and controversies in regard to these to the difference between these being overlooked.

PART I.

Phenomena of Vegetation on which Meteorological Effects of Forests Depend.

Chap. I.—Primary Phenomena of Vegetation.

The study of the phenomena of vegetation, on which meteorological effects of forests depend, may advantageously be begun by the consideration of what takes place in some of the more simple forms of vegetables.

The simplest form of vegetable appears to be what is called Red Snow. In Alpine and Arctic regions, there are occasionally seen on the rock or on the snow patches of red-coloured matter, not unlike dust. When this matter is examined microscopically it is found that each particle of the dust-like substance is a small cell, or bladder-like body; it is not a crystal; it does not appear to be an animal; it seems to be a plant—and a plant of simpler structure it would be difficult to conceive. It is known to botanists as the *Protococcus Nivalis.*

A plant similar to this, but somewhat more complex in structure—if the term complex can be employed with propriety in speaking of a structure so very simple—is seen in the Yeast Plant.

With a stick or a spoon there may be drawn from yeast in active fermentation thread-like bodies which, when examined microscopically, appear like a string of beads, each bead being a cell, not unlike the Red Snow in structure, but colourless. This is the Yeast Plant, and if the thread be broken each cell may be developed into a thread-like plant similar to that from which it has been dissevered.

In *Confervæ*, and in many confervoid plants found in streams and fresh water pools, we find a similar structure, but this is enclosed in an investing skin, and the cells are drawn out from a globular into a more or less elongated cylindrical form. And in the larger *Algæ*, or sea weeds—some of which there are which are 1000 feet in length—when they are examined microscopically we find, and find only, a mass of such cells less regularly arranged, enclosed in an investing skin of similar cellular structure.

The growth of all such bodies—as it is of many others, but it is of these I speak at present—is effected by the multiplication of the cells of which they are composed. The process of cell growth and cell production has been studied in numerous structures, both vegetable and animal, with similar results; and it may be described in general terms thus:—In many cells, when examined microscopically, there may be seen at one place a thickening of the cell wall; in some may be seen, in the cell contents, floating bodies, two, four, or more in number, from which there is being developed a fine transparent membrane, with an appearance like that presented by the glass on a watch; this gradually expands and is distended with liquid, until, in process of time, the mother cell is ruptured by their distension, and they continue to expand as independent cells, giving birth to others, and in like manner giving place to these in their turn.

It is not necessary to my present purpose that I should discuss the question of how this process is originated and maintained. It is with the process and what follows from it with which I have to do. To prevent misapprehension, I may state that I do not know of the process having been in any case observed continuously from its commencement to its completion; but different cells have been seen and studied in all the stages of growth and reproduction to which I have referred.

The increase of bulk in each cell may be too minute and too slow to be noted, but with the process going on simultaneously in a long line of cells the effect may be perceived. I have seen the extremity of a *conferva*, held fast at the other end, advance across the field of vision in a microscope with which I was examining it. Nor will this be astounding if it be considered with what rapidity the process of cell production, growth, and reproduction must sometimes go on. Large tracts of snow in Arctic regions, and in Alpine districts, are sometimes quite suddenly reddened by the production of the Red Snow plant, to which reference has been made, the consequence of the development of innumerable cells. One form of fungus, the *Phallus impudiens*, has been observed to shoot up three inches in the space of twenty-five minutes. Another, *Bovista Gigantea*, the giant puffball, "has grown," says Balfour, "in a single night in damp weather from the size of a mere point to that of an enormous gourd. From an approximate calculation it is found that in this plant not less than 20,000 new cells are formed every minute. Kieser estimated that the tissue of some fungi augmented at the rate of 60,000 cells *per minute*."

In South Africa I have frequently observed a marked difference in the altitude of the flowering stem of the American Aloe, *Agave Americana,* as I returned to my home in the evening from what it had been in the morning as I passed on my way to Capetown. Dr Asa Gray, writing on the cell increase in this gigantic peduncle, says,— "After waiting many years, or even for a century, to gather strength and materials for the effort, Century Plants which grow in our conservatories send up a flowering stalk which grows, day after day, at the rate of a foot in twenty-four hours, and becomes about six inches in diameter. This, supposing the cells to average 1-300th of an inch in diameter, requires the formation of over *twenty thousand millions* of cells in a day!"

It is by such cell production, development, and multiplication that the growth of all plants, from the Snow Plant to the monarch of the wood, is effected; nor is it without consideration that I make use of the term multiplication in speaking of the increase of their number, for it is the case that it is by such metrical progression that the increase is effected. Not only may each cell be studied as in itself a complete organism, an integer, and consequently an *integral* part of the more comprehensive structure into which it enters—as a man is in himself complete, an integer, and, consequently, an *integral* part of the nation to which he belongs, and as such may be made the subject of study apart from the other men of whom, along with him, the nation is composed,—but, in the Red Snow, we have a single cell constituting a complete plant; and in this we may study more conveniently some of the phenomena of vegetation on which some of the alleged meteorological effects of forests depend as consequences.

The absorption of moisture appears to be an invariable concomitant of cell growth and, consequently, of cell development and cell increase. We may afterwards enquire what function the moisture fulfils in the vegetable economy, at present it is only the fact and the mode of its accomplishment which are brought under consideration.

A cell is too minute for ocular demonstration of the mode of absorption of moisture through the cell wall to be given by it. The cells vary in different plants, from about the thirtieth to the thousandth of an inch in diameter; an ordinary size is from 1-300th to 1-500th of an inch, so that there are generally from 27 to 125 millions of cells in the compass of a cubic inch of vegetable cellular structure. In cells so minute occular demonstration of the *modus operandi* is not to be expected. But they have been spoken of as bladder-like bodies; and with a bladder may be shown on a large scale what is done by them on a small.

If a bladder be partially filled with water holding salt or sugar in solution, have the orifice closed tight, and be put into a basin of water, it will be found after a time that the bladder will become filled and distended; water has been absorbed through the tissue. While it is thus with the bladder, if the remaining water in the basin be examined it may be found to have acquired the peculiar taste of the salt or the sugar of which a solution was introduced into the bladder before its immersion; or if the taste be not perceptible, an application of appropriate chemical tests will show that there is such salt or sugar there in solution. Apparently there must have been a transference of water from the outside into the inside of the bladder, and a transference of a lesser portion of the solution of salt or sugar from within to the water without in the basin; apparently this can only have taken place through the tissue of the bladder; and all that is known of the process goes to prove that it is not only so to appearance but that it is so in fact. To these two distinct operations the designations *Endosmose* and *Exosmose* have been given by Dutrochet, a French physiologist; and these designations have come into general use in treatises on the subject in our own and other languages, *Endosmose* being applied to the passage of pure water, or of weaker solution, or a solution of other matters, from without, and *exosmose* to the passage of the water with matter in solution from within.

Reasoning from a widely extended analogy, it is thus that the moisture is imbibed, absorbed, or, to speak more guardedly, transferred from without into the interior of the cell.

In consideration of this process being the initiative of phenomena of vegetation on which the alleged meteorological effects of forests depend, it may be well to ascertain, as satisfactorily as we can, how it is that what takes place is effected, that we may carry with us a definite conception of this radical operation in our subsequent consideration of subsequent operations to which attention must be given.

Without entering on the question how matter is held together, I may call attention to three manifestations of the attractive force: that of cohesion, whereby particles of the same substance are held together, as in a piece of wood, a drop of quicksilver, or a drop of water; adhesion, whereby particles of one substance adhere to another substance, as water, treacle, or tar adheres to the finger dipped into it, while quicksilver does not; and chemical affinity, whereby particles of one substance attract and enter into combination with particles of another substance with which they may be combined, as in a solution of soda-water powders the tartaric acid attracts the soda from the carbonate of soda and combines with it, leaving the carbonic acid with which it was combined disengaged and free to escape as it does in the effervescence which it occasions.

A clear conception of the differences thus indicated will make the process of endosmose and exosmose more intelligible. In the illustrations of adhesion which I have given, the attraction of adhesion between the finger and the quicksilver was of less force than the attraction of cohesion by which the particles of matter of which the finger is composed, and than the attraction of cohesion by which the particles of quicksilver are held together, and the finger could be withdrawn unbroken leaving the quicksilver entire. But in the other cases mentioned the attraction of adhesion, though less in force than the cohesion betwixt the particles of matter of which the finger is composed, was greater than that by which the particles composing the water, the treacle, or the tar were held together, and this giving way a portion adhered to the finger.

In the endosmose taking place in the case adduced for illustration the adhesion to the bladder of the water in the basin must have been greater in force than the attraction of cohesion by which the particles of water were held together, and the chemical affinity of the saline solution within the bladder for the water greater in force than the attraction of adhesion by which it was held by the bladder. From the moistened tissue of the bladder, water by which it was moistened was attracted by and combined with the saline solution; this was replaced by more from the basin, which in like manner was withdrawn, and the process went on continuously, producing the phenomenon of endosmose.

The process of exosmose was similarly produced: the force of adhesion between the saline solution and the inside of the bladder was greater than the force of cohesion by which the particles of that solution were held together; but the chemical affinity of the water in which the bladder was immersed for that saline solution was still greater in force than that adhesion, and thus a portion of the saline solution was withdrawn and combined with the water in the basin.

This is not given as a full explanation of all the phenomena of endosmose and exosmose, but as an explanation of the more striking phenomena produced, which is all that is required for the object in view. I may add that the explanation given does not render necessary the supposition of two distinct currents flowing in opposite directions and crossing each other, one flowing in unbroken continuity from without inwards, and the other flowing in unbroken continuity from within outwards, either in the same or in different channels. More probable is it that the transference is going on continuously, simultaneously in both directions—a process which may perhaps be made more intelligible by an explanation of what takes place in the decomposition of water by galvanic influence. If a plate of zinc and a plate of copper connected by a wire be kept apart and introduced into a vessel of water, the water will be decomposed, one of its elements, oxygen, will be disengaged in connection with one of these plates, and hydrogen, the other constituent element, will be disengaged at the other; but there is no *appearance* of decomposition taking place at any one or more points, and of the elements flowing thence to their respective issues,—and what is actually seen, may be explained by supposing that in immediate contact with one plate, or with each, a particle of water is decomposed by the liberation of one of the constituents which escapes, and the other is transferred from particle to particle, only becoming visible when it escapes in contact with the other plate.

The process may be illustrated mechanically by means of a six-inch parallel rule, thus: let the one scale represent oxygen and the other hydrogen; let perpendicular lines divide them into six equal spaces, which conjointly may represent particles of water composed of oxygen and hydrogen; let these be numbered, the first couple each marked 1, the second couple 2, and so on; let the two scales of the ruler next be drawn in opposite directions, and if the spaces marked on them be equal to the distance which each projects beyond the other, you will have again spaces appropriately representing particles of water; but you will have oxygen No. 1 above hydrogen No. 2, oxygen No. 2 above hydrogen No. 3, and so on; hydrogen No. 1 and oxygen No. 6 representing what seems to take place in the decomposition of water by that simple galvanic apparatus.

As in the decomposition of water by galvanism thus illustrated, the escape of the hydrogen of water in contact with one plate, and that of the oxygen of water in contact with the other plate, seem to result from a transference of hydrogen from particle to particle, and simultaneously with this a transference in the opposite direction of oxygen from particle to particle, through the whole line of particles of water intervening between the two plates,—so in the exosmosic and endosmosic action may the tranference be going on from particle to particle, through the whole tissue of the bladder, without the formation of any distinct currents of the two fluids as they exist.

It may be mentioned that the effect would be similar if the pure water were put into the bladder, and the solution of salt or sugar into the basin in which the bladder is immersed; but in this case, in accordance with what has been stated, the exosmose would be in excess of the endosmose, more water would be withdrawn than would be replaced. The difference in the quantity passed by endosmose and exosmose may in both cases be attributed to the difference between the force of the chemical affinity of the saline solution, or the salt in it, for water, and the force of the attraction of adhesion, by which the water is kept attached to the bladder, being greater than the difference between the force of the chemical affinity of the pure water for the saline solution, and the attraction of adhesion by which that solution is attached to the bladder.

If the chemical affinity of the saline solution for water be equivalent to 8, and the attraction of adhesion of this solution to the bladder be equivalent to 6, the difference between these is 2. If the adhesion of water to the bladder be equivalent to 1, and the chemical affinity of the pure water for the salt in the solution be equivalent to 1, the difference between these is 1; and the endosmose would be to the exosmose as 2 is to 1.

Dr Asa Gray, Professor of Natural History in Harvard University, Cambridge, Massachusets, in writing of endosmose and exosmose with a solution of sugar as the subject of experiment remarks, in accordance with what I have stated,—"At the same time, the water in the vessel will become slightly sweet; showing that a small quantity of syrup has passed through the pores of the membrane into the water without, while a much larger portion of water has entered. The water will continue to enter, and a small portion of syrup to leave it, until the solution is reduced to the same strength as the liquid without. If a solution of gum salt, or any other substance, be employed instead of sugar the same result will take place. If the same solution be employed both in the vessel and in the [bladder] no transference or change will be observed. But if either be stronger than the other a circulation will be established, and the stronger solution will increase in quantity until the two obtain the same density. If two different solutions be employed, as, for instance, sugar or gum within [the bladder] and potash or soda without, a circulation will in like manner take place, the preponderance being *towards* the denser fluid, and in a degree proportionate to the difference in density. Instead of animal membranes, any vegetable matter with fine pores, such as a thin piece of wood, or even a porous mineral substance may be substituted with the same result."

All this is in accordance with observations made by Mateucci, an Italian physiologist, who gave very careful consideration and study to the phenomena as produced by experiments with various substances, transferred by endosmose and exosmose through various media, embracing the analogues, or homologues of almost every action of the kind observed in animal physiology; and many, if not all similar actions observed in vegetable physiology may be accounted for as being thus produced. Thus, apparently, is the moisture absorbed by uni-cellular plants like the Red Snow, and by the cells of which such plants as the Yeast Plant, the Confervæ, and the sea-weeds are composed, and by the cells entering into the structure of such plants as grass, and herbs, and bushes, and trees.

With the knowledge thus attained, attention may be given to the absorption of water as a concomitant of vegetation.

"There is hope of a tree if it be cut down that it will sprout again and that the tender branch thereof will not cease. Though the root thereof wax old in the earth, and the stock thereof die in the ground; yet through the scent of water it will bud and bring forth boughs like a plant." Thus wrote the author of the Book of Job more than three thousand years ago—more than fifteen hundred years before the coming of Christ! On the other hand, drought is, I shall not say destructive, but, interruptive to vegetation.

We need not yet enquire into the function of the moisture in the cell development, we have only to do at present with the two facts adverted to, that the scent of water promotes and revives vegetation, while drought interrupts it.

In the case of the most of the lower forms of vegetation which have been cited, the absorption is supposed to take place over all parts of their surface, and in the case of all of these, excepting the Red Snow, they are found growing surrounded with moisture; and thus the growth of the gigantic sea-weeds is continued by the absorption of moisture by the myriads of cells of which exclusively their covering is composed.

But forests consist of trees and not of sea-weeds. And trees are not algæ and confervæ, but gigantic plants growing on dry land—land hard and dry as the mountain brow. And to another phase of vegetation promoted by the absorption of moisture attention may now be given.

As with algæ so with grasses and herbs, and shrubs and trees, their whole structure is built up of cells, some of which may have been elongated into vessels, or otherwise metamorphosed; and the dry dead cell walls of these constitute the pith and the woody fibre of which trees seem chiefly composed. Of some of the vessels through which the milk sap flows it may be that they have been formed otherwise; but the principal difference between the gigantic tree and the gigantic sea-weed in the source of growth is only this, that while the latter absorbs nutriment over the whole of its surface the former does it mainly by the roots, and almost exclusively by the cells at the extremities of the rootlets, where are masses of them, which have, in reference to this function, received the designation spongioles, or little sponges, resembling these as they do, not in their structure, indeed, but in their power of absorption. They are often represented in cuts as rounded elongated expansions, but they are not always to be so seen by the enquiring learner; examined microscopically, they appear as numerous unprotected living cells at the extremities of the rootlets, of which those furthest from the root to which they belong continue to increase and multiply with rapidity in appropriate soil, while those behind, and nearer to the stem, seem to have lost in a great measure this power of reproduction.

It may seem that the absorbing surface bears but a very small proportion to the entire bulk of the plant, and I am not concerned to dispute the correctness of the conclusion that proportionally it is small, but what is proportionally small may be absolutely great. Count the rootlets of an onion, or of a leek, or of a stalk of wheat, and estimate if you cannot measure the superficial extent of the spongioles; calculate if you cannot count, and estimate if you cannot even calculate, the hair-like fibrillæ of the roots and ramified rootlets of a shrub or a tree, and by reasoning try to form some idea of the vastness of the superficies of the spongioles there, and you may find that it is not to be despised. Bear in mind that much of the mass of a growing tree is fixed and stable,—that a small streamlet may have filled and may keep filled an extensive lake, provided only the outflow do not exceed the supply,—that a very small orifice or mouth, and that used only occasionally for the purpose, may suffice and does suffice for the feeding of a man or other animal,—and any prejudice hindering the ready acceptance of the doctrine, that the absorption of moisture by the spongioles of a tree is the homologue of the absorption of moisture by the whole surface of the confervæ of the streamlet and of the algæ of the sea, will be removed.

I have oftener than once made use of the term absorption, but as may have been seen, from the explanation of exosmose and endosmose which has been given, it is scarcely applicable with propriety to such a process; but with this *caveat* I may be allowed to make use of it in lack of some term less exceptionable. It is solely in reference to that process that I here employ it.

The water thus absorbed by the several cells composing the spongioles of the root is by a similar process absorbed from them by cells behind them; and by continuous repetition of it by those beyond the moisture absorbed from the soil is passed on and on, from the extremities of the rootlets to the extremities of the smallest twigs, and to the furthest and the loftiest extremities of the branches of the trunk. There, through the leaves, a part, and that a large portion of it, is given off into the atmosphere, while a part, comparatively a small portion, is returned by the same duplex process of exosmose and endosmose by the same cells, and others, their progeny, towards the root. By the way is deposited, by exosmose, nutriment for the tree, the leaf, the flower, and the fruit; and the residuum is in part deposited by the same process in the leaves, the bark, or the root, and passed off into the soil by the exosmosic action of the cells composing the spongioles of the root.

It may now be seen how vegetation may have some effect in increasing the humidity of the atmosphere; but, as a preliminary to the consideration of this, some further attention may be given to the phenomenon of the rising of the sap.

The rise of the sap in trees is to many a phenomenon or fact for which they cannot account satisfactorily to themselves; or, if this they can do, or think they can, they cannot do so in such a way as to cover all the phenomena to the satisfaction of others. The pressure of the atmosphere will not account for what is seen. Capillary attraction has been thought of, but this does not account for a downward flow of the sap, which is a part of the phenomenon, and it is a downward as well as an upward flow which has to be accounted for. Experiments have been made with a view to account for the upward flow, the results of which, and perhaps some others, could be accounted for by what was called a *vis a tergo*, a power or pressure from behind; but this, like the older aphorism that Nature abhors a vacuum, will not stand examination; and the elasticity and tension of the wood accounts for all that was seen in the experiment which suggested the phrase *vis a tergo*, or pressure from behind, though not for all the phenomena connected with the rising of the sap. But in endosmose there may be found a satisfactory mode of accounting for all that is known to take place in connection with the flow of the sap.

I do not know a more simple illustration of exosmose and endosmose than that which I have given, but to illustrate more fully the phenomena, with a view to the explanation of the rising of the sap, I may give the following: Let a piece of bladder be stretched over the mouth of a funnel and tightly fastened there, and let a tube, if one of glass so much the better, be attached to the orifice of the funnel; let this funnel, half-filled with a solution of salt, be immersed in water with the tube projecting upwards. The water in the vessel will become slightly saline through the escape, by exosmose through the organic tissue, of a small portion of the solution of salt, but this will be replaced by a much greater quantity of water entering by endosmose, and so increasing the quantity of water within the funnel and tube, that this will be seen to rise in the tube, until—through the dilution of this, and the loss, by exosmose, of a portion of the substance held in solution—an equilibrium be established between the strength of the solution on the one side and on the other of the separating membrane. But should the tube be insufficient to contain such a quantity as this would render necessary, the surface of the solution will rise till the solution overflows, and it will continue to flow until the equilibrium spoken of be established.

This experiment, with its results, makes manifest the difference between endosmose and capillary attraction, depending, as they do, on different actions; and it seems to indicate that the process of endosmose may supply a satisfactory explanation of the rise of the sap in lofty trees, though capillary attraction fails to do so.

The phrase capillary attraction is employed to account for the rise of liquids to a considerable height in tubes of small diameter, and through interstices of similar size in solid bodies. If several tubes of different diameters of bore have their lower extremities immersed in water and be held erect, the water will rise in them to different heights and be sustained so elevated. The smaller the bore is the greater will be the height to which the water will rise and at which it will be sustained, hence the derivation of a name from *capilla*, a hair. In such phenomena the attraction of adhesion may be inferior in force to the attraction of cohesion, or equivalent thereto, but it is so great as to overcome the attraction of gravitation and to elevate the contained column of water above the level of the mass to which the attraction of gravitation would lower it but for the conteracting influence thus exercised upon it. The quantity of water thus raised is proportional to the area of the surface of adhesion, and to this the attraction is confined; and thus it comes to pass that capillary attraction cannot raise water till it overflow, as it does in the experiment on endosmosic action which has been spoken of, and for which the different action by which endosmose is effected enables us to account. That action has already been explained.

If a worsted thread six inches long have two inches at the one end immersed in water filling a basin to within half an inch of the top, and the other end be allowed to hang down outside the vessel, the water may rise in it and after a time begin to drop from the pendant extremity, which it will do more readily if it be thoroughly moistened immediately before; and this may seem at variance with what I have just said. If, however, we distingnish things which differ, we may see that it is not so. The water may be raised in the capillary interstices of the worsted thread in opposition to the attraction of gravitation to the level of the basin, and it may be onward beyond it; it may have been attracted a little way on its descent outside by the same force, but here there came into operation along with this the attractive force of gravitation; as the water was drawn onwards and downwards by capillary attraction, the co-operating force of gravitation would be increased; and at length the worsted thread without ceasing to act by capillary attraction would become a veritable syphon, in which the gravity of the water in the longer limb, and the pressure of the atmosphere on the surface of the water in the basin would occasion a continuous flow.

I have not said all that might be said in regard to this; but I have said enough to show that this is different from the overflow at its upper extremity of a tube filled by endosmose from below, and, conversely that this is different from that, leaving it free to indicate that endosmosic action may, as has been said, supply an explanation of the rise of sap in lofty trees, though capillary attraction fails to do so.

I have referred to an opinion that the rise of the sap may be attributable to a *vis a tergo*, and some of my readers may think that in endosmose he has found this *vis a tergo*, or, at least, a *vis a tergo* which will explain all; and to this I would next attend.

The indication of the existence of what is called a *vis a tergo*, and the illustration of its power usually given, is one supplied by an experiment devised by Hales to measure, as he thought, the force with which sap ascends in a stem. A tube, bent so as to ascend, descend, and ascend again, had a quantity of mercury introduced into the curvature between the descending and re-ascending portion, and was attached firmly to a stem, the top of which had been cut off. It was fastened on the stem by means of a copper cap which was secured by a lute, and this was covered with a piece of bladder firmly bound above and below the upper and the lower extremities of the cap; the level of the mercury at the commencement of the experiment was noted, and as the sap rose in the stem, and through the stem into the ascending limb of the tube, which it did, the pressure caused the mercury to sink in the descending limb and rise in the ascending one; and thus could the pressure occasioned by the ascending sap be measured.

Brucke, experimenting with such an apparatus, found that in a vine the spring sap, having a specific gravity of 1·0008, raised a column of mercury to the height of 4½ inches, and therefore must have created a pressure equal to that of a column of water 195 inches high. In another experiment, sap of specific gravity 1·0009 raised mercury to the height of 17½ inches.

The force of the pressure in one experiment which was tried was found to be equal to 38 inches of mercury, which Hales states is nearly five times greater than the force of the blood in the crural artery of a horse, and seven times greater than the force of the blood in the same artery of a dog.

These statements I accept unhesitatingly. I know not what precautions were adopted against error, and I cannot divest my mind of the impression that the force of the pressure may have been due in some measure to the elasticity of the stem released of the pressure of the portion of the tree cut off. Knowing of no *vis a tergo* but that of endosmose, I accept the facts as an approximate measurement of that action, and an indication of the rapidity with which it is carried on; but I do so only provisionally. The impression to which I have referred remains. I have oftener than once cut down a banana plant in vigorous growth, and in a few minutes seen the inner portion half an inch or more above and beyond the entire integument, which may have been occasioned by rapid growth; but in the one case as in the other, in the absence of certain knowledge, I cannot divest myself of the impression that the phenomena may have been to some extent the result of the elasticity of the stem released of the pressure of the portion cut off; and I claim only to have shown, *as yet*, how water is taken up by trees from the soil, and that endosmose may supply an explanation of the rising of the sap to the highest twigs, and to the extreme ramifications of the most distended boughs.

Exosmose and endosmose are found to take place freely through two tissues, the surfaces of which are contiguous to each other, the double tissue acting much as a homogeneous tissue, thicker than either of them would do; and in the knowledge of this—the knowledge of the fact that sap does rise from the rootlet to the stem, the knowledge that capillary attraction cannot explain all the phenomena of the case, the knowledge of the fact that no other *vis a tergo* has been discovered, and the fact that by endosmose and exosmose all the phenomena of the case are explicable,—it seems not unreasonable to conclude that thus it is that the rise of the sap may be effected.

At this stage of our consideration of these phenomena the determination of this is of importance, mainly, in satisfying us that we have not lost sight of the moisture in tracing, or endeavouring to trace, its course from the rootlets to the leaves. It will subsequently again demand our attention. It is the absorption of moisture from the soil and the emission of a large portion of this into the atmosphere with which we have chiefly to do in studying the meteorological effects of forests on the humidity of a climate. It is by the spongioles that it is absorbed, and by the leaves that it is emitted. The transmission of that moisture from the spongioles to the root is, in so far as our present study is concerned, not unimportant, but its importance is only secondary in view of the absorption and emission; and to the means whereby this passage of moisture from plants by their leaves is effected would I next direct attention.

The passage of moisture from plants by their leaves is effected by means of what may be described, in mechanical phrase, as a beautifully simple self-regulating ventilating-evaporating apparatus. The operation of this I would illustrate thus: In the oxalis as in the clover we have a leaf composed of three leaflets. In an oxalis brought from Guatemala the whole leaf is almost transparent, and it is said that six sets of vessels can be distinctly traced—three pairs, one pair proceeding from each leaflet; and it is conjectured that in other plants a similar arrangement exists; but in most plants it is difficult to separate and distinguish the different sets of vessels. These vessels, with less or more of cellular matter, constitute the mid-rib and leaf-stalk, and go to form the twig, branch and stem, or trunk and root.

When the leaf itself is broken across, or cut, it may appear to be as homogeneous as a sheet of paper of the same thickness, with scarcely space sufficient for any more complicated structures; but when examined with a microscope of considerable power it is seen to be composed of a great number of cells piled loosely together, six or eight or even more it may be in depth, with large spaces intervening, and framed by a layer of similar cells, compactly arranged like a brick floor, forming the back of the leaf, and a double or triple layer of cells, similarly compactly arranged like brick-work, two bricks or three bricks thick, forming the face of the leaf. These are compact enough, but those constituting the body of the leaf, filled with sap, are so loosely grouped, apparently without any very determined or strongly marked arrangement, that they only touch each other on parts of their surface, and the air may play freely almost entirely round each and through amongst them all. A simpler arrangement for thorough ventilation perhaps man could scarcely imagine.

In the back of the leaf are numerous stomates, or mouths. The structure of these differs in different plants, but what may be considered the typical structure is two elongated cells, resembling a microscopic black pudding or thick sausage, so built into the structure of the skin of the leaf that this will not admit of their being further elongated; each of these is, along one side, attached to that skin, but on the sides along which they are in contact they are free. When moisture is in excess they become distended, but the structure of the skin of the leaves is such that they cannot be elongated, and they bulge away from each other, leaving a wide opening between them through which the vapour with which the air surrounding the cells in the interior of the leaf is charged finds an open exit. When the pressure is relieved they, having lost some of the moisture or water with which they were filled and distended, collapse to such an extent as to diminish the opening; and in this way, exactly to the degree required, they vary and regulate that aperture—varying it, it may be, I shall not say twenty times in the day, but, if necessary, twenty times in the minute; and if drought become such as to render it desirable that every drop of moisture in the plant should be preserved, under the influence of that drought they become flaccid and completely close the aperture.

Such is the arrangement, in these galleries of the laboratories of the tree, for carrying off by evaporation all moisture which may escape from the cells, which may ooze out, or may be passed by exosmosic action; and a little further consideration may lead to the conclusion that the arrangement has been made, not to get rid of accidental leakage, but of all moisture in excess of what is actually required after the sap has been so elaborated as to fit it to minister to the nutriment of the tree. Be this as it may, it is not unreasonable, but the reverse, to suppose that, however compact the tissue or structure of the cell wall may be, there may be, or that there must be, interstices between the molecules of which it is composed. A drop of water falling upon a heap of fine dust, or of powdered rosin, immediately draws around it a waterproof covering of the material amongst which it has fallen, which, though waterproof, is not airproof, and the enclosed waters may be evaporated through the interstices of the investing covering. So may it be with these, though on a scale infinitesimally reduced.

Professor Huxley, in a paper "On the Border Territory between the Animal and Vegetable Kingdoms," which appeared in Macmillan's Magazine for February 1876, citing some remarkable observations on certain monads by Messrs Dallinger and Drysdale, which were embodied in two papers in the Monthly Microscopical Journal for 1873, speaking of certain granules, living embryos, remarks,—"The authors whom I quote say that they cannot express the excessive minuteness of the granules in question, and they estimate their diameter at less than 1–200,000th of an inch. Under the highest powers of the microscope at present applicable such specks are hardly discernible. Nevertheless, particles of this size are massive when compared to physical molecules; whence there is no reason to doubt that each, small as it is, may have a molecular structure sufficiently complex to give rise to the phenomena of life." Compared with such embryos, cells such as those of which the substance of a leaf is compose are giants. In a cubic inch of a leaf of the carnation there are said to be upwards of three millions of cells; in some of the cucumber tribe, and in the pith of aquatic plants, what are reckoned larger cells are found—they are from 1–50th to 1–30th of an inch in diameter; but cells are frequently seen only 1–300th, 1–500th, and 1–1000th of an inch in diameter. It would be difficult for many to conceive of the size of a cell 1–1000th of an inch in diameter; but these granules, were not the two hundredth part of that in diameter, and one of these smallest cells, could contain six millions of the granules in question!

To one conversant with structures so minute there is nothing astonishing in the supposition that molecules of moisture should pass through interstices between the molecules of which the cell walls are constructed; and, with what is known of endosmosic and exosmosic action, it seems to be not unreasonable to suppose that any moisture passing through the cell wall from within outwards might, by the increased density following the evaporation of a portion of it, determine a current to follow it which would flow continuously. To the consideration of what function of the leaf is thus subserved we shall afterwards return: it is with the arrangement for the passage into the atmosphere of moisture taken up by the spongioles with which alone we are at present concerned.

Of the extent of the provision made for this evaporation some idea may be formed from a consideration of the number of the *stomata* or stomates to be found in the leaves of plants, often symmetrically disposed. The number varies in different plants, for which variation a reason may be found in the different conditions of growth to which they are subjected in their several natural habitats. In the back of the leaf of the apple tree there are about twenty-four thousand stomates to the square inch. In the leaf of the lilac there are a hundred and sixty thousand of them to the square inch. Sixty thousand have been reckoned in a square inch of the under surface of the white lily and three thousand in a square inch of the upper surface. In the leaves of the cherry-laurel there are none on the upper surface of the leaf, but ninety thousand have been counted on the lower surface of the leaf. In the true lilies they are so large that they may be seen with the aid of a simple lens of an inch focus. In the water lilies, and other plants having leaves which float upon water, all the stomates are on the upper surface, where alone evaporation can take place. Leaves of plants which grow entirely under water, where there can be no evaporation, have none.

The mechanism of the opening and shutting of stomates has been carefully investigated by Mohl, a distinguished German botanist, the results are given in the *Botanische Zeitung* for 1866, p. 697; and it appears that, while the general action is such as I have described, other processes co-operate to ensure the result. It is partly controlled by the effects of light, though depending mainly upon endosmose. Mohl has shown that while the cells of the stomate themselves act so as to open the stomate in moist weather and close it in dry, the adjacent cells of the epidermis, or skin enveloping the leaf, in swelling when moist, tend to close the stomate, and their contraction when dry to open it; so that the actual state of the stomate at any one time is the resultant of nicely adjusted opposing forces, and thus is secured a self-regulation of the apparatus far more efficient than could be secured in any laboratory of man, though an attendant were stationed, hydrometer in hand, ready to close partially or entirely, or to reverse such action in the ventilators of the evaporating chambers exactly in regard to time and extent as the ever-varying state of the process of evaporation in the chamber and state of the atmosphere might render desirable.

But further, it is possible that in some cases, under peculiar conditions or circumstances, it might happen that more moisture might be evaporated than was conducive to the vigorous vitality of the plant—in other words, the process of evaporation might go too far—and we find that provision against this exists in many leaves, in the existence of hairs which by endosmosic action can imbibe additional moisture.

These hairs are always more numerous on the back of the leaf than on the face, which in some plants is entirely devoid of them, though the back be densely covered with them; and they may be found in some plants to be always at the junction of veins in the back of the leaf, as if designed only to act when it should become manifest that surplus water which might happen to be retained in one of these would not suffice to counteract a deficiency in the other.

Such is the beautifully-simple self-regulating ventilating-evaporating apparatus in the leaf of a plant.

In the absorption of moisture by the spongioles of the rootlets, the ascent of the sap, and the evaporation of excess of moisture after the elaboration of the milk sap, we see some of the principal phenomena of vegetation on which meteorological effects of forests depend.

CHAPTER II.

On the Quantity of Moisture Evaporated through the Stomates of Leaves.

On results obtained by observation and calculation in regard to the quantity of moisture evaporated through the stomates of leaves a considerable difference of opinion exists.

Remarking on the results arrived at by observations of Schleiden, Pfaff, and others, Marsh says,—"Allowing two hundred days for the period of forest vital action, the wood must, according to Schleiden's position, exhale a quantity of moisture equal to an inch and one-fifth of precipitation per day; and it is hardly conceivable that so large a volume of aqueous vapour, in addition to the supply from other sources, could be diffused through the ambient atmosphere without manifesting its presence by ordinary hygrometrical tests much more energetically than it has been proved to do; and in fact the observations recorded by Ebermeyer show that though the *relative* humidity of the atmosphere is considerably greater in the cooler atmosphere of the wood, its *absolute* humidity does not sensibly differ from that of the air in open ground. The daily discharge of a quantity of aqueous vapour corresponding to a rainfall of one inch and a fifth into the cool air of the forest would produce a perpetual shower, or at least a drizzle, unless, indeed, we suppose a rapidity of absorption and condensation by the ground, and of transmission through the soil to the rootlets and through them and the vessels of the tree to the leaves, greater than have been shown by direct observation."

Cézanne, also, writing in regard to the action of vegetables as "veritable alembics, which distil into the air a certain quantity of water which their roots have drawn up from the soil," says,—"The Marshal Vaillant put a branch of an oak like a bouquet into a vase full of water; he measured the water lost through its leaves and he considered himself enabled to conclude that the tree from which this branch had been detached would be emitting into the atmosphere in twenty-four hours upwards of two thousand kilogrammes of water.*

* "*Revue des Eaux et Forêts,*" July 1865 and June 1867.

But this experiment has not satisfied all others. First of all, the branch thus treated died in three days; and then, even if it had lived longer, it might have been said that the vegetable cut off from the nourishing sap may have been able to absorb more than its usual ration of clear water. It was in the situation of an animal deprived of substantial aliment, which availed itself of pots of weak *bouillon*, and yet died of hunger. And, moreover, the experiment has been repeated not with a branch but with a young tree deprived of its roots, and the evaporation proved to be very insignificant."

But whatever may be said of such experiments, and of calculations founded on them, we have other means of testing the quantities of water passing through trees in the process of their growth; and we find they must be far from inconsiderable. I have cited one statement by Marsh, with this I cite also the following:—

"The amount of sap which can be withdrawn from living trees furnishes, not, indeed, a measure of the quantity of water sucked up by the roots from the ground—for we cannot extract from a tree its whole moisture—but it supplies numerical data which may aid the imagination to form a general notion of the powerful action of the forest as an absorbent of humidity from the earth.

"The only forest tree, known to Europe and North America, the sap of which is largely enough applied to economical uses to have made the amount of its flow a matter of practical importance and popular observation, is the sugar maple, *Acer saccharinum* of Anglo-American Provinces and States. In the course of a single 'sugar season,' which lasts ordinarily from twenty-five to thirty days, a sugar maple, two feet in diameter, will yield not less than twenty gallons of sap, and sometimes much more. This, however, is but a trifling proportion of the water abstracted from the earth by the roots during this season; for all the fluid runs from two or three incisions or augur holes, so narrow as to intercept the current of circulation of comparatively few of the sap vessels, and, besides, experience shows that large as is the quantity withdrawn from the circulation, it is relatively too small to affect very sensibly the growth of the tree. The number of large maple trees on an acre is frequently not less than fifty, and, of course, the quantity of moisture abstracted from the soil is measured by thousands of gallons to the acre. The sugar orchards, as they are called, contain also many young maples too small for tapping, and numerous other trees—two of which, at least, the Black Birch, *Betula lenta*, and Yellow Birch, *Betula excelsa*, both very common in the same climate and far more abundant in sap than the maple—are scattered among the sugar trees; for the North American native forests are remarkable for the mixture of their crops.

"The sap of the maple and of other trees with deciduous leaves, which grow in the same climate, flows more freely in the early spring, and especially in clear weather, when the nights are frosty and the days warm; for it is then that the melting snows supply the earth with moisture in the justest proportion, and that the absorbent power of the roots is stimulated to its highest activity."

In foot notes he adds:—"Emerson (in his *Trees of Massachussets*, p. 493), mentions a maple, six feet in diameter, as having yielded a barrel, or 31½ gallons of sap in 24 hours, and another, the dimensions of which are not stated, as having yielded one hundred and seventy-five gallons in the course of the season. The *Cultivator*, an American Agricultural Journal, for June 1842, states that twenty gallons of sap were drained in eighteen hours from a single maple, two and a-half feet in diameter, in the town of Warner, New Hampshire; and the truth of this account has been verified by personal enquiry made on my behalf. This tree was of the original forest growth, and had been left standing when the ground around it was cleared. It was tapped only every other year, and then with six or eight incisions. Dr Williams (*History of Vermont*, p. 91), says,—'A man much employed in making maple sugar, found that, for twenty-one days together, a maple tree discharged 7½ gallons per day.'

"An intelligent correspondent, of much experience in the manufacture of maple sugar, writes me that a second growth maple, of about two feet in diameter, standing in open ground, tapped with four incisions, has for several seasons generally run eight gallons per day in fair weather. He speaks of a very large tree from which sixty gallons were drawn in the course of a season, and of another, somewhat more than three feet through, which made 42℔ of wet sugar, and must have yielded not less than 150 gallons.

"The same correspondent informs me that a Black Birch, tapped about noon with two incisions, was found the next morning to have yielded sixteen gallons. Dr Williams (*History of Vermont*, I. p. 91) says,—'A large birch, tapped in the spring, ran at the rate of five gallons an hour when first tapped. Eight or nine days after, it was found to run at the rate of about two and a-half gallons an hour, and at the end of fifteen days the discharge continued in nearly the same quantity. The sap continued to flow for four or five weeks, and it was the opinion of the observers that it must have yielded as much as sixty barrels [1890 gallons]."

These observations may give some idea of the quantity of moistnre taken up by the rootlets of trees.

Such is a report of facts ascertained in regard to the maple. It does not follow that an equal quantity of moisture is raised by every kind of tree; but it may be said a corresponding quantity is, by every one, or a quantity which may be spoken of as something like an approximation to this. And though the fact has not, so far as I know, been tested by exact observation, it is probable that the greater portion of the moisture thus raised from the ground by plants, whether arborescent or herbaceous, is by many of them passed into the atmosphere by the stomates of the leaves—succulent plants with few stomates being the exception—and that a portion, and it may be a large portion, of the remainder passes into the soil by the process of exosmose by which the circulation of sap in the plant is effected, but returns to the soil only to be again taken up by the rootlets of the same, or of some other plant, when it has been relieved of some of the residuary matter with which it returned charged, and has taken up a return load of nutriment; but the probability that the quantity thus returned to the soil bears but a small proportion to the quantity passed into the atmosphere may be demonstrated by an observation of the process referred to.

To some one charged with the watering of flowers, and who finds the charge a burden, it may have occurred that he seemed to have to supply far more water than could be employed in the structure of the plant, that some, such as the balsam, seemed to require a fresh supply morning, noon and night to keep them growing, and that to planted cuttings and transplanted plants he could scarcely give too copious a supply, and unless he had trimmed them by removing some of the leaves scarcely would what he gave have sufficed : now perhaps it may be understood why all this was necessary, and how the diminution of the foliage helped the growth of the plant when the supply of moisture might otherwise have been inadequate to its maintenance in life.

CHAPTER III.

DISPUTED AND SECONDARY PHENOMENA OF VEGETATION.

BESIDES the phenomena of vegetation which have been detailed there are other alleged phenomena, the import of which is more open to question: amongst these may be reckoned the absorption of moisture by the leaves of plants, the production of water by the plants themselves, and the dropping of water from the leaves of certain trees.

SECT. I.—*On the Absorption of Moisture by the Leaves of Plants.*

It is a prevalent opinion that moisture is absorbed by plants by their leaves. I scarcely open a popular treatise on the subject in which I do not meet with it; but I have met with no evidence that this is a normal action of leaves, excepting to a very limited and easily defined extent. Abnormal action of leaves absorbing moisture would prove as little as the abnormal absorption of moisture and nutriment into the human frame by enemas and baths; and the absorption of moisture by gigantic algae over the whole surface of their stalks and their fronds proves as little. But this cannot be said of experiments which have been made on the growth of epiphytes and of mundane plants, which have grown and flourished when freed of all soil; or of trees growing naturally and at the same time luxuriantly on narrow ridges, on steep declivities, on partially decayed stumps many feet above the ground, on walls of high buildings, and on rocks, in situations where the earth within reach of their roots could not possibly, it is alleged, contain the tenth part of the water which, according to Schleiden and Pfaff, they evaporate in a day. There are, too, forests of great extent on high bluffs and well-drained table-lands where, it is said, "there can exist neither in the subsoil nor in infiltration from neighbouring regions an adequate source of supply for such consumption."

These are facts established beyond all question; but in regard to what seems to be the natural conclusion, that in such cases the moisture must have been absorbed by the leaves, I may remark that this appears to me to be a *non-sequitur ;* and the burden of proof rests on those by whom it is advanced.

In regard to the general opinion that moisture is absorbed by the leaves of trees I may state that I believe this to be the case where leaves are covered more or less densly with hairs, which are highly hygroscopic, and which appear to be organs well fitted for the accomplishment of such a function, and are often placed as if such were their function in given conditions ; and further, that to some extent moisture may have been absorbed by endosmose where a deposit of what may be called a secretion on the surface of the leaf gives something like an indication of this having occurred, but that the effect of this must be small.

I have no testimony to the alleged absorption of moisture to an appreciable extent by leaves having been observed ; and on the other hand I have testimony on which I can rely that in South Africa there are fig trees growing on rocks, over which the roots spread like solidified molten lava or rosin, dipping down into every crevice and spreading onward to the earth beyond ; and in the absence of evidence of extensive absorption by leaves I consider it more probable that the moisture is absorbed by such roots than by the leaves of the tree, and the conclusion justified in such cases suggests the conclusion that so may it be in others.

SECT. II.—*On the Production of Water by Plants.*

Amongst trees brought under my consideration in Africa by the late Mr James Chapman—a man of careful observation who travelled extensively throughout the whole region from Walfish Bay to the Victoria Falls of the Zambesi and thither from Natal, traversing in various directions the country intermediate between the region thus indicated and Table Bay at the Cape of Good Hope—was the Kusché, a large tree with a smooth dark grey-coloured bark and dark-coloured oblong leaves, in the heart of the trunk of many of which is found a large reservoir of water. From the description given to me, the tree appeared to be the *Millettia Caffra,* known elsewhere in South Africa as the Oomzambeete, or Kaffir Iron wood.

Mr Chapman first saw this tree when he and his companions were suffering from thirst. Observing one of his native servants placing forked boughs against a tree and preparing to climb, he asked what he was going to do. "Look for water," was the reply. The man having mounted, cried "Here it is." The hard wood had decayed, leaving a very deep hole, which was almost closed at the top, apparently by the spreading arch of subsequently formed bark. One of the companions of the man cutting then a twig or shoot from the root, cut through the bark of this at two places two feet or thirty inches apart, treated this as boys in Europe treat branches of alder, of which they wish to make whistles, beating and pressing it; and drawing out the wood, like drawing a sword from its sheath, he handed up the bark to the man aloft, who, using this as a suction-pipe, soon quenched his thirst, and made way for the others in succession to do the same.

Frequently did Mr Chapman while travelling avail himself of the supply of water thus retained.

Between the Victoria Falls of the Zambesi and Daka these trees are found in clusters, sometimes 10 feet in circumference, and of a much greater height than the other trees of the forest-country around. They generally grow in clumps, in the higher portions of the country.

Similar supplies of water are found in the Pitcher Plant, and several other herbaceous plants of somewhat similar structure; and in the Teazel, the *Dipsacus fullonum*, a quantity of water is often found in the cup-like receptacle formed by the opposite leaves embracing the stem.

In more than one of these cases the water may possibly be only rain-water collected and retained, and in the other cases it may be elaborated sap, the water of which was derived from the soil; but even were such cases thus disposed of, the question has been raised and awaits an answer—May not water be a secretion of plants themselves?

I have intimated or stated explicitly what are my views in regard to the source of the great bulk of the moisture passed into the atmosphere by the stomates in the leaves of vegetable production; but I know of nothing incompatible with the supposition of a portion being added from the combination of oxygen and hydrogen, meeting in a nascent condition in the process of chemical changes accompanying vegetation.

Water is a product of the combustion of wood, and of coal, of oil, of tallow, and of gas; it is a product of respiration in man and many other animals, and may be obtained deposited by their breath; and there are lower forms of animals by which it is produced, and that, in proportion to their size, much more abundantly. The question, Whence is this obtained? has been raised oftener than once.

Dr Livingstone, in describing a severe and long-continued drought at Kolobeng (the mission station occupied by him before he entered on his journeyings in the interior), a drought during which "needles lying out of doors for months did not rust, and a mixture of sulphuric acid and water, used in a galvanic battery, parted with all its water to the air instead of imbibing more from it, as it would have done in England," says,—"The leaves of indigenous trees were all drooping, soft and shrivelled, though not dead; and those of the Mimosæ were closed at mid-day, the same as they are at night. In the midst of this dreary drought, it was wonderful to see those tiny creatures the ants running about with their accustomed vivacity. I put the bulb of a thermometer 3 inches under the soil in the sun at mid-day, and found the mercury to stand at 132° and 134°; and if certain kinds of beetles were placed on the surface they ran about a few seconds and then expired; but this boiling heat only augmented the activity of the long-legged black ants." And having raised the question, "Where do these ants get their moisture?" he proceeds,—"Our house was built on a hard ferruginous conglomerate, in order to be out of the way of the white ant, but they came in despite the precaution; and not only were they, in this sultry weather, able individually to moisten soil to the consistency of matter for the formation of galleries, which in their way of working is done by night (so that they are screened from the observation of birds by day in passing and repassing towards any vegetable matter they may wish to devour), but when their inner chambers were laid open these were also surprisingly humid; yet there was no dew, and the house being placed on a rock they could have no subterranean passage to the bed of the river, which ran about 300 yards below the brow of the hill. Can it be that they have the power of combining the oxygen and hydrogen of their vegetable food by vital force so as to form water?"

A still more remarkable case is mentioned by Dr Livingstone. Writing from Golungo Alto Angola, on the west coast, lat. 91° S., he says,—"Before leaving I had an opportunity of observing a curious insect which inhabits trees of the fig family *(Ficus)*, upwards of twenty species of which are found here. Seven or eight of them cluster round a spot on one of the smaller branches and there keep up a constant distillation of a clear fluid, which, dropping to the ground, forms a little puddle below. If a vessel is placed under them in the evening it contains three or four pints of fluid in the morning. . . To the question, Whence is this fluid derived? the people reply that the insects suck it out of the tree, and our own naturalists give the same answer. I have never seen an orifice, and it is scarcely possible that the tree can yield so much. A similar, but much smaller homopterist insect, of the family *Cercopidæ*, is known in England as the frog-hopper *(Aphrophora spumaria)* when full-grown and furnished with wings; but while yet in the pupa state it is called '*Cuckoo-spit*,' from the mass of froth in which it envelopes itself. The circulation of sap in our climate, especially in the Graminaceæ, is not quick enough to yield much moisture. The African species is five or six times the size of the English. In the case of branches of the fig-tree, the point the insects congregate on is soon marked by a number of incipient roots, such as are thown out when a cutting is inserted in the ground for the purpose of starting another tree. I believe that both the English and African insects belong to the same family and differ only in size, and that the chief part of the moisture is derived from the atmosphere. I leave it for naturalists to explain how those little creatures distil, both by night and day, as much water as they please, and are more independent than Her Majesty's steam-ships, with their apparatus for condensing steam, for without coal their abundant supplies of sea water are of no avail. I tried the following experiment:—Finding a colony of these insects busily distilling on a branch of the *Ricinus communis*, or castor-oil plant, I denuded about 20 inches of the bark, on the tree-side of the insects, and scraped away the inner bark so as to destroy all the ascending vessels. I also cut a hole in the side of the branch, reaching to the middle, and then cut out the pith and internal vessels. The distillation was then going on at the rate of one drop each 67 seconds, or about 2 ounces $5\frac{1}{2}$ drams in 24 hours. Next morning the distillation, so far from being affected by the attempt to stop the supplies, supposing they had come up through the branch from the tree, was increased to a drop every 5 seconds, or 12 drops per minute, making one pint (16 ounces) in every 24 hours. I then cut the branch so much that during the day it broke; but they still went on at the rate of a drop every five seconds, while another colony on a branch of the same tree gave a drop every 17 seconds only, or at the rate of about 10 ounces $4\frac{4}{5}$ drams in 24 hours.

"I finally cut off the branch; but this was too much for their patience, for they immediately decamped, as insects will do from either a dead branch or a dead animal, which Indian hunters soon know when they sit down on a recently killed bear. The presence of greater moisture in the air increased the power of these distillers; the period of greatest activity was in the morning, when the air and everything else was charged with dew.

"Having but one day left for experiment I found again that another colony on a branch denuded in the same way yielded a drop every two seconds, or 4 pints 10 ounces every 24 hours, while a colony on a branch untouched yielded a drop every 11 seconds, or 16 ounces $2\frac{19}{20}$ drams in 24 hours. I regretted somewhat the want of time to institute another experiment, namely, to cut a branch and place it in water, so as to keep it in life, and then observe if there were any diminution of the quantity of water in the vessel. This alone was wanting to make it certain that they draw water from the atmosphere. I imagine that they have some power of which we are not aware besides that nervous influence which causes constant motion to our own involuntary muscles, the power of life-long action without fatigue. The reader will remember, in connection with this insect, the case of the ants already mentioned."

The same question is taken up by Sir J. E. Tennant, in writing of what he had observed at Ceylon.

"Entomologists," says he, "have raised the interesting question, Where do the termites, or so called white ants—though of another genus than the common ant—where do they derive the large supplies of moisture with which they not only temper the clay for the construction of their long-covered ways above ground, but for keeping their passages uniformly damp and cool below the surface? Yet their habits in this particular are unvarying—in the seasons of drought as well as after rain, in the dryest and least promising positions, in situations inaccessible to drainage from above, and cut off by rocks and impervious strata from the springs below. Dr Livingstone, struck with this phenomena in Southern Africa, asks—Can the white ants possess the power of combining the oxygen and hydrogen of their vegetable food so as to form water? And he describes at Angola an insect resembling the *Aphrophora spumaria*, seven or eight individuals of which distil several pints of water every night. It is highly probable that the termites are endowed with some such faculty. Nor is it more remarkable that an insect should combine the gases of its food to produce water, than that a fish should decompose water to provide itself with gas. Fourcroix found the contents of the air-bladder in a carp to be *pure* nitrogen; and the aquatic larvæ of the dragon-fly extracts air for its respiration, from the water in which it is submerged. A similar mystery pervades the enquiry—Whence plants, under peculiar circumstances, derive the water essential to vegetation?"

The constituents of water are oxygen and hydrogen; the constituents of ammonia are hydrogen and nitrogen; the constituents of carbonic acid are carbon and oxygen; and the principal constituent of atmospheric air are nitrogen and oxygen; with these is combined or intermixed carbonic acid; carbonic acid and ammonia are likely to be absorbed largely by water, and so carried into the plant; carbon is fixed, being the principal constituent of wood, and thus oxygen is set free; a smaller quantity of nitrogen is fixed, but enough to indicate a decomposition of ammonia to have taken place; and it is not unreasonable to suppose that all the ammonia taken up by the plant may have been decomposed, the nitrogen combining with oxygen, set free by the decomposition of the carbonic acid yielding material for the woody structure, and appearing as atmospheric air, and the hydrogen combining with oxygen and forming water.

With regard to the second statement by Dr Livingstone, I would require to be in possession of much more information than I am to enable me to form an opinion on the subject; but I may state that I find nothing in the narrative incompatible with the supposition of the moisture in this case having been obtained from the tree; and I avail myself of the interest which such a narrative may have excited to direct attention to the similar copious supplies of moisture flowing from leaves and from incisions in the trunks of trees.

Sect. III.—*On the Dropping of Water from the Leaves of certain Trees.*

Of the dropping of water from trees there are numerous instances; but while in some of the more remarkable cases the popular opinion is in favour of the supposition that this was one of the primary phenomena of their growth, the consideration of the conditions under which it occurs leads to the conclusion that it is one of the secondary effects of vegetation.

I have spoken of some of the more remarkable cases. In an old work, entitled *Historia de la Conquista de las siete islas de Gran Canaria de Juan de Abreu Gal indi*, published in 1832, at page 47, mention is made of a celebrated laurel, in Ferro, which is said to have furnished drinkable water to the inhabitants of the island. According to the statement, every morning the sea breeze drove a cloud towards the wonderful tree, which attracted it to its huge top, and the water flowing from its foliage uninterruptedly, drop by drop, was collected in cisterns.

I have met with a similar account of a tree to the east of Tocat in Asia-Minor, visited by the Rev. Mr Van Lennep, and described by him. Mr Lennep is said to be well-known as a competent observer.

In the case mentioned first there is the explicit statement that "Every morning the sea breeze drove a *cloud* towards the wonderful tree." And there is nothing in any of the statements I have seen relative to these phenomena inconsistent with the supposition that they may have been produced by the deposition of moisture on the surface of the leaves, irrespective of the source whence the moisture was obtained.

Dr Wells, in an essay on Dew,—a little work which, according to Sir John Herschel, deserves to be considered as a model of experimental enquiry,—was the first to place in a clear light the nature of the process of dew formation. According to his views, as epitomised by Sir John Herschel, "The chief facts to be accounted for are these: 1. Dew (as distinguished from small rain or moisture produced by visible fog) is never deposited except on a surface colder than the air. 2. It is never deposited in cloudy weather; and so strict is its connection with a *clear sky* that its deposition is immediately suspended whenever any considerable cloud passes the zenith of the place of observation. 3. It is never copiously deposited in a place screened or sheltered from a *clear view of the sky*, even if the screen be of very thin material, such as muslin or paper suspended over it. 4. It is most copiously deposited on all such leaves as are *good radiants and bad conductors of heat*, such as grass, paper, glass, wood, &c., but little or not at all on *bad radiants*, such as polished metals, which are also *good conductors*. And lastly, it is never deposited if there is much wind. All these circumstances, as Dr Wells has shown, point to the escape of heat from the bodies exposed by *radiation out into space*, or into the upper and colder regions of the air, faster than it can be restored by counter-radiation, or by *conduction*, from contact with the warm air—or with solid substances—the wind acting in this respect with great efficiency by continually removing the air in contact. Hoar frost differs only from dew by being frozen in the moment of deposition, and therefore accreting in crystalline spiculæ."

It may have been observed that tufts of grass and other herbage are often covered with dew-drops in the early morning, or with hoar frost if it be winter, though the ground be not so; and it may have been observed that heavy drops of water fall from a tree in a fog though not a drop of rain may be seen to fall beyond it. The phenomena may be similar.

The temperature of the human body, as ascertained by a thermometer with its bulb placed in the shoulder-pit or under the tongue, is within a very limited range—when the man is in a state of health—the same in the Arctic regions and in the tropics, and the degree known as blood-heat is as stable as is the boiling point of water. Scarcely less stable is the freezing point of water or the freezing point of mercury. It is something similar with trees. According to experiments made by Meguscher, in Lombardy, and results of these recorded in *Memoria sur Boschi della Lombardia*, and cited by Marsh, trees maintain at *all* seasons a constant mean temperature of 54° Fahr.

Observations which have been recorded by others have made it appear questionable whether a tree does resist the cooling process induced by external cold, but I know not of any question having been raised in regard to its counteracting the effects of external heat of a higher temperature than its own. This seems to be generally admitted. In the animal this resistance is effected by evaporation; in the vegetable it is probable it is effected by the same means, or by evaporation and radiation combined. The subject will again come under consideration, when it may be discussed at greater length.

I have called attention to the dew and hoar-frost being seen on the grass and herbage at early morn. In hygrometry mention is frequently made of the dew-point: this is the temperature at which the air is exactly saturated with the quantity of moisture it contains, any fall from which would occasion a deposit of all that was in excess of what exactly saturates the air at the lower temperature. In accordance with observation, and with reasoning on the subject, the dew-point is frequently the same as the lowest temperature of the night; and the lower temperature of the grass and herbage, consequent on radiation from their surface, occasions a deposit of dew-drops in the same way as a glass of cold water, by lowering the temperature of the air adjacent to it, is in like manner bedewed.

According to the observations of Meguscher, whenever the temperature of the air is above 67° degrees Fahr., the temperature of the tree will be, to the extent of the excess, lower. If the temperature of the atmosphere be 90°, and the dew-point 75°, there will be a copious deposit of dew; and if the lower temperature be the consequence of radiation the deposit may be expected to take place over the whole of the upper surface of the leaves, these in the aggregate, according to the statement of Humboldt, measuring several thousand times the area of the ground they cover. And there should be as little to startle one in finding dew-drops falling from a tree while the sky is cloudless and serene, as in finding melted hoar-frost dropping when the sun has arisen upon the tree in winter.

But in the case of the laurel at Ferro it is expressly stated, " every morning the sea breeze drove a cloud towards the wonderful tree, which attracted it to its huge top." Such were the phenomena, and the explanation which suggests itself is more simple. In regard to fog or mist—and a cloud is only a form of this—Sir John Herschel, in the treatise from which I have already quoted, says,—" The form in which the moisture so precipitated first appears will necessarily be that of very minutely-divided particles, which, however, having the refractive power of water, reflect and refract light as such, and appear therefore as a mist, fog, or cloud of greater or less density and opacity, according to the amount precipitated in a given volume. It is a favourite dogma with many meteorologists that the particles so precipitated assume the form, not of drops, but of hollow spheres or bubbles. De Saussure states that he has seen such, floating before his eyes in clouds and fogs on the Alps, and the dusty appearance of the vapour floating over a cup of coffee in the sunshine is adduced in illustration. The strongest argument adduced in their favour, however (for there is great room for optical illusion in such matters), is that adduced by Kratzenstein, that the sun striking on a cloud or fog produced no rainbow, which it ought to do were the water collected in spherical drops. This argument does not admit of a ready answer; but the difficulty, on the other hand, of conceiving any possible mode in which such bubbles can be formed disposes us to believe that the extreme minuteness of the globules may be found to afford one, their diameter being of an order comparable with the breadth of the luminiferous undulation."

Thus wrote Herschel in the article in the Encyclopædia. To the second edition of the article, published as a volume in 1861, he added in one foot-note that he had never himself seen such a phenomenon as was spoken of by Saussure, and that he had questioned Alpine excursionists of far more extensive experience than his own, with a like negative reply. And in a second foot-note he says,—" On the Newtonian doctrine of fits of easy transmission and reflection, or (which comes to the same thing) on the hypothesis of light consisting in rotating corpuscles with attractive and repulsive poles, there would be no difficulty of the kind [mentioned in the text]. A globule, or a particle of water of any other form, whose greatest linear diameter did not exceed the thickness of that central spot in a soap bubble which reflects no light, would be equally non-reflective, and therefore incapable of forming a rainbow. In the undulating theory, however, it is the parallelism of the surfaces of the film of which that central spot consists which renders it non-reflective. I suspect, however, that in the case contemplated in the text that theory, carefully re-examined, would render a somewhat different account of the singular abruptness of transition from the most brilliant reflexion to an almost absolute extinction of the reflected ray, and of the uniformity over large areas of a thin film of the still remaining fraction of the incident light which it *does* reflect, than that usually given."

Of the undulatory theory of light I shall have occasion, in a subsequent part, to treat at some length.

Whatever may be the form of the cloud particles, be they drops or bubbles, they are in the cloud or mist so far apart—and are kept apart by conflicting attractions, exercised by all upon each and by each upon all—that it is long before multitudes coalesce to form rain-drops, and a slight rise of temperature may lead to their being again absorbed by the air without their falling to the ground; but the particles deposited on the leaves, brought into closer proximity, and in many cases contact, rush into each other like drops of quick-silver, and the attraction towards the earth becoming greater than the attraction of adhesion they fall from the leaf to the ground. And thus may the dropping reported have been occasioned.

In passing through a fog the moisture collects like dew-drops on the hair, the whiskers, the eye-brows, and even on the eye-lashes, and on every projecting filament of wool in the clothes; and so is it also with the cloud or mist surrounding a tree, or borne through the interstices of its twigs by the wind, the minute drops collect upon its leaves. And I presume the fact has only to be mentioned to recall to some of my readers that in a mist they have seen heavy drops falling from foliage while there was no rain.

I find some pertinent observations on this point in a work entitled "The Climate and Resources of Madeira," by Dr Graham, a work which I shall afterwards again have occasion to quote. The author remarks,—"The power of trees upon mist is very great. Where there are no trees, the cloud drives along, depositing little or no moisture. But trees largely intercept mist; and the small component vesicles of water coalesce upon the leaves and branches, and fall in drops of water upon the earth. The mists form, whether there be trees or not; but the water is strained out and saved by the forest foliage." He says, "I have watched with much interest for the commencement of dripping, in reference to the pre-eminence of certain kinds of foliage in powers of condensation. The pine trees invariably begin first, the rough brush-like clusters of leaves being well adapted to intercept the smallest particles of moisture. The yield of water from this source is very great. The laurels extract water plentifully from mists which are more sensibly damp."

Dr Graham further states that,—"In one of the Canary Islands, the people show the place where, at the head of a deep valley, stood a fine solitary til tree, which daily used to strain a large quantity of water from the humid mist, conveyed inland by the sea breeze. The tree is mentioned by Cordeyro and subsequent writers. But both the spring of water and the tree are now gone; and the mists, though they still remain, pass over unstrained of their moisture."

The difference noted by Dr Graham in the effect of different kinds of trees may be attributed in some cases—in others if not in those mentioned by him—in some measure, First, to differences in the number of stomates through which the evaporation from the leaves of the tree itself is effected. These vary in different plants from a few to 160,000 or more in the square inch of surface. The number in the leaves of the cherry-laurel is 90,000 in every square inch on the back of the leaf. In such state of atmosphere as is specified by Dr Graham, every stomate would probably be distended, an atmosphere of dense moisture would surround the tree and this precipitated by a fall of temperature might in part create the supply.

The difference may be attributable, in some measure, Secondly, to differences in the extent of the radiating surface, supplied by the leaves, whereby the temperature might be effected. This is much greater in the foliage of a pine tree than in the herbage of a laurel.

And the difference between the effect produced by the laurel and other trees may be attributable, in some measure, to difference in the attraction of adhesion between water and the leaf. From the glossy surface of the laurel leaf the moisture deposited might run off quickly, while to the leaves of other trees it might cleave, as if loathe to shake itself free, and adhere till again evaporated, or till it fell in drops undistinguishable from the rain, when this began to drizzle.

In all such cases as have been mentioned, whether fog be visible or it be otherwise, the precipitation and consequent dripping is attributable to the temperature of the atmosphere surrounding the tree being below the dew-point, and the moisture contained in it there being in excess of what saturates it, in accordance with the elements by which that dew-point is determined. These are ascertained by observation of the difference of temperature indicated by a wet and a dry bulbed thermometer, of the barometric pressure, and of the elastic force of the vapour at the temperatures, and under such pressure. The elements are numerous, but the formula of calculation simple, and copious tables for facilitating this have been published.

In regard to the effects of different trees, I find it stated by a writer on the subject, in "The Farmers' Magazine," Mr Cuthbert W. Johnstone, that "the dew under some large oak trees, by the side of his bowling green, at Croydon, is always considerable of an evening; but that under a witch-elm growing by their side the dew is almost always absent." In Europe, generally, it has been found that the most copious humidity or moisture has been produced by the elm, and, in decreasing order, by the poplar and horse-chestnut, while the least effect is produced by firs.

PART II.

EFFECTS OF FORESTS ON THE HUMIDITY OF THE CLIMATE.

CHAP. I.—IMMEDIATE EFFECTS OF FORESTS ON THE HUMIDITY OF THE ATMOSPHERE.

THERE is a wide-spread opinion that forests attract clouds and rain, and a similar effect is attributed to mountains. The facts which have been adduced may enable us satisfactorily to account for the phenomena upon which the former opinion is founded; and with the explanation thus supplied we may be enabled also satisfactorily to account for the latter. The phenomena referred to may be stated generally to be these: forests and mountains are frequently seen surmounted by clouds, stationary or passing over them, when few or none are seen elsewhere in the heavens; and, though it may be an unwarrantable conclusion that they have been attracted thither, it does not excite surprise that this conclusion has been drawn from the phenomena observed. In the case of forests we know, however, of no kind of attraction exercised by them which could produce this effect; the effect can be accounted for satisfactorily in accordance with the phenomena of vegetation which have been under consideration; and in these circumstances it is reasonable to conclude that these supply the correct *rationale* of what is seen. Of this a simple exposition can be given, and one not less simple can be given of the similar phenomena in the case of the mountains; and the exposition of the former supplies at the same time the means of accounting for the proverbial dampness of houses overshadowed by trees, or situated in close proximity to woods.

The meteorological effects of trees and forests may be apparently paradoxical, and accounts of them conflicting and contradictory; but if instead of acting on the principle of cutting the knot we act on the principle of unloosing it we may find that all facts observed and reported are consistent with each other, and that many of them can be accounted for satisfactorily in accordance with what is known of operations patent to all. If, instead of attempting the reconciliation of conflicting theories, we study the facts separately and apart, we may find that, when all is done, there are no conflicting views to reconcile; and this I shall endeavour to do, stopping at any point when lack of information renders further advance hazardous.

SECT. I.—*On the Humidity of the Atmosphere in the Vicinity of Trees, indicated by the Dampness of Houses overshadowed by Trees, or situated in close proximity to a Wood.*

It is matter of common observation that houses closely surrounded with trees are damp. Oftener than once have I heard a sufferer from rheumatism told, You must get your husband to cut down that tree overshadowing the house, or you will never be well.

There may be nothing injurious in damp itself, but in evaporation damp induces cold, and cold may be injurious to the human frame; damp, moreover, is conducive to the decomposition of dead organic matter; the products of vegetable decay or decomposition tend to produce ague, intermittent fever, rheumatism, neuralgia, and toothache; and in the absence of appliances for determining the hygrometric condition of the atmosphere, the frequent occurrence of such maladies may be considered indicative of the existence of the moisture to which reference is made.

With the information which has been produced, one need not be surprised at the dampness of houses so situated. With evaporation going on continuously, from stomates so numerous in every one of such a multiplicity of leaves, the quantity of moisture in the air must be much greater than it is in an open space; and though the temperature may be such as to keep it suspended in solution, an affinity for moisture in the material of which the house is built will attract it thence and keep the walls, and the apartment within, damp, or at least less dry than otherwise they would have been.

The quantity of moisture which clay, bricks, and granite, and other forms of stone can retain in their structure, while to touch and to sight they appear to be dry, has been ascertained, and it has been found to be great; and some of them not only retain moisture, but absorb moisture from the atmosphere. I know a noble mansion uninhabitable in consequence of the dampness produced by this property of the stone of which it is built. I have known a wall to be kept constantly damp through the attraction of moisture from the atmosphere by the sand employed in the manufacture of the mortar; and I do not recollect of ever seeing a house, built of unburnt brick, perfectly dry,

—and I have seen hundreds,—the clay having this property in a pre-eminent degree.

The walls of houses built of such materials, standing in an atmosphere kept humid by over-shadowing trees, or trees growing in close proximity, or even in a proximity not very close, absorb moisture with which the atmosphere is charged. The moisture transmitted or permeating it to the inner surface may be evaporated by the heat of the apartment within, but only to be followed by more and more, keeping the interior of the house constantly humid. Many have suffered for years in consequence of taking up their abode in a newly built house not thoroughly dried. In the case of such a house as I have referred to, it is never thoroughly dried, the drying process will go on continuously, or be continuously renewed, for a hundred years and more, if the house stand as long.

Not a little of the dampness may be attributed to the shade and the shelter of the trees, and the consequent want of ventilation; all which will afterwards come under consideration. What is brought under consideration at present is the humidity of atmosphere consequent on the copious evaporation of moisture by the leaves of trees. Reference has been made to the hydroscopicity of the walls of houses simply to show that the damp is not produced, but only transmitted by them; and it must be apparent that, in like manner, the damp experienced in connection with want of ventilation with shade and shelter, is damp not produced but only retained by them. The dampness of houses overshadowed by trees, or situated in close proximity to a wood, is indicative of humidity of atmosphere; and this humidity of atmosphere is occasioned, in part at least, by the copious evaporation proceeding from the leaves of the trees.

SECT. II.—*On Clouds occasionally seen surmounting Woods, while the Atmosphere around is comparatively Clear.*

The clouds occasionally seen over woods, while the atmosphere around is comparatively clear, are consequent on the condensation of the humidity occasioned by the evaporation from the leaves.

There is always moisture existing in the atmosphere; it is reckoned one of its constant constituents, but it varies in quantity. The quantity is minute compared with that of the oxygen and nitrogen of the air; but it is never absent. There it is, on the highest mountain and in the deepest mine; on the ocean's surface and on the dry land a thousand miles away.

But, as has been mentioned, while moisture may be found in the atmosphere everywhere, it is not always present in the same quantity in the same space. In almost any circumstances, but more especially where there is an unlimited supply of moisture, the quantity varies with the temperature, and varies with the temperature to a very great degree. According to Sir John Leslie, it doubles with every rise of twenty-seven degrees of temperature; and, according to subsequent observers, it varies to a still greater extent, the doubling taking place at different intervals, which increase slowly with the temperature—the mean being 23° 4′—from the freezing point to 100° Fahrenheit.

According to Leslie's calculation, the air at a temperature of 59° or 60° will hold twice as much as at 32°, or the freezing point; and at 86° it will hold twice as much again. And, according to later observers, at 121° it will hold twice as much again, or sixteen times as much as at 32°, eight times as much as at 53°, or four times as much as at 75°.

It is customary to speak of this as the solvent power of the atmosphere, as if the moisture were dissolved in the air as sugar may be dissolved in water; but it is more in accordance with fact to consider that as water requires a certain amount of heat to keep it from passing into a state of ice, so it requires a certain amount of heat to keep it in a state of vapour and prevent it from passing into a state of water.

In accordance with this, it happens that if air of a higher temperature, having as much moisture in it as can be sustained in a state of vapour, be cooled down some degrees, a quantity of moisture, which can no longer be maintained in a state of vapour, will assume the form of water in minute drops, and appear as fog, or cloud, or mist; but let the temperature be again raised to the same elevation as before, and this water will again assume the state of vapour, and the air become transparent, the fog or cloud having melted away. In illustration of this fact, I may refer to what is seen in the laying of the cloth on Table Mountain when the south-east wind blows. The temperature on the top of Table Mountain is lower than that of the wind blowing over its summit, and the mountain cooling down the air, a quantity of the vapour intermixed with it is deposited in the form of a cloud which is blown over the face of the mountain, and falls, threatening to bury the city below; but before it can reach

Cape Town it must pass through an intermediate stratum of air of a higher temperature than that to which it has been reduced. By this it has its temperature again raised, and the cloud evaporates and disappears, followed by continuous masses of cloud, which on reaching the same level vanish into thin air, leaving no trace behind.

The quantity of moisture passing into the atmosphere from the leaves of a forest in active vegetation must be considerable. Calculate the number of stomata, or stomates, on a leaf, multiply this by the number of leaves on a branch, the product by the number of such branches on a tree, and the product of this by the total number of trees in the clump, or the total number of trees in the forest, and the final product will indicate the provision made for evaporation from the forest. There are similar stomates on every verdant plant on the dry land; but the evaporating surface supplied by the leaves, rising tier above tier, far exceeds in extent that supplied by the herbage and the grass growing elsewhere; and in many places these may be found growing as luxuriantly on the soil of the forest as in the fields beyond, or perhaps more so, and adding their quota of evaporation to the evaporation from the trees.

Of the moisture thus raised by the tree, and no longer required when the sap has been elaborated in the leaf, the air will only take up what quantity it can, at the temperature at that time and place, dissolve and hold in solution; and cases have been cited in which the excess is so great that the leaves seem to act as alembics, distilling water which falls in great drops to the ground.

Where this does not take place, what the air dissolves it will hold in solution so long as the temperature is maintained at the same or a higher point; but if the temperature fall below the point at which it can do this, what it cannot sustain as invisible vapour will be deposited or suspended in the form of mist, or cloud; and such a reduction, may follow the setting of the sun, or even the decline of it in the afternoon and towards nightfall; or if there come over the trees a wind in any degree colder than the air in which they are enveloped, the air is thereby cooled down, and a quantity of the moisture which it held in solution may be deposited in the form of fog, or of dew, or of rain.

But this is not all; we shall afterwards have occasion to consider more fully the effect of vegetation on temperature, but here it may be remarked that it will generally be found that the temperature, both of the earth and of the atmosphere, is lower amidst abundant vegetation than in a barren, sterile, stony district, probably by heat being absorbed and retained in a latent form by the process of vegetation in the one case, while in the other it is reflected unchanged. In consequence of this, if a wind in any degree hotter blow over the district covered with trees, this wind is cooled down; its power of holding water in a state of vapour is thereby diminished, in a geometrical ratio, with every fall of temperature, and a large deposit of moisture may follow in the form of dew, of mist, or of rain.

The deposit may be much greater than may seem to be proportionate to the fall of temperature, but a reference to the observation of Sir John Leslie, and others, that a fall of temperature from 121° to 86°, which is not impossible in a semi-tropical country, occasions a deposit of half of the whole of the moisture held in solution, which is sixteen times as much as could be held in solution by air at 32°, eight times as much as could be held at 53°, and four times as much as could be held at 70°.

In illustration of what deposit of moisture might take place on such a fall of temperature if the air were nearly saturated, and the quantity of air so saturated great, I may quote the following descriptive account of one of those storms which frequently relieve the heat of Bengal, given by Mrs Murray Mitchell, in a volume, entitled "Indian Sketches of Life and Travel," lately published. The oppressiveness of the heat is described as such that one's hands "have a boiled feeling, like a washerwoman's who has been all day manipulating in the tub." Outside, the sun floods everything with one white blaze. "Nature is perfectly still, as if awed; the leaves hang limp and parched; the grass crumples up and disappears; the poor birds hide themselves away in any corner where there is a bit of shade; there is not even a fly abroad; all life seems frightened into quiescence, and mankind—at least the native portion—is asleep." At such a moment the storm suddenly descends. It is thus described:—

"Last week we arranged a nice little garden entertainment for our native friends, and invited some people to meet them. The green was set with numbers of small tables, covered with cakes, and tea, and ices, and flowers. Seats of all sorts and bits of carpet were put down everywhere. Some of our friends had come, and our garden-party promised to be both pretty and pleasant, when, lo! Mr Don said quietly, 'Look there!' and truly enough a cloud like a man's hand had risen in the west, and we knew what would follow. Consternation seized us; we all jumped to our feet; each one snatched up something—chair, table, cups, fruit, everything—and rushed pellmell into the house. Not a moment too soon. The heavens grew black as ink; the birds flew in terror to some cover, filling the air with their screams; the wind swept past with a low portentous sigh: and we had hardly our goods and ourselves under shelter, and the doors and windows secured, when the storm was upon us, and raging in mad tumult without.

"The air becomes thick with sand, and lurid, like the yellowest of London fogs; the wind rises into fury, and the dust is driven hither and thither as by a whirlwind. The sun seems blotted out, and in the appalling darkness you see the lightning play and dart, and zigzag from heaven to earth, without one moment's intermission. The thunder comes, not in distinct explosions, and then a pause, but in one continuous roll of terrific reverberating noise, while the rain descends with an *abandon* quite in keeping with the other forces of the storm. It generally comes in horizontal sheets of water instead of drops, and is driven by the mighty wind as you have seen seaspray driven from the wave-tops in showers of foam. A storm like this is a magnificent spectacle, and its effects are delicious. In a wonderfully short time the conflict ceases—the thunder rolls away into the distance, the wind is hushed, the sun shines out, and Nature, though tearful, looks happy and refreshed. Everything literally rejoices on every side; the air feels cool and light, and for some days there is pleasure in existence.

"Our little fête was spoiled; but when the war without ceased, we made up by doing what we could for the pleasure of our guests within, and all is well that ends well."

I design not to convey the idea that the moisture thus precipitated had been passed into the atmosphere by the foliage of a forest; I find no indication that a forest was there—it is the precipitation occasioned by the reduction of temperature alone which I seek to illustrate.

Previous to such a downpour of rain the heavens were perfectly clear, without a cloud to be seen; yet there, it may be, the whole of that moisture was suspended, dissolved in the air. The rain-cloud may have appeared to proceed from beyond the horizon, and to come thence, advancing onwards with resistless force, borne forwards by the gust of wind, more like a tornado than aught else; but there are reasons, and these satisfactory ones, to warrant the conclusion that the cloud had not been blown thither by the blast, but had been formed at the various points of its advance, by the wind suddenly cooling down the air below a temperature at which it could hold the moisture in solution: very much as is the case with the sand and dust filling the air immediately before the falling of the rain; whatever proportion of these may have been brought from a distance more or less remote, most of it may have been seen raised from the ground on the spot as the mighty rushing wind passed on in its course; and the little lapse of time between the appearance of this precursor and the precipitation of the rain was only such as was required, or at least such as was occupied, in the aggregation of the rain particles into the larger drops which fell, and the precipitation of these by gravitation and by the blast, aided, it may be, by the co-operation of electric force, the process being essentially the same whether the blast have come on like an onward moving cold wave, or have advanced as an advancing whirlwind which raised the air through which it passed to an elevation at which, it may be in consequence of sudden expansion, the temperature was too low to retain all the moisture in solution.

With the copious evaporation going on from the leaves of a forest there is nothing, in view of such a rainfall, surprising in any change of wind producing a cloud or mist above a forest, where formerly the air had been perfectly transparent; and everything known in regard to such phenomena makes it probable that in general, if not invariably, the cloud is produced there, and not attracted thither by the forest.

In connection with this, there is an observation, made by Mr Marsh, which demands attention :—" There is one fact," says he, " which I have nowhere seen noticed, but which seems to me to have one important bearing on the question, Whether forests tend to maintain an equilibrium between the various causes of hygroscopic action, and, consequently, to keep the air within their precincts to an approximately constant condition, so far as this meteorological element is concerned. I refer to the absence of fog or visible vapour in thick woods in full leaf, even when the air of the neighbouring open ground is so heavily charged with condensed vapour as completely to obscure the sun. The temperature of the atmosphere of the forest is not subject to so sudden variations as that of cleared ground, but, at the same time, it is far from constant, and so large a supply of vapour as is poured out by the foliage of the trees could not fail to be condensed into fog by the same causes as in the case of the adjacent meadows, which are often covered with a dense mist while the forest air remains clear, were there not some potent counteracting influence always in action. This influence, I believe, is to be found in the equalization of the temperature of the forest, and partly in the balance of the humidity exhaled by the trees, and that absorbed and condensed invisibly by the earth."

I accept the statement with all confidence in the correctness of the observation by Mr Marsh. The fact was previously unknown to me.

By the fall of leaves and their decay, and in other ways, the soil in which trees grow becomes rich with humus, by which means its power of attracting moisture from the earth is increased. In a forest the temperature is more equable than in the open country; to both of these facts Mr Marsh refers, and I may add, what is also held by him, that there is heat evolved as well as heat absorbed in vegetation, a point which will afterwards be discussed more fully. In virtue of this and of the shelter of a forest, it may in certain conditions continue for a time, more or less protracted, protected from a change of temperature, producing a fog in the open country around.

Without ampler information, or personal observation of the fact with opportunity of noting the circumstances, I am not in a position to say more.

SECT. III.—*On Clouds occasionally seen surmounting Mountains while the Atmosphere is otherwise Clear.*

With regard to the phenomena of clouds apparently attracted by mountains, Mr Marsh, in his treatise "On the Earth as Modified by Human Action," writes,—"In discussing the influence of mountains on precipitation, meteorologists have generally treated the popular belief that mountains attract to them clouds floating within a certain distance from them as an ignorant prejudice, and they ascribe the appearance of clouds about high peaks solely to the condensation of the humidity of the air, carried by atmospheric currents up the slopes of the mountains to a colder temperature; but if mountains do not draw clouds and invisible vapour to them, they are an exception to the universal law of attraction. The attraction of the small Mount Shehallien was found sufficient to deflect from the perpendicular, by a measurable quantity, a plummet weighing but a few ounces. Why, then, should not greater masses attract thence volumes of vapour weighing many tons, and floating freely in the atmosphere within moderate distances of the mountains?"

As stated thus, the popular belief assumes a form in which it can be dealt with more satisfactorily than in the vaguer form in which it is generally met with. The answer I would give to the question is, However plausible the supposition may be, I desiderate evidence that gravitation can occasion a deposit of moisture suspended in a state of solution in the atmosphere, operating on it otherwise than it does upon the other constituents of the air; and the phenomena seen can be accounted for satisfactorily otherwise.

All that was done by Mount Shehallien was to cause a deflection of the plummet; the preponderating attraction was towards the earth's centre. The phenomenon under consideration is not a deflection from the perpendicular, but the appearance of clouds on the mountains alone.

We cannot get rid of the idea that the earth by gravitation exerts an attractive force upon clouds, but they do not fall precipitately upon the earth. Solid matter, so comminuted as to appear as dust, floats in the atmosphere for a length of time, rising even with aerial currents in despite of gravitation; so is it with the molecules of water in a fog. With regard to invisible vapour, it appears to be subject to the law of gaseous diffusion, in which, though still held by gravitation within the atmosphere, it is free within the limits of this to go any whither. True, moisture can be withdrawn from the atmosphere, and it is so withdrawn, but this is not attributable to gravitation; it is attributable to chemical affinity, whatever that may be, and it varies with the composition of the soil and the chemical affinity of its constituents for moisture.

In lack of evidence that the attraction of gravitation exercised by the earth abstracts moisture dissolved in the atmosphere from the air, I see no reason to conclude that by gravitation has moisture been abstracted from the air on the mountain top when there the cloud is formed.

While I desiderate evidence that gravitation can occasion a deposit of moisture suspended in a state of solution in the atmosphere, operating on it otherwise than it does upon the other constituents of the air, and evidence that the gravitation occasioned by mountains differs in its nature from the more powerful gravitation exercised by the earth, I see no evidence of their attracting clouds; and all the phenomena connected with the appearance of clouds surmounting mountains may be accounted for in accordance with the way in which the appearance of clouds surmounting forest has been accounted for, that is by a fall of temperature below that at which the vapour there suspended in the atmosphere could be sustained by it in solution.

It is in defence of that view that the subject comes under consideration, and what has first to be established is the possible production of clouds in a transparent sky. The case of a Bengal storm has been cited; but as evidence of the case in question it may be considered insufficient, I therefore supplement it with more explicit testimony.

At the Cape of Good Hope, again and again, I have seen the heavens gather blackness where shortly before the sky was cloudless, the first manifestation of a change being the appearance of clouds the size of a man's hand, not blown thither, but there appearing as if formed there, and the progress and completion of the change resembling somewhat the dissolving view represented by a magic lantern. The clouds were neither blown thither bodily nor attracted, but were formed there, apparently by an intermixture of currents of air of different temperatures. And again, the whole cloudland structure—bold in its outline as the smoke belching forth from the cannon's mouth at the moment of discharge, and magnificent as a realization of Fancy's dream of Ossa piled on Pyleon, and Pyleon-like mountains on Ossa again—passed away like the deposition of vapour breathed upon the polished steel, passed away as if it had never been, leaving not a wreck behind. And the corresponding phenomenon I have seen when, according to the local phrase, the Devil lays his table-cloth on Table Mountain. To this I have already had occasion to refer.

At these times the summit of the mountain is covered with a dense mass of beautiful white fleecy cloud in constant flow over the precipice, and pouring down the almost vertical front of the mountain facing Table Bay as if threatening to bury in an avalanche the capital of the colony at its base; but long ere it reaches the town, notwithstanding the continuous flow, it stops; to that line it flows on continuously, but beyond it, not: there the cloud in unceasing flow terminates, the spectator sees not why.

The beautiful and interesting phenomenon is occasioned by a south-east wind, which, up to the Table Mountain range, was undimmed. The wind was strong, but the sky blue and serene, though the wind was loaded with vapour—vapour dissolved and invisible.

But passing over Table Mountain the elevation of this is such that the decrease of temperature, consequent on expansion under diminished pressure bringing this below the dew-point, the moisture is deposited by the air in the form of cloud, which, as it reaches at lower level to leeward, a locality with a higher temperature, the moisture is again absorbed and the air loaded with it is again transparent, as is all the air around, and as it was itself before passing over Table Mountain in its course.

From Claremont, or Wynberg, or the Flats, or any place to the back of Table Mountain, it may be seen that the cloud is not blown to the mountain, but there it first appears; and if some few cloudlets, formed over the crests of hills belonging to the range situated to windward, be seen sailing towards it, it is evident that they are "A sailing, a sailing with the wind," and not attracted only, for none are seen floating towards the Table-Cloth in other direction than that in which the wind blows.

Of this phenomenon Sir John Herschel writes, "That the mere self-expansion of the ascending air is sufficient to cause precipitation of vapour, when abundant, is rendered matter of ocular demonstration in that very striking phenomenon so common at the Cape of Good Hope, where the south or south-easterly wind which sweeps over the Southern Ocean, impinging on the long range of rocks which terminate in the Table Mountain, is thrown up by them, makes a clean sweep over the flat table-land which forms the summit of that mountain (about 3850 feet high), and thence plunges down with the violence of a cataract, clinging close to the mural precipices that form a kind of background to Capetown, which it fills with dust and uproar. A perfectly cloudless sky meanwhile prevails over the town, the sea and the level country, but the mountain is covered with a dense white cloud, reaching to no great height above its summit, and quite level, which, though evidently swept along by the wind, and hurried furiously over the edge of the precipice, dissolves and completely disappears on a definite level, suggesting the idea (whence it derives its name) of a 'table-cloth.' Occasionally, when the wind is very violent, a ripple is formed on the aerial current, which, by a sort of rebound in the hollow of the amphitheatre in which Capetown stands, is again thrown up, just over the edge of the sea, vertically over the jetty—where we have stood for hours watching a small white cloud in the zenith, a few acres in extent, in violent internal agitation (from the hurricanes of wind blowing through it), yet immovable as if fixed by some spell, the material ever changing, the form and aspect unvarying. The 'table-cloth' is formed also at the commencement of a 'north-wester,' but its fringes then descend on the opposite side of the mountain, which is no less precipitous."

I mean not to affirm that in every case the clouds capping mountains and mountain ranges have been formed in the same way. All that I affirm is that thus it is there in the circumstances stated, and thus it may be elsewhere oftimes when clouds are seen covering a mountain brow, and that, whether these mountains be wooded or bare.

When the mountains are covered with forests of deciduous trees, the great quantity of moisture passed into the atmosphere by the stomates of the leaves may render the air more readily indicative of any fall of temperature, but that is all.

The phenomenon in question comes under consideration here solely because this and the phenomenon of clouds surmounting woods are generally referred to as indicative of an attractive power over clouds being exercised by the one and by the other; and it may be satisfactory to some student of the meteorological effects of forests to see that neither in the one case nor in the other is there any necessity to call in the aid of some unknown, and consequently mysterious, power of attraction to enable us to account for the phenomena observed.

CHAPTER II.

EFFECTS OF FORESTS ON THE HUMIDITY OF THE GROUND.

IT may be considered a departure from the professed subject of this treatise to speak here of the effects of forests on the humidity of the ground; but the subjects are correlated. Practically it is humidity of soil which is what is desired, and the conservation of moisture in the soil has a direct influence, in different ways, on the moisture in the atmosphere, so important as to justify, if not to require, some attention, being given to it in treating of the meteorological effects of forests.

The subjects coming under consideration here are the following: The wetness of roads when overshadowed by trees; the shelter afforded by trees against drying winds; and the attraction and retention of moisture by vegetable mould; and to this might be added the effect of trees in arresting the flow and escape of the rainfall—but a better opportunity for bringing these under consideration will afterwards present itself.

SECT. I.—*On the Wetness of Roads where these are Overshadowed by Trees.*

We have had under consideration the dampness of houses overshadowed by trees, or situated in close proximity to woods. Not less noticeable than this is the wetness of roads where these are overshadowed by trees. This may frequently be observed while elsewhere the road is dry, and it may be supposed that in this we have only an exaggerated effect of what occasions the dampness of such houses; but there is more in the phenomenon than this would imply.

While much of the rain which falls upon the earth, and much that falls in the form of snow and hail, flows away to the sea—the tiniest streamlet and the mightiest river or flood being alike the product of such flow—and while a portion is absorbed by the earth, a great deal is evaporated and absorbed by the air. The higher the temperature of the ground the more rapid is this evaporation. The effect may be seen in the steaming of the streets after a short shower in summer: there is then more evaporated from the hot stone than the superincumbent air can sustain in solution, and the surplus is temporarily deposited in a visible form. And in the wetness of the roads under the condition stated we see, in addition to effect of the trees in increasing the humidity of the atmosphere by evaporation through the stomates of the leaves, the effect which they bear in checking or preventing such evaporation from the ground.

The quantity of moisture held suspended in solution in air, or which may be so held, increases with the temperature, and when the sun's rays fall unimpeded upon the road this raises the temperature of the earth and stones; and these by contact and radiation raise the temperature of the incumbent air, which in its turn takes up the moisture with which they were covered: the moisture being evaporated in the same way as is a drop of water falling on a hot stove, or as the moisture on a wet handkerchief when this is held to the fire, but less rapidly, as the temperature is not so high.

The same difference as is seen on the exposed and shaded part of the road may be seen in the ground on the sunny and shaded sides of a house, only less marked because the shade is less complete.

I have stated in another volume that, to test the correctness of some statements, I had had occasion to make at the Cape of Good Hope, on the effect on the destruction of herbage by fire on the desiccation of the country, Mr W. Blore, M.L.A., Fellow of the Meteorological Society of London, and Secretary of the South African Meteorological Society, made some experiments with the following result:—He sunk two cylindrical jars, of the same size, in the ground to the depth of 4 inches, leaving them projecting an inch above the surface, as a precaution against sand and other matters being blown into them, and covering each with wire gauze to keep out flies, &c. The one was placed where it was partially protected, but not covered by bush, the other was sunk in a newly cleared plot of ground, measuring about 60 feet in diameter, surrounded by sugar bushes, *Protea mellifera Thbg*, of a considerable height, and otherwise protected from the prevailing wind by a belt of pine trees, about 120 feet distant.

Into each of these jars was put 20 oz. of water on January 31st, at 10 A.M. On February 5th, at 5 P.M., the water remaining in each was carefully measured, and the evaporation was calculated, when it was found that the evaporation from the jar sunk in the cleared ground had been more than double the evaporation from that which was partially protected, though not covered by the bush; the former being 1·854 in.; the latter ·863 in.; giving an excess of ·991 in. The experiment was repeated with similar results.

In reporting these results Mr Blore remarked that had the experiment been made in a more arid district, the evaporation would have been greater; and that had it been made in the open country, the difference would have been marked. But, taking the results obtained as the basis of calculation, he arrived, by the following process, at a conclusion for which, probably, few who have not given attention to the subject are prepared.

The excess of evaporation from the more exposed jar above that from the jar partially shaded, but not covered, being one inch, more strictly speaking upwards of $\frac{99}{100}$ of an inch of water, and more than double that of the latter. "An inch in six days," says he, "will give for 102 days, the ordinary duration of the hot windy and dry season in the district, 17 inches. This is equal to about three hundred and eighty-four thousand (384,000) gallons per acre, and supposing 1,000 acres to be burned, blackened, and dried—what with sunlight, fire, heat, and wind, the evaporation would be an excess of three hundred and eighty.four millions of gallons of water above what would have been evaporated if the bush or grass had been left unburned."

In the prosecution of his researches, Mr Blore ascertained by experiment that on Wynberg hill, while the deposit of dew on a green surface amounted to 4·75, that on a white surface amounted only to 2, showing that the deposit of dew upon a green surface is more than double that upon a white; and he further ascertained that, while the difference of temperature in the water in the two jars employed in the former experiment was only a few degrees, the difference of temperature between black ground and ground shaded by bush was about 25°, which would occasion a vastly greater difference in the amount of evaporation than that which occurred in his experiment.

In a letter on planting trees by water-courses, appended to Report of Colonial Botanist for 1863, it is stated:—"In the course of my tour I have found that in some places an opinion prevails that trees growing by the side of a stream, steal away the water. And in support of this opinion, my attention was directed to the fact that under trees or plants the moisture spreads for several inches, eighteen or twenty it may be, over and through the banks towards the tree, while at exposed places between the trees the moisture spreads not above one or two inches from the surface of the water. But this, so far from proving what was alleged, may be adduced as evidence of the correctness of my view of the matter. The water spreads from the stream by what is called capillary attraction, and spreads in all probability quite as far in the exposed as in the covered spots, but where it is exposed it is continuously evaporated by the heat of the sun's rays, so that, excepting during the night and early in the morning it never becomes visible in the darkened hue of the soil, while under the shade of the trees it has been protected from evaporation. There the water which has spread so far is retained with very little loss. But at the exposed parts of the bank there is a constant drain throughout the day. Water evaporates; more rises to supply its place; but this is carried off in like manner, till the setting of the sun suspends for a time this wasteful process. So far from the tree stealing the water, it takes up no more than it retains in the structure of its sap, wood, flowers, fruit, and green leaves; the heat is the thief, if thieving there be. The tree has not stolen away the water which occasions the moisture seen under its shade. The soil did that, and it did the same all along the water-course; and the tree, like the faithful dog, has watched over and protected that portion from the heat of the direct rays of the sun, by which it would otherwise have been conveyed away and transported by the air to regions, it may be, far remote."

While I adhere to the statement thus made, I may add that in the remark which called it forth there is—as there often is in popular remarks—a mixture of truth and error; it was neither absolutely correct nor absolutely erroneous: the tree had actually withdrawn moisture from the streamlet, for thence it was that the moisture retained in its structure and the moisture evaporated by its leaves had mainly been obtained; but the blackness and dampness of the soil between the streamlet and the tree to which it was that my attention was called had not thus been produced,—that moisture had not been occasioned by the vegetation of the tree but by the capillary attraction of the soil. The shade of the tree had prevented the direct rays of the sun falling upon this as they did upon the ground around; thus an evaporation, such as had dried the ground beyond, had been prevented; and in the same way is the desiccation of a road retarded where it is overshadowed by trees.

In the Journal of the Royal Agricultural Society, N.S., vol. ii., p. 110, there is a statement, by Mr R. Orlebar, of Willingborough, on the advantage of planting trees around ponds, in which he says, "It is astonishing what effect a little shade has in checking evaporation. A pond that is well shaded will hold water for weeks after one of equal dimensions, but lacking shade, will become dry. The best shade is that given by fir trees, or other evergreens, for they give it all the year round. The yew, perhaps, would be even better for shade than the fir, but for its poisonous qualities. After the fir, I doubt whether there is, on the whole, any better plant for shade than the hawthorn bush. Its leaves sprout early, and fall late; and it possesses, besides, the great advantage that it forms its own fence." And the writer tenders the counsel, suitable for Europe and countries in the northern hemisphere, "Always, if possible, have the mouth of your pond on the north side, and the shade on the south side." A suggestion which commends itself. While the writer speaks only of shade, it may be that the effect mentioned by him was to some extent due to shelter afforded to the pond from wind.

I find it stated, in reference to the suggestion of Mr Orlebar, by a writer, On the Dew of Heaven and the Influence of Forests, in the *Farmer's Magazine*, Mr Cuthbert W. Johnstone, that in some parts of England they are careful to have the oak planted around their ponds; and he mentions, as bearing upon this point, a fact to which I have already referred, that the dew under some large oak trees by the side of his bowling-green, at Croydon, is always considerable of an evening; but that under a witch-elm, growing by their side, the dew is almost always absent. Observation will show whether this difference is attributable to the difference in the shade afforded, or to a difference in the quantity of moisture evaporated through the stomates of the leaves, in accordance with what has previously been stated with regard to the dropping from trees (ante p. 35).

SECT. II.—*On the Desiccation of Ground by Drying Winds being Prevented by the Shelter afforded by Clumps of Trees.*

In the case of a tree by the side of a stream with the ground between the stream and its trunk moist, while all beyond was dry, we had an indication of the effect of a tree in preventing evaporation by protecting the moist ground from the sun's rays, and it may be, in part, by reflecting or confining vapour rising from the soil; but not less important is the influence exerted by a clump of trees in preventing evaporation, by protecting moist ground from the desiccating effect of wind.

We often hear of *a drying wind*; and many may have remarked that a clear wind does more to dry the roads in spring than does even bright sunshine. Every clear wind is a drying wind; it is composed of air not surcharged with moisture; up to the measure of saturation every particle of this air can take up and dissolve additional moisture, and it will do so by simple contact therewith. Were the air stagnant, evaporation might go on slowly, the air in contact with the moisture taking up a portion of it and slowly transferring this to the stratum above, to be in like manner transferred to the strata beyond; but moved on, as every particle of the air is, by and with, and in the wind, it imbibes a portion and passes off loaded to let more follow to do the same; and we see the effect in the rapid drying of ground over which the wind has free course; while we see the effect of shelter in the continued humidity of the ground wherever it is protected from the wind by a wall, a house, a hedge, or a clump of trees.

To this effect of wind, and the modification of it produced by shelter, reference is made in the before mentioned experiments and observations made by Mr Blore.

It is stated by Mr Milne Home, chairman of the Council of the Scottish Meteorological Society, in a paper containing suggestions for increasing the supply of spring-water at Malta, and improving the climate of the island, to which I shall afterwards have occasion to refer at greater length, "Halley found that, when water is kept in a room, to which neither sun nor wind had access, the evaporation amounted to 8 inches in a year; but when exposed to sun and wind, even in the cloudy atmosphere of London, it amounted to 48 inches yearly. More recent and accurate observations make the natural evaporation from soil kept moist not quite so much. Howard of London gives, as the mean of eight years' observations, 30 inches. Dobson of Liverpool found, after four years' observations, a mean annual loss by evaporation of 37 inches;—the least evaporation being in December, when the temperature was 44°, the greatest in July, when the temperature was 70°. Dalton of Manchester found that evaporation there was at the rate of 30 inches;—the lowest being 1·01 inches, in December, the highest 40·9, in July.

"An instructive table was framed by Dalton, showing the number of grains of water evaporated, from a given surface and during a given period, at different temperatures, and with different velocities of wind. The following extracts are made from this table :—

Temp. Fahr.	Light Wind.	Strong Wind.
50°	1 50	2 36
60°	2·10	3 33
75°	3 40	5·34
80°	4 ·0	6·29
85°	4·68	7·46

The shelter from drying winds, and the consequent protection against rapid desiccation of ground, afforded by a wood, extends far beyond the shade of the trees; and thus the prevention of evaporation by the wind becomes, in most cases, of more importance than the prevention of evaporation by sunshine.

Of the extent of such protection there are illustrations given by Mr Marsh, in his treatise on the "Earth as Modified by Human Action" (pp. 162–166). They are adduced by him in illustration of the effects of forests on climatal temperature; but the subjects are correlated, and the statement by Mr Marsh will be afterwards given.

It is not only to leeward that the beneficial action of a forest in giving direction to the wind is felt; in some respects the calm it secures to windward may be equal in importance to that which it ensures beyond. Some years since a stage coach from the head of Loch Long to Oban was usually driven by a coachman whose jests, and jibes, and pleasantries, and humours, often kept the occupant of the seat beside him, and the occupants of the seat immediately behind in roars of laughter foı miles. It is said that on one cold windy day he had as occupant of the box-seat a Scottish Judge, one of the Lords of Session, who remarked in many places sheep crouching on the windward side of whin bushes, and after a time, calling the attention of the coachman to the circumstance, he asked him why they did so. "To keep them from the wind, my lord," was the respectful reply. This called forth the unhappy remark. "If I were a sheep I would lie down on the other side of the bush." When forth came without a moment's warning the rejoinder, "Ah! but, my lord, if you were a sheep ye wud hae mair sense!" The sheep and the coachman were right. The beautiful curve of a snow-wreath shows what was the course taken by the wind in its formation and indicates the course usually taken by it in surmounting a barrier: a long sweep on the windward side, a comparatively precipitous fall to leeward. The observatory erected by Sir John Herschel with a view to securing calm for the immense tube of his telescope was erected in relation to prevalent winds to windward, not to leeward, of Table Mountain. And a calm prevails at Herschel and Bishop's Court while the wind is blowing strongly on the Flats, and pouring over the front of Table Mountain like an avalanche.

To some to whom the fact may be new, it may prove corroborative of what has been stated if I call attention to another fact, which has been observed by others. In walking along the edge of a sea-cliff facing the wind it has been found, when the breeze was slight or moderate, that it was felt in full force up to the edge of the precipice; but when the breeze was strong, there was a breadth of perfect calm along the edge of the cliff, while a little way inward the blast was felt in all its fury,—the width of the calm being proportionate to the force of the wind, the upward concave curve of the leeward current passing into a convex curve carrying it over the head of the observer.

It is in connection with my advocacy of the conservation and extension of forests at the Cape of Good Hope as a remedial measure against the aridity—and progressing aridity—of the soil and climate, that I have brought this subject under consideration. I am quite aware that an argument in favour of the cutting down of forests, woods, and trees, as well as an argument for the conservation and extension of them by plantation, may be founded on the fact to which I am calling attention. It is the case that there are places in which the one operation may be as advisable as the other may be in others: there are countries, in which woods and moisture are both in excess, the clearing away of forests to a certain extent is advocated on the very ground that their effects are such as I am endeavouring to show that they are. But this only goes to strengthen my argument and establish the fact which I am endeavouring to expound, irrespective of the practical application of it which may be made by myself or others: that fact is, that belts of wood, and fences, and forests, in their several degrees, acting as windbrakes, retard both to leeward and to windward the desiccation of ground by the evaporation promoted by drying winds.

SECT. III.—*On the General Phenomena of Evaporation from Forests.*

It appears to be unquestionable that by the shade which they occasion, and by the shelter against drying winds which they afford, forests exercise a considerable influence in diminishing the evaporation of moisture from the soil; but, in connection with the consideration of this, there should be taken into consideration the general phenomena of evaporation from forests.

M. Cézanne in his *Suite to Étude sur les Torrents des Hautes Alpes*, by M. Surell, remarks that "evaporation is for modern physical science a phenomenon comparatively simple and well understood. It is known, for each degree of temperature, what is the tension and what is the measure of saturation of the air. But looked at from a meteorological point of view the phenomenon is one of the most obscure; and the limited number of observations which have been made cannot admit of their being compared together.

"What, in a given place, is the depth of water which is carried off in one hour by evaporation? This varies according as the evaporating surface specified may be drenched or only damp, be stagnant or running water, be in the sunshine or shade, according as it may be summer or winter, according as the air may be saturated or not, or be more or less saturated, and according as the air may be at the time windy or calm.

"Two adjacent basins, placed in the same meteorological circumstances, evaporate unequal quantities of water if they be larger or smaller, if their sides be more or less elevated, if they be sheltered from the wind or not, etc.

"When it is said that the annual evaporation at Rome is 2·462 millimètres, at Marseilles 2·289, at Paris 0·698, at London 0·754, at Toulouse 0·649, at Copenhagen 0·209,* all that is meant to be said is that in the circumstances in which the observers were placed they have determined these results. But the mean annual evaporations furnished for each place are far from having the same scientific value as the mean annual rainfalls, which present on the contrary a specific character. It may always be affirmed with certainty that evaporation goes on decreasing from the equator to the pole, where, however, it is far from being *nil*, even in the greatest frost;† that it is more feeble near the coast than in the interior of a country; and more feeble also under the *equatorial* wind from the south-east than under the *polar*

* Vallès: *Inondations*, p. 23.

† Hayes: *La Mer libre du Pole*, p. 224. Wet linen, exposed to the air, dried at the lowest temperatures; and a sheet of ice, suspended by a thread, evaporated away by little and little.

wind from the north-east—the former being saturated with moisture, while the latter has been deprived of it."*

And having stated what the effect of this is on the flow and delivery of rivers, he goes on to say,—"If such be the important part played by evaporation, it is evident that forests exercise an appreciable influence on water-courses, according as they promote or retard, to whatever degree it may be, evaporation. But in what do they exercise this action? On this point the whole world seems to be at sixes and sevens.

"Throughout all time the poets have sung of the cool shade—the moist shade of extensive woods. A nave of verdure thrown over a road keeps it moist, and as a consequence protects it or injures it, according to the climate or the seasons. In every page of works on forestry may be met allusions to the humidity, which is favourable to the seedlings, and which the shade maintains.

"If any one entertain a doubt, let him follow in the suite of a forest-guard the day after a storm of rain; when, although the open country and *a fortiori* the roads are already dry, he may procure for himself a cold bath in penetrating into the clumps of copse-wood. At his feet the tall herbs are little better than a stream, and on his head every shaken branch will pour down a *douche*, which will make itself be felt." And in explanation he adds in a foot-note,—"Any one may observe that on the leaves of certain vegetables, but not of all, the rain-drops take a spheroidal form; in this state they resist evaporation energetically, as one may see globular drops run about on red-hot iron without ebullition. The foliage of other plants has been dried for a long time, while these pearls sparkle still on the herbs which bear them. Certain species preserve thus the rainfall until the agitation of the leaves cause these spheroidal drops to fall." And he goes on to say, "It seems then natural to believe that forests oppose themselves to evaporation, and, consequently, acquire for the ground the product of the rain. But objections are not awanting.

"Attention is called to the circumstance that the foliage of trees arrests a notable portion of the water falling as rain. When a light rain-storm follows some days of dry weather, it may be seen that each tree casts a dry shadow, which on the wet ground of the road is marked out by a dust-covered patch. The water arrested by the leaves is lost to the ground underneath; the tree or the air will absorb it, and the importance of this is such as is not to be overlooked.

* Schmit: *Grundriss der Meteorologie.*

"The Maréchal Vaillant has frequently drawn public attention to forest hydrology. He instituted experiments to measure the quantity of rain which is arrested by the foliage of trees; and the following are some of the results he obtained; the observations were made in the forest of Fontainebleau, during the year 1866:—*

QUANTITY OF RAINFALL.

Months.	In open air.	Under leafy woods of 30 years' growth.	Proportion.
	millimètres.	mm.	mm.
January	35	24.5	or ·70
February	78·5	63	·81
March	80·8	58·2	·72
April	67	50.9	·76
May	46·2	31·5	·68
June	66	32	·48
July	105 8	53·8	·50
August	117	60	·51
September	123·5	65	·51
October	31	14·2	·45
November	47·5	29	·62
December	61·2	43·5	·70
	859·5	524·7	0·60

"From this it is seen that the leaves arrested in winter 30 %, in summer 50 %, and, on an average, throughout the year 40 % of the rain which fell.

"Under the Epicéas [*Picea excelsa, Link*] of 35 years' growth, probably in dense clumps, the pluviomètre received only 21 % of the years' rain-fall: the tree arrested 79 %. In a forest adjacent to Versailles, the pluviomètre, placed under a leafy wood, received 80 % of the year's rain: the foliage arrested only 20 %. Under a timber forest of oaks, of from 70 to 100 years of age, the instrument received 85 % of the year's rain.

"Perhaps there may be ground for some little discussion in regard to these experiments: the position in which the pluviomètre might have a marked influence on the results. Two instruments placed under an umbrella, one towards the centre, the other at the circumference, under the droppings of the ribs, would give a bad measurement of the mean fall of water on the soil.

* *Revue des Eaux et Forêts.* 1867. P. 161.

"M. Mathieu, sub-director of the Forest School, has undertaken a series of experiments under very favourable conditions. Of these the following is one which is particularly interesting, and one, the results obtained by which scarcely agree with those of Marshal Vaillant. Two udomètres were placed at the forest station of Cinq-Tranchées, the one in the open wood, under a patch of beeches and hornbeams, of average denseness, and of the age of 42 years; the other, at a little distance, in the middle of an open space many hectares in extent. It may be well to note that the forest udomètre is of special construction; that the receiver embraces the stem of one of the perches of the clump, and presents a surface quite equal to the projection of the top of the tree; that by this means the indications of the instrument are quite exact, and represent well, without exaggeration or diminution, the depth of the sheet of water received by the wooded ground; and that this water, dropping from leaf to leaf, passes through them, or flows down the trunk.

"Under these conditions the udomètre gave, in 1868, the following quantities of rain:—

MEASUREMENT OF RAIN.

Months.	Under wood. *millimètres.*	Outside wood. *mm.*	Proportion. *mm.*
January,	68	73	0·931
February,	37	36	1·025
March,	50	50	1
April,	69	73	·945
May,	8	8	1
June,	48	52	·923
July,	31	34	·911
August,	26	37	·702
September,	59	61	·962
October,	118	122	·967
November,	26	28	·928
December,	163	174	·936
Total,	703	749	·939

"It may be astonishing to see in the table that during the months of February, March, and May the sheltered pluviomètre received as much or more rain than the pluviomètre in the open space; it is necessary to consider that, either through some caprice of the rain, or by some such effect of the trees, there fell more water in the wood than in the adjacent open space. This result, moreover, might explain itself quite naturally, and without calling in any special action of vegetation, if the open space were less accessible to the rainy wind than was the wooded clump.

"It is worthy of remark that the mean proportion between the two instruments, which was 0·939 for 1868, had been 0·938 for 1867, and 0·952 for 1866: that is to say, that the proportion varied very little."

Along with the allowance, which it may be deemed necessary to make for the quantity of rain which may be arrested by the foliage and evaporated thence without reaching the ground, in a rough estimate of the benefit which trees may bring to the soil by preventing evaporation thence, it may be deemed necessary to make some allowance in certain circumstances for the evaporation, through the stomates of the leaves, of moisture which is dissipated in the atmosphere, if this be in excess of the difference between what is evaporated from the soil under the shade and shelter of the wood and what is evaporated from adjacent open country.

I am disposed to question whether such a case be of frequent occurrence, or if it be likely to occur at all, but the possibility of its occurrence must not be ignored. I cannot do more than refer to it to show that it is not ignored by me.

In a preceding section I have referred to the observations of Mr Blore on evaporation, under shade and shelter, and in open ground, at the Cape of Good Hope; and in connection with a notice of these observations I had occasion to cite some experiments on evaporation made by M. Mathieu. A report of these was published by the French Government in the "*Atlas Météorologique de l'Observatoire Imperial*, 1867," from which it appears that, during the seven months comprised between April and October in that year, whilst the quantity of water evaporated from forest leaves was 3.23 inches, the quantity evaporated from land clear of forest was 16.29 inches, or about five times as much.

In April, before the development of leaves, if 1,000 represented the evaporation from the open country, 623 represented the evaporation from woodland; but after the trees became clothed with foliage the amount of evaporation from the woodland was only 130, as against 1,000 of open country evaporation. In October the woodland evaporation was to the open country evaporation as 90 to 100.

The experiments were continued in 1868.

At the station of Belle-Fontaine, M. Mathieu measured the evaporation by means of vessels exactly comparable placed outside of a wood, and under a leafy wood. During the months of January and February no observations could be made on account of the frost. But in the subsequent months the following results were obtained :—

WATER EVAPORATED.

Months.	Outside the wood. *millimètres.*	Under the wood. *mm.*	Proportion. *mm.*
March,	33	9	3.66
April,	50	19	2.63
May,	105	23	4.56
June,	107	19	5.63
July,	95	10	9.50
August,	75	8	9.37
September,	55	11	5.
October,	12	3	4.
November,	2	0	9.
December,	8	4	2.
Totals,	542	106	5·11

From this it is seen that during ten months in 1868 the evaporation was more than five times greater in the open space than it was in the forest, which consists of high perches, dense and close, of hornbeams, beeches, oaks, and ashes of sixty-two years' growth.

There are cited by Marsh some valuable observations by Risler on the evaporation from cultivated soils and the exhalation and exudation of humidity by field plants and forest trees, given in the *Archives des Sciences (Bibliothèque universelle de Genève)* for Sept. 15, 1869; March 25, 1870; and Nov. 15, 1871, which seem to lead to this general conclusion, that forests evaporate less than an equal extent of pasturage, and that if we suppose a mean precipitation of two and a half millimetres per day, of which two millimetres penetrate into the soil, the forest takes up less than one half of this supply, the remainder descending into the sub-soil and percolating through earth and rock until it issues in the form of springs. He found an evaporation of one and one tenth millimetre per day to be the maximum from a forest of firs under exceptionally favourable conditions of a fertile and humid soil and abundance of sunlight.

Risler, in the experiments referred to found that in 1867, not far from Geneva, no water escaped from a parcel of ground thoroughly underdrained at the depth of 1m,20, in the months of July, August, September, November and December, and but a very trifling quantity in June and October; in 1868, very little in May and September and none in June, July and August. In 1867 the total precipitation was 1066.84 millimetres; the evaporation, as measured by the difference between rain-fall and drainage, 733.44 millimetres; in 1868, these quantities were 1032.36 and 755.74 millimetres respectively.

M. Cézanne remarks in regard to all the observations cited by him, —"In conclusion, and with every allowance for the small quantity of water which is retained by the leaves, the foregoing observations strengthen the conclusion that, under the same measure of rain-fall, the soil of the forest receives and retains notably more water than does uncovered ground.

SECT. IV.—*On Moisture being Attracted from the Atmosphere, or otherwise retained in the Ground by Vegetable Mould.*

The meteorological effects of forests are, as has been intimated, somewhat complicated, and the student of these availing himself of my guidance may be beginning to perceive something of the complication in which they are involved; but thus far the unravelling of different strands has been found to be practicable, and this operation may be carried a little further without difficulty.

A distinction has been drawn between the effects produced on the ground by the shade from sunshine, and by the shelter from drying winds afforded by trees and forests. It is necessary, further, to distinguish between the effects produced by shade and by vegetable mould, which exists always, in greater or less quantity, in forest soil, in consequence of the decay and decomposition of fallen leaves and and fallen twigs, and broken or decaying rootlets.

In the soil of a forest there generally exists more moisture than can be attributed to shade, or to shade and shelter combined; and much of this is attributable to the attraction of moisture manifested by this vegetable mould.

By a series of simple experiments this fact may be demonstrated, the quantity of moisture determined, and the proportion attributable to each of the effects mentioned approximately ascertained.

Take the weight of a hundred grains or of a hundred drams, or the weight of a hundred shot of uniform size, of the apparently dry soil of a forest, sheltered and shaded by the trees, and expose it for some hours to the bright sunshine; after this weigh it, and most probably it will be found to have lost weight. This loss will have been occasioned by the sunshine and open air having caused an evaporation of moisture from the soil, though it appeared to be dry, and the quantity of moisture so evaporated may be determined by the weight lost.

Take again the same weight of such forest soil, so dried in the air and sunshine, and of such dry gravelly sandy soil as you may find on the road, similarly exposed to the drying influences of the air and sunshine; expose them together on papers for an hour in an oven heated to such a degree that the papers will be browned, but not burned; weigh them again, and probably both will be found to have lost weight, but the loss of weight sustained by the soil taken from the forest will probably greatly exceed the loss of weight sustained by the soil taken from the open field. The loss of weight is occasioned in this experiment, as in the first, by loss of moisture contained in the soil, notwithstanding that this was sun-baked and apparently dry.

Had the papers been burned there might also have been burned organic, vegetable, or animal remains in the soil, occasioning a loss of weight in addition to that occasioned solely by the loss of moisture, for which allowance must have been made; but this has been avoided by the precaution adopted. And the heat prescribed was to be such as would brown the paper without burning it, to secure as great a heat as possible short of what would have done more than merely drive off the moisture contained in the soil. And if the loss of weight sustained by the soil from the forest so exposed be in excess of that sustained by the soil taken from the road, this indicates that it, when apparently dry, contained more moisture than did that other, which excess was attributable to moisture held fast by products of vegetable decomposition in the soil.

But this is not all. If equal portions of the two parcels of thoroughly desiccated soil be spread out on glass, and exposed for a day or two to the atmosphere, protected from rain or dew (within doors or without, in a dry room or in a cellar), and these be then again weighed, they will be found to have gained weight, but in different degrees, much more having been gained by the forest soil than by the sandy gravelly soil of the road. This will be done by their imbibing moisture from the atmosphere, dry as that atmosphere seemed to be; and the proof is forthcoming: expose them again in an oven as before, and the weight gained will again be lost.

In this effect of vegetable mould we see how forests may exercise a third influence, over and above and distinct from both shade and shelter, in maintaining a humidity of soil.

This matter may deserve a little further consideration.

In treating of *Reboisement* in France, I had occasion (p. 95) to cite certain experiments made by Thurmann, made with a view to ascertain to what extent different minerals could absorb and retain moisture, and to state results obtained by him showing that cubes of different minerals thoroughly dried, weighing each 100 grammes, immersed in water for five minutes, varied in the quantities absorbed by them from half-a-gramme to from 10 to 30 grammes.

These results have been considered indicative of the absorption of water being proportional to the state of molecular sub-division of the material comprising the rock, and they have been resolved into distinct phenomena—hydroscopicity and capillarity: the former, the power of each molecule of the rock to retain around it a layer of moisture difficult to withdraw; the latter, the power of structures of molecules of earth to retain in interstices by which they are separated small globules of water. And thus may the results obtained by the first-mentioned experiments be accounted for. They indicate greater hydroscopicity and capillarity to be possessed by the soil of the forest than is possessed by gravelly and sandy soil of the road—this being, as may afterwards be proved, an effect or consequenee of forest products embodied in that soil.

But besides substances which manifest capillarity and hydroscopicity there are substances which attract and abstract moisture from the air, some of them doing so to such an extent that they deliquesce or dissolve in their own brine; and unless the air be kept excluded from them, or they be kept in a warm place, where the heat will either keep the air comparatively dry, or evaporate the moisture attracted and absorbed by them, you cannot keep them dry. This is signally the case with the carbonate of potash—the potash of commerce; it is manifestly the case with chloride of sodium, or table salt; it is also the case, though less manifestly so, with clay; and to a very marked degree is it the case with humus, the product of the decay and decomposition of vegetable matter, and one which abounds in forest soil from the fall of leaves and twigs.

To this humus mainly may be attributed the great attraction of the forest soil for moisture, indicated by the gain of weight when, after being thoroughly desiccated, it is exposed to a dry atmosphere;

and to the great quantity of humus in that soil, the excess of the quantity of moisture absorbed from the atmosphere over the quantity absorbed by the dry gravelly sandy soil taken from the road.

The quantities of humus and the quantities of clay, which exercise similar power, though not to the same degree, in each of the parcels, can easily be determined.

It may be noted that what is now spoken of is not the deposit of dew, which depends on a reduction of temperature.

Wherever the difference of temperature between day and night is great, and the atmosphere is heavily charged with moisture, the deposit of dew is considerable. In England, Luke Howard, with a well-constructed rain gauge, found the deposit of dew in one night towards the end of September equal to ·01 inch of water; and in the last six days of October he obtained ·11 of an inch from copious dews and mists.

In Algeria, at the stations on the coast, writes Steinmitz, in a little volume entitled " Sunshine and Showers," after the driest and hottest days, immediately the sun has set, the soldiers' uniforms become wet with dew, and in a single night the blades of knives in the pocket become rusted.

But apart from this deposit of dew, moisture is absorbed from the atmosphere by the soil. The driest soils contain 13% of moisture. It has been determined by experiments by Schubler that when a soil, which weighs about 1000 tons per acre, is pulverised so as to be freely permeable by the atmosphere, and is exposed to the air after being thoroughly dried, it will absorb in twenty-four hours, if a sandy clay, what is equal to 26 tons of water; if a loamy-clay, 30; if a stiff clay, 36; if garden mould, 45.

Cézanne states that, " In the Roussillon, rain is a rarity; the inhabitants can recall periods extending over a year without notable rain; and that the littoral hillocks behind the buttresses of the Pyrenees are of a very permeable limestone, but the vine flourishes in this region, the leaves cover the rocks with verdure, and the grapes swell with a savoury juice, while along the dusty roads the grasshopper follows the traveller with its cry, the emblem of aridity and drought.

" It is certainly not from the soil devoid of humidity that the vine drinks its supply, it is from the atmosphere; and the vine-growers do not deceive themselves—it is not for rain that they look, they know that hope of this would be vain—they cry for the sea breeze, which will perfectly satisfy them.

"On the other hand, in the *palus* of Bordeaux, the vine is seen growing, so to speak, with its feet in the water.

"It is then probable that vegetables, or at least some of them, are endowed with an eclectic power; they take water where they find it, they distil away subterranean water when it is in excess, and they know also how to condense and absorb water from the atmosphere."

I accept the facts, but demur to the reasoning. I think all can be otherwise accounted for. M. Cézanne cites in a foot-note, in illustration, the description given by Mr Thomas Baines of the *Markwhæ*, a large watery root, measuring in its greatest circumference 40 inches and in its smallest 30, with the statement of Mr Baines that when he and his party, travelling in an arid district of South Africa, felt thirsty the Bushmen would pull up some of those roots, and by eating of them they would quench their thirst. I have heard of several different kinds of such juicy plants growing in the most arid districts of South Africa; but never have I heard anything in regard to their natural history, or their structure, which would warrant the conjecture advanced; while the proved affinity of soil for moisture supplies a satisfactory explanation of all the phenomena referred to.

From experiment and observation it has been deduced that pure sand has little affinity for moisture; but that such affinity is manifested both by clay and by humus in a high degree, and to these conjointly may be attributed the attractive affinity of the soils for moisture, indicated by the gain of weight in the second set of experiments, when the desiccated soils were exposed for a long time to the air.

To this affinity of soil for moisture attention is given in analyses of soil in agricultural chemistry. It is in general inversely proportionate to the proportion of sand, and directly proportionate to the quantity of clay in the composition of soil taken from the open country, in which these constituents greatly preponderate; but it is also proportionate in a much higher ration to the quantity of humus in the soil, and the quantity of this can easily be determined.

If the two parcels of earth last referred to as subjects of experiment be raised to a red heat in iron spoons, and after all appearance of brighter incandesence in portions of the mass has ceased, they be weighed, care being taken to remove all scales of iron or of iron rust, they will again be found to have sustained a loss of weight; this is attributable to the combustion of organic matter, most of which was humus, or capable of becoming humus, and the loss sustained by the forest soil will be found much greater than the loss sustained by the other. In the case supposed, the affinity for moisture will be found to be proportionate to the different results; but it may be modified by the proportions of clay, if in either this be greatly in excess—and this also can easily be determined.

If the two parcels of soil be next drenched with hot water, and this poured off when discoloured with the muddy matter suspended in it, and the process be repeated until the water comes off limpid, upon their being again desiccated in an oven, as before, and weighed, the loss they have sustained in weight will indicate the quantity of clay which was in their composition, together with free soluble salts, the quantity of which may be little or may be much. Thus will have been removed all the materials manifesting a marked affinity for atmospheric moisture; and in few cases, if any, the results greatly modify the conclusion arrived at by the removal of the humus and its constituents.

I prescribe not these proceedings as certain to give precise results, in absolute accordance with the actual constitution of the soils made the subject of experiment, but as rough and ready experiments which may be made by the inexperienced, the results of which will indicate, and to some extent measure, the property of forest soil not only to retain moisture, but to attract moisture from the atmosphere in a superior degree to that in which such property is possessed by the gravelly and sandy soil taken from the highway.

Should any one desire more accurate results, the following course of procedure may be followed :—

1. Ascertain the quantity of moisture in the apparently dry soil by the mode of desiccation described, weighing the soil before and after the operation.

2. Ascertain the affinity for moisture by lengthened exposure of the desiccated soil to the air anywhere, and subsequently weighing it to learn what it has gained.

3. Ascertain the quantity of organic matter in the soil by heating it to incandescence as directed, but doing this in a plantinum crucible, previously desiccating it as before, and weighing it before and after this third operation.

4. Drench it with spirit of salt, muriatic acid, or hydrochloric acid, as it is now generally designated, adding soft water, and continuing the operation till all effervescence has ceased. Drench it then with water; let it settle; pour off the water when limpid; desiccate as at first, and weigh: and the loss of weight will then indicate the quantity of lime which was in the soil.

5. Ascertain the quantity of clay by the operation described.

6. By sifting the residuum through a piece of fine muslin, the sand may be separated from the gravel, and the quantity of each determined by weighing them apart.

A comparison of the results will show the difference in the composition of the two soils—and in none of the constituents will the difference be more marked than in the organic constituents and in the sand and gravel; the former, composed mainly of humus or the constituents of humus, having a great affinity for moisture, being greatly in excess in the forest soil, and the latter, having little or no affinity for moisture, being almost awanting.

This humus is a product of vegetation, inasmuch as it is a result of the decay and decomposition of vegetable products; and it is not only not decreased but it is constantly being increased by vegetation. Under no crop is this more manifestly the case than under a crop of deciduous trees. For this the annual fall of the leaves enables us without difficulty to account. The shelter afforded by a wood prevents both the fallen leaves, and the dust to which they may be reduced, from being borne away by the wind, and the shade prevents the humus from being so decomposed as to be carried off by the air.

With the smaller quantity of humus in the soil not protected by shelter and shade, it is otherwise. What there occurs is thus stated in a paper I had occasion to cite in treating of the effect of denudation of the country on the hydroscopicity of the soil,* a paper on the philosophy of arboriculture, by the Rev. Dr Macvicar, of Moffat, who was the first editor of the *Quarterly Journal of Agriculture*, issued by the Highland and Agricultural Society of Scotland, and who subsequently resided in Ceylon, where he had opportunities for prosecuting researches upon which he had previously entered. The writer remarks, in regard to effects following the destruction of forests,—"The soil when stript of the clothing which the forest afforded, and exposed naked to the heat of the sunbeam, changes very rapidly from the rich mould which the long-continued fall of the leaf in the forest had made it, and becomes very unproductive. Had occasional trees in the forest been left to give shade during part of the day, the destination of the carbon in the mould would have been to have been slowly converted into carbonic acid, and so to supply food to the successive crops growing on the soil, as they required it. But when the sunbeam is left to break in its full force on the soil all

* "Hydrology of South Africa" (p. 213).

day long, it burns the carbon in the soil with great rapidity into carbonic acid; and this gas, unless there be in the soil some oxide having an affinity to it to retain it, goes off in gas, injuring the salubrity of the air perhaps, and at all events wholly impoverishing the soil,—for carbonic acid is the principal food of all plants. The same course of things it might be shown happens with regard to ammonia; and thus, both as itself the immediate food of plants and as that which by oxidation yields nitre, ammonia is lost. Thus the indiscriminate destruction of forest over any great breadth of country, if that country has plenty of sunshine, is a great evil."

In correspondence with Dr Macvicar on the subject, he wrote to me, —"As to the point to which you refer—the rapid generation in the soil, and the vaporization from it of ammonia and carbonic acid, under the impact of the tropical sunbeams and breezes—I do not remember to have seen it dwelt upon by any writer, though both in the writings of Boussingault and of Liebig it is implied; and it is an inevitable consequence of the eremacausis, or the slow combustion of organic matter. It is familiarly verified by the process of bleaching. Even with such sunshine as we have in this country the organic matter which imparts colour to tissues is carried off much more rapidly in the sunshine than out of it; and it can only be carried off as carbonic acid and ammonia: that is, it is not merely changed from coloured to colourless, as is proved by the loss of weight which the web has sustained when it is bleached. In this country we have generally less sunshine than we require, and, except in fallows, the surface of the soil is never left bare. Hence the effect of the impact of the sunbeam has been but little considered. But from what I have observed in the tropics, I am persuaded that its power of affecting plant food in the neighbourhood, by the destruction of the fertility of every surface that is left bare, is very great. It intensifies to a wonderful extent that action of the incumbent atmosphere by which the carbon and hydrogen in the soil unite with the oxygen and nitrogen of the air, and give moisture, carbonic acid, and ammonia almost immediately after, if they be not utilized on the spot where they are generated, dispersing all but that quantum which the soil can retain at a temperature of perhaps 140° or 150° F., which is not much."

CHAPTER III.

Effects of Forests on Marshes.

In studying the effects of forests on marshes there come under consideration the drying up of marshes by the growth of forests, the occasonal appearance of marshes on the destruction of forests, and also the occasional destruction of forests by the creation of marshes.

The combined consideration of all of these phenomena may be necessary to a satisfactory view of the first; but this is susceptible of satisfactory explanation by itself, and the second may be considered to be confirmatory of the first, and the third not otherwise than accordant therewith.

And by the consideration of these several phases of the correlation of forests and marshes, we may be prepared for the consideration of the effect of forests, in drying up marshes upon a grand scale through protracted ages, in rendering what was a marshy land so dry as to become a fit habitation for man, of which Denmark supplies an illustration.

Sect. I.—*On the Drying up of Marshes on the Growth of Trees.*

We have latterly been considering the effect of arborescent vegetation in preserving the humidity of the soil; but we had previously been considering the effects of forests in increasing the humidity of the atmosphere; and previously to that we had under consideration the phenomena of vegetation on which meteorological effects of forests affecting humidity of soil and atmosphere depend: moisture being withdrawn from the soil by the spongioles of the root, transmitted by the trunk to the branches and passed off into the atmosphere by the stomates of the leaves.

It may seem paradoxical to speak of forests both drying up marshes and keeping the soil moist; but it is not more so than to speak of a man blowing both hot and cold. There is a great difference between moist soil and marsh. All moisture in excess of what can be retained by shelter and shade and humus in the soil is free to be otherwise disposed of, and the effect of forests in drying up marshes, viewed as an isolated fact, may be proved as satisfactorily as any of the effects of forests which have been under consideration.

I have already alluded to this effect in stating that the allegation of the South African farmer, that the trees stole the water from the water leadings, by the sides of which they were planted, was not altogether without foundation, though the phenomenon on which his opinion was founded was one which did not prove this, but proved something very different.

We have had under consideration the fact that very extensive provision has been made for the evaporation of water from the leaves of trees: in the case of one tree, the Lilac, so many as 160 thousand stomates being found on every square inch of the under surface of the leaf. Whence is the moisture to be so evaporated obtained? Mainly and almost exclusively, if not entirely so, from the ground. It seems to follow that what the atmosphere thus gains the earth must first lose, even though a portion of it may be subsequently restored. And the quantity thus raised from the ground and given forth to the atmosphere is very great.

Mr Marsh, whom I have already quoted elsewhere, states:—"The present estimates of some eminent vegetable physiologists in regard to the quantity of aqueous vapour exhaled by trees and taken up by the atmosphere are much greater than those of former inquirers. Direct and satisfactory experiments on this point are wanting, and it is not easy to imagine how they could be made on a sufficiently extensive and comprehensive scale. Our conclusions must therefore be drawn from observations on small plants, or separate branches of trees, and of course are subject to much uncertainty. Nevertheless, Schleiden, arguing from such analogies, comes to the surprising result that a wood evaporates ten times as much water as it receives from atmospheric precipitation. In the Northern and Eastern States of the Union [America] the mean precipitation during the period of forest growth—that is, from the swelling of the buds in spring to the ripening of the fruit, the hardening of the young shrubs, and the full perfection of the other annual products of the tree—exceeds, on the average, 24 inches. Taking this estimate, the evaporation from the forest would be equal to a precipitation of 240 inches, or very nearly 150 standard gallons, to the square foot of surface."

Startled by this, he questions the correctness of the conclusion at which Schleiden had arrived; but he states in a foot-note:—"Pfaff, too, experimenting on branches of a living oak, weighed immediately after being cut from the tree, and again after an exposure after three minutes, and computing the superficial measure of all the leaves of the tree, concludes that an oak tree evaporates, during the season of growth, eight and a-half times the mean amount of rainfall on an area equal to that shaded by the tree." Corresponding observations made by others are not awanting.

Marshal Vaillant writes :—" Even the most humble plants, such as chickweeds and meadow grasses, evaporate considerable quantities of water. Independently of all the other actions, which ought not to be overlooked, this is the chief cause why the abundant summer rains make so little impression on our rivers. This is why the gardener uses the hoe so carefully, and why he removes all weeds which would exhaust the moisture of the soil.

" The intelligent gardener is not deceived, he knows that if any weed has long numerous roots, like the *triticum repens* (couch grass), they do more harm than others, because by spreading to a distance they deprive a larger extent of ground of its share of moistnre. This is why a *paillis,* although on account of its dark colour it becomes sooner warm than turf or other grass plants, does so much good to cultivated vegetables, by not depriving their roots of moisture.

" The quantity of water exuded by rapidly-growing plants is far greater than could be supposed possible by people who have not made direct experiments; it is especially plants of soft texture with hollow stems that excite our surprise. A branch of *helianthns annuus* (a sunflower), placed in a caraffe full of water, and exposed to the sun, exhausts the water very rapidly; thus this plant, with its far-spreading roots, is a very dangerons neighbour to others, and we may be thankful that the passage of water into the roots does not go on so quickly as the evaporation by its leaves, otherwise the exhaustion caused would be much greater than it really is. It is this difference between the quantity of water transmitted from the soil to the roots, and from the leaves to the air, that causes the latter to wither in warm weather. Rain does not penetrate the leaves, but only diminishes their evaporation, so that an equilibrium is re-established.

" If from herbaceous plants or modest shrubs we turn to our large forest trees, we may expect that, compared with the weeds of which we have just spoken, they will transpire a great quantity of water, which is probably in proportion to the number of leaves and their extent of surface; and it is our belief that this summer function of the leaves is carried on by the trunk and branches during the whole year. Of the energy and rapidity with which water ascends through the trunk of a tree, the operation called *boucherie*, for the preservation of timber, affords a remarkable example. In a very short time a poisonous liquid is transmitted from the base of the trunk to the extremity of the branches.

"From whence comes the water so rapidly transpired by the foliage? Certainly from the soil; and as the roots of these vegetable giants penetrate far—as some say, in some cases, to the same extent as the branches—it is easy to understand how the ground becomes dried up and incapable of supplying nourishment to plants of smaller growth.

"It is therefore impossible for anything to thrive close to, or even at a considerable distance from, the root of a tree. It is not only the shade and the want of rain that hinders growth: indeed, plants at some distance from a large tree are as much shaded as are those close beside it, and the rain, which seldoms descends vertically, always moistens such plants more or less, they are also refreshed by the dew, and, nevertheless, they die or languish. It is because they grow in a soil which is always dry and deprived of nourishing power. Certainly the invitation addressed by the oak to the reed in the fable bespeaks a good disposition; but had it been accepted the poor reed would soon have died of thirst. Its tall and powerful protector would soon have dried up the damp borders of the kingdom of the wind, which nature has appointed as the habitation of reeds.

"Whoever has uprooted old trees must have remarked to what a great depth the earth around the roots is exhausted and dried up. This state of things can be easily acounted for, after the particulars of the following experiment may have been read.

"We placed in a large jug of water, as tightly closed up as possible so as to hinder the effect of natural evaporation, the end of an oak branch, 1^m 40 centimètres [nearly 5 feet] long, and 4 centimètres [nearly 2 inches] in circumference at its lower extremity. The branch was cut off from a tree about 25^m [upwards of 80 feet] high, add 2^m 63 centimètres [about 9 feet] in circumference at 1^m [40 inches] from the ground

After twenty-four hours' exposure in the open air at a temperature of 15° 7″ [60° Fahr.] at the minimum, and 25° 7′ [77° Fahr.] at the maximum, the water in the vase diminished 510 grammes [18 oz.]. The sun was shining brightly. In forty-eight hours from the beginning of the experiment the water in the jug had again lost 300 grammes [10½ oz.] of its weight. The sun had been very warm, the thermometer having risen to a maximum of 27° 7″ [82° Fahr.], the minimum having been only 10° 7″ [57° Fahr.]; the wind on this day and the preceding had been from the north or north-east. Seventy-two hours after the introduction of the oak branch into the water the vase had again lost 140 grammes [5 oz.] of its weight. The weather had been as lovely as the day before, the minimum of the temperature having been at 12° 5″ [54°] and the maximum 25° [77°]. Thus the weight of water evaporated by the branch was, at the end of the first day, 510 grammes, at the the end of the second, 810, and at the end of the third, 950 [30 ounces]. The experiment was not carried further. In the first place, because several of the leaves were withered and incapable of performing their functions; secondly, because the water in the jug was beginning to be affected by being mixed with the substances which always are deposited by plants when placed in water.

" If we believe that all the leafy parts of a tree will act, as regards the faculty of transpiration, like the leaves of the above-mentioned branch: in other words, if we suppose that the quantities of water expired by the entire tree were in like proportion, we arrive at the astounding result that an oak like the one described will, in a summer day, cause the evaporation of more than 2000 killogrammes of water, more than two cubic mètres, [or 440 gallons].

" We are not decided in regard to the value of our experiment, and we see very well that our deductions are not free from objections; but it must be allowed that supposing that every one-half or one-quarter of the estimated quantity be omitted, the quantity must greatly exceed what might have been expected. . . . .

" A forest should produce on the soil which it covers the effect of a large umbrella pierced in many places, it may be, but, nevertheless, arresting and imbibing a certain quantity of rain, of which it deprives the neighbouring soil. So long as the leaves are imperfectly soaked, no moisture reaches the ground; and it can be easily imagined that a moderate continuous rain would be entirely absorbed by natural evaporation, and in effect the humidity of the air, even in damp weather, never reaches the maximum of the hygrometer in the lower atmospherical strata, and evaporation is never entirely suspended.

" If we further add to these causes of exhaustion that there is little dew deposited under trees, it can be believed that the ground of a forest is less favoured as regards the quantity of moisture received from the heavens than that which is exposed to the open sky.

" And, nevertheless, it is an accepted fact, and that not without good reason, that the neighbourhood of forests is cold and damp.

This is far from astonishing when one thinks of the enormous volume of water transformed by forests into vapour, and the quantity of heat absorbed in this transformation. This heat must have been obtained somewhere—perhaps from the soil of the forest and that of the neighbourhood.

" In the same way, there should be great damp in the neighbourhood of forests, especially when the temperature is high, and it cannot be otherwise on account of the enormous amount of water in the form of vapour which is discharged by forests into the adjacent atmosphere.

" This vapour is emitted in much greater abundance during the day than during the night. Towards night, a little after sunset, when the general temperature begins to fall, the transpiration not yet having had time to slacken, and ascending into a colder air, changes into visible fog, like our own breath in like circumstances and this fog in its turn becomes a cloud on the following morning, when the sun warms its particles; but whether clouds or fogs they will be carried away by the first breeze, to descend in showers far from the place of their birth.

" It is evident that the rain of these showers, pumped up, in the first place, by the tree-roots from the forest soil, if it be sometimes restored to this soil it is only in part; so that even in this respect we can assert that, with regard to water, forests place the soil in a much worse position than a crop of cereals.

" If these details as to the formation of forest-fogs be correct, such fogs should be more frequent in calm weather, when the air is naturally more moist, and especially when the contrast is greatest between the cool of the evening and the heat of the day. The test of conditions for the formation of thick forest-fogs is especially complete, at least in our climate, towards the end of summer and the first half of autumn; and it is during this period that the phenomenon is most frequent and noticeable.

" If the transpiration carried on by the leaves were coloured and perceptible, it would be a grand sight to see great columns of vapour ascending majestically into the air, diminishing by their height the distance between the tops of the trees and the stormy clouds; and as this vapour facilitates the passage of electricity, by increasing the moisture of the air with which it mingles, the frequency with which isolated trees are struck with lightning can be accounted for. Perhaps, also, if attention were turned to this point, the reason would be discovered why so many people, taking shelter under trees, are struck by lightning. It is difficult to refuse to believe that these people were not more exposed to danger in such a situation than if they had remained in the open field."

These statements I give as the views advanced by Marshal Vaillant. There are points on which my own views are somewhat different; but with regard to the grand fact, that the emission of moisture by the leaves of the forest is very great, we are at one.

With what is known of the affinity of humus and of clay for moisture, it may be considered probable that not a little of the moisture evaporated by the stomates may be re-absorbed by the soil, though never precipitated as rain. But even supposing that this should have happened, not once, but times innumerable in the course of a specified period—and thus much of the moisture evaporated should be substantially the same moisture, passing again and again and again through the circuit, evaporated, passed through the stomates, absorbed by the air, thence absorbed by the soil, and thence absorbed by the rootlets to be passed on by endosmosic action again to the leaves, to go through the same round again and yet again—it is not unreasonable to suppose that a large portion, a very large portion, must be taken from the soil.

The experiments founded on by Pfaff, like that of Marshal Vaillant's, give the result of evaporation which could not have been sustained in this way, for the branch was severed from the tree. I have no means of verifying his calculation resulting in the conclusion that the quantity of moisture passing out by the stomates in the time specified must have been equal in quantity to eight and a-half times the whole quantity of rain which fell on the spot in the course of the period specified; but with what I happen to know of vegetable physiology his conclusion in no way startles me.

By Dr Asa Gray it is remarked :—" The quantity of water exhaled from the leaves during active vegetation is very great. In one of the well-known experiments of Hales, a sunflower three and a-half feet high, with a surface of 5,616 square inches exposed to the air, was found to perspire at the rate of twenty or thirty ounces avordupois every twelve hours, or seventeen times more than a man. A vine, with twelve square feet of foliage, exhaled at the rate of five or six ounces a-day; and a seedling apple tree, with eleven square feet of foliage, lost nine ounces a-day. The amount varies with the degree of warmth and dryness of the air, and of exposure to light; and is also very different in different species, some exhaling more copiously even than the sunflower. But when we consider the vast perspiring surface presented by a large tree in full leaf, it is evident that the quantity of watery vapour it exhales must be immense."

Of the moisture thus evaporated and passed into the atmosphere a very great quantity must have been withdrawn from the soil and dissipated, and thus even a marsh might in course of time be dried up.

Of this effect let me give one illustration, one which was communicated to me by a distinguished agriculturist in Berwickshire, not less distinguished for his knowledge of the science and literature of agriculture than he is for the practical application he has made of the knowledge he possesses. On the farm in his possession, and which has been long in the hands of himself and his family, there is a rising ground at the base of which there was a piece of waste land, which, though not a bog, was characterised by its large and luxuriant crop of rushes, and into which sunk the feet of horses, if not of men, when they got upon it, leaving footprints wet, if not filled with water, and there was adjoining this a corner of enclosed cultivated land which it was attempted to make dry by drains, but the attempt was vain.

Shortly after 1820 the top of the rising ground was planted with firs and larch. The plantation covered a space of 20 acres. From this time both the swampy waste land and the enclosed drained but damp land became more dry, and at length became perfectly so. Some forty years after the planting of these trees a furious gale produced great devastation in the plantation, uprooting or breaking over most of the trees and leaving standing only here and there one. The scene was unsightly, and ultimately the whole were felled and the land cleared; but immediately the low-lying ground became swampy as before, and this was its condition when I visited the locality some eight years thereafter.

The phenomena were accounted for by my friend and informant by the supposition that there must have been a fissure in the rising ground, from which the water oozed out, formerly and now; but that the rootlets of the trees, during the growth of these, absorbed the moisture, and though their doing so may have increased the humidity of the atmosphere enveloping the trees, it prevented the percolation of the moisture into the ground below, which was previously so wet; but the removal of the trees allowed it, in oozing out, to descend to the lower-lying soil as before.

To this explanation I offer no objection—an examination of the rock alone would enable me to test the correctness of it. At the same time, another explanation of the cause of the phenomena suggested itself to me when the details were given, namely: that before the rising ground was planted much of the moisture falling as rain upon the upper part of it spread under the surface, being prevented by rock or clay from sinking, and oozed out at the lower level; but after the plantation was formed less of the rain-fall reached this impervious layer.

But in either case all may be accounted for without prejudice to the doctrine now under consideration. The planting of the trees was followed by the desiccation of the swamp; the destruction of the trees, by its restoration.

SECT. II.—*On the Occasional Appearance of Marshes on the Destruction of Forests.*

In the case of the disappearance of a swamp on the planting of an adjacent rising ground with trees, and the reappearance of the swamp on the destruction of the trees, the one phenomenon may be considered the counterpart to the other, and both of them in accordance with the exposition which has been given of the absorption of moisture from the soil by the roots, and its emission into the atmosphere by the leaves. Other cases of the destruction of woods having been followed by the appearance of swamps have been brought under my notice.

In Russia, some years ago, in the course of conversation on the state of the forests with an intelligent lady, the niece of a forest official, I learned that there, as elsewhere, when ground is cleared of firs and pines, as it often is by extensive fires, it often happens, so often that in some districts it may be said that generally, there spring up birches in great abundance; and, she added, that in some cases the clearing away of a wood converts the ground on which it grew into a morass, which, when it is replanted, is commonly replanted with willows.

I accept the statement as made. I pass at present the growth of birches where previously grew the pine and the fir, but with the intention of reverting to it afterwards. I call attention to the morass, and suggest the enquiry, How came it to pass that there was no morass there before?

I consider there was none before, most probably because all the water which went to the subsequent creation and maintenance of the morass which subsequently appeared was raised by the trees and passed into the atmosphere, in accordance with what has been advanced; and that this was the case I have no doubt. But along with this there may have been combined another operation, more simple, mechanical, and intelligible, which must not be overlooked.

I have never heard particulars of a case which seemed to run counter to the exposition which I have given, of which I have not been able to show that it was compatible, or consistent, with the supposition that the operation was such as I have supposed. But there is another operation, noticed by Becquerel, to which Marsh considers that sufficient importance has not, until very recently, been generally ascribed, namely, the mechanical action of roots as conductors of the superfluous humidity of the superficial earth to lower strata. "The roots of trees," says he, "often penetrate through sub-soil almost impervious to water, and in such cases the moisture, which would otherwise remain above the sub-soil, and convert the surface earth into a bog, follows the root downwards and escapes into more porous strata, or is received by subterranean canals or reservoirs. When the forest is felled, the roots perish and decay, the orifices opened by them are soon obstructed, and the water, after having saturated the vegetable earth, stagnates on the surface and transforms it into ponds and morasses. Thus, in La Brenne, a tract of 200,000 acres resting on an impermeable sub-soil of argillaceous earth, which ten centuries ago was covered with forests, interspersed with fertile and salubrious meadows, has been converted by the destruction of the woods into a vast expanse of pestilential pools and marshes. In Sologne the same cause has withdrawn from cultivation and human habitation not less than 1,100,000 acres of ground, once well-wooded, well-drained, and productive."

It is with the fact that such results have followed such proceedings that we have to do. From the facts alone we may learn wisdom, though we should be baffled in attempting to trace the process by which the results have been produced, and explanations offered by others may appear to us unsatisfactory.

We have learned that food invigorates us and sleep refreshes, and we act upon the knowledge of the facts, though we may be unable to explain how it is that these results are produced. And we find that thus the knowledge of these facts has been utilised in Russia, where a morass appearing on the destruction of a forest is replanted with willows. Pines and firs grew there before; but pines and firs would not grow now, and thus is brought before us another view of the subject: not only has the destruction of forests given rise to the appearance, on the spot or near it, of a morass, but a morass otherwise produced has brought about a destruction of forests.

SECT. III.—*On the Occasional Destruction of Forests by the Creation of Marshes.*

The cases of forests having been destroyed by the creation of marshes are numerous. There is nothing in this which is otherwise than in accordance with the views of the meteorological effects of forests which have been advanced; but it may be well that this should be shown, and it may be not improper that in doing so the phenomena should be brought under consideration in more than one of the phases which they present.

I have, in the preceding section of this chapter, given my explanation of the fact communicated to me that in some cases in Russia the clearing of the portion of a forest by a forest fire, or by a hurricane, has been followed by the conversion into a morass of the ground on which it grew; and I have brought forward other facts suggestive of how it may be that the results followed. But these exhaust not the means by which morasses are produced in forest land.

In forests we meet with swamps which appear to have destroyed trees growing on the spot, but which may have been themselves produced by the destruction of other trees through a process in no respect similar to any which have been noticed.

I submitted the account I have given of the facts communicated to me by my friend in Russia to an intelligent English engineer who had resided much in the interior of the country, who was a man of careful observation, one who reasoned on what he saw, and one from whom I had received much information in regard to forests in Russia. He returned my statement with the following annotation:—"In the interior there occasionally occur great hurricanes, tearing all before them and blowing down large spaces of the forests, laying the trees with their roots attached to them in all directions, and being in many cases far from towns or villages the blown down trees are never taken away, but decay where they have fallen, as I have seen. When the ground is level, the little river is, from the fallen trees, raised in its bed, or, as is often the case, is changed in its course. There is thus always more of the space kept longer under water in the spring than formerly, and during the summer a rank vegetation springs up, which tends also to keep the ground damp and watery. This, along with the decaying wood, soon gets into a complete marsh, and will eventually become what is called in Britain a peat moss.

"In cases where these hurricanes have destroyed the forest near to inhabitated districts, and the land is low-lying, the space is cleared and turned often into meadow, which is what the Russians like—good meadow land. Their method of getting the hay from the soft and marshy land is to put it up into ricks in some raised part of the meadow, inclose it round with a wicker fence, and when the winter sets in they take it home in their sledges, in the same way as their wood is all taken to its destination, advantage being taken then of sledges on the snow, where there are often no roads in summer; and also in the winter time, the peasant farmers having nothing do on their land are thus able to get their rye, etc., conveyed to the nearest market; and having then plenty of time, some of them go to the large towns and factories, and work there during the winter, returning home in the spring, generally about the Easter holidays."

I have given the annotation entire, because to me it speaks throughout of the abundance of moisture existing when the forests have been destroyed. The allusions to what is done in leading rye and leading wood speak of the abundance of water in the ground kept comparatively dry by the forest, but accumulating when superficial drainage is prevented.

My correspondent assumes, and not without reason, that in the cases alleged the water level may have been raised by the damming up of an outlet; and I accept the explanation as one given by an intelligent observer, living in the country and familiar with the facts. His statement is suggestive of much which might illustrate the operation of trees in drying marshy land, utilizing and dispersing the excess of moisture, and fitting the land, otherwise comparatively useless to man, for bringing forth herbs meet for them by whom it is dressed. But at present we have to do with the one fact that thus also morasses may be produced, along with the effects referred to; and of this other illustrations may be given.

In the Northern States of America, and in the Dominion of Canada, we meet occasionally with extensive patches of weird-like trees, standing leafless and dead in a shallow waste of waters, miles in extent, produced by the accidental or designed damming up of some streamlet it may be by which it had previously been drained. It may have occurred through some such accident as my friend in

Russia has suggested; it may have occurred in connection with some endeavour to divert into another channel the waters of the same or some other water-course; it may have occurred in consequence of the damming up of some outlet from a lake which it was sought to enlarge as a reservoir for the supply of a canal, or a mill-lade, or some other purpose; or it may have been the effect of the work of a beaver, for cases of all such occurrences can be cited. But, however produced, the consequence to that portion of the forest which is laid under water, though only to the depth of one or two feet, is the same —the trees are killed as if girdled by fire, or by the woodman's axe, and, most probably, by a similar operation, through the decay and destruction of the bark and sapwood at the water-line, or between wind and water, promoted by alternate exposure to each by the ripple, and the consequent severance of the communication between rootlet and leaf, or it may be by such a severance being occasioned by the rupture and decay of vessels through which that communication was maintained.

A graphic sketch of the destruction thus wrought occurs in an account given by Gosse of a forenoon's excursion, which he made in Canada to the *Bois Brule*, a large tract of land which lay at no great distance from his residence, but was so hidden in the recesses of the woods, and so out of the way of any travelled road, that it was not often visited except by the trapper. The first quarter of a mile lay through what he calls a very rough slash. "Such a labyrinth of fallen timber we had to penetrate," says he, "climbing over the trunks, and scrambling through the dry branches of the prostrate trees, often falling through; and, to make the matter worse, these were concealed by the tall Indian wickup, *epilobium latefolium*, with which the ground was absolutely covered, and, as the long seed-pods were just bursting, our every movement dispersed clouds of the light downy cotton, which, getting into our mouths and nostrils, caused us considerable inconvenience. Presently we descended the steep bank, and walked, or rather scrambled, up the rocky bed of the stream, by means of the stones which were above water, though, as they were wet and slimy, we occasionally wetted our feet. Thus we went on, sometimes in the stream, sometimes among the alders and underwood of the banks, for about a mile and a-half. We were much surprised in going up this brook, about a mile up, at coming upon a ruined building, which had been erected over the stream at a craggy fall, the timbers of which had fallen down, and some of them had been carried a considerable distance down by the freshets. I supposed it must have been a mill, but wondered at its situation, so far from any road. I have since been informed that it was a saw-mill, and that there was a good road to it, but this road being now overrun with bushes and young trees, escaped our notice. The mill has been disused nearly twenty years. On the borders of the brook I met with seed-vessels of the touch-me-not, *impatiens nolli tangere,* the handsome sub-conic scarlet fruit of the white and the red death, *trillium pictum* and *T. fœtidum,* the large umbelled bright blue berries of *smilacina borealis,* and many others. In pressing through the bush we got our clothes bedaubed with a nasty substance, which we discovered to proceed from thousands of the *aphis lanata (?)* which we had crushed; they were so thickly clustered round the branches of the alders as to make a solid mass half-an-inch thick, covered with ragged filaments of white down. We were getting tired of the ruggedness of our path, when we suddenly came upon a new and very good bridge across the brook, made of round, that is, unhewn logs, which connected a good broad path, from which the fallen trees and encumbrances had been cleared away, and which had evidently been used for drawing out mill-logs in winter with sleds. This we followed. The sides of the road were lined with the stumps of large spruces and hemlocks, which had been felled the previous winter; and the road itself was strewn with the chips of the axe-men. The course lying through a cedar swamp, the ground was mossy, and in some places wet; here the scarlet stone-berry was abundant, as well as the berries mentioned before. The former, *fragaria canadensis,* is a low and pretty plant, having a white flower, resembling that of a strawberry, and four large oval green leaves on the ground; at present they were crowned with the little cluster of bright red berries, which were ripe, and we ate many—they were farinaceous and agreeable. This plant is common in Newfoundland. We continued to follow this path till it appeared almost interminable, though its tedious uniformity made it seem longer than it really was, as I suppose we did not walk more than a mile and a-half on it when I perceived by the increasing light among the trees that we were approaching a large opening.

"We now pressed eagerly on, and found that we had reached the borders of the *Brule,* which was not a clearing, as I had expected, but was covered with a stunted and ragged growth of moss-grown spruce, from eight to twelve feet in height, exactly resembling the small woods of Newfoundland. On the borders of the large marshes I found also the same plants that inhabit such situations in that country, and which I now saw for the first time in Canada. I also recognised numbers of another old acquaintance, an exceedingly curious plant, the Indian cup or pitcher-plant, *sarracenia purpurea.*" Some of the plants he describes, and then goes on to say, " The road by which we had approached did not enter the Brule, but merely touching its edge, went straight on, entering the tall woods on the other side. We penetrated a few roods into the Brule, to see if there were any clearing, but could perceive no change in the ugly, dead, half-burnt spruce, and therefore returned. This singular piece of ground contains some thousands of acres, and is said to owe its origin to the beavers, which were formerly numerous, damming up the streams, which, overflowing and spreading over the flat-lands, killed the growing timber. It is a resort of wolves, bears, and other wild animals, though we perceived no sign of life in the stillness which pervaded the solitude; nor, indeed, in the whole journey, with the exception of one or two little birds, which were not near enough to be identified, and a few insignificant insects in the forest. Having satisfied our curiosity we began to return as we came, until we arrived at the bridge, when, instead of retracing the course of the stream, we crossed the bridge and continued to pursue the road, which, for some distance, led us through towering spruces and hemlocks, as before. On a sudden the character of the woods changed: we found the sides lined with young maple, birch, beech, &c., which met overhead at the height of about twelve feet, forming a very perfect and regular continued Gothic arch, or rather a long series of arches. This long avenue was the most pleasant part of our walk, and the more so because it was quite unexpected. We presently opened into a large field, which had been just mown, and here we were rather laughably bewildered: the place was a *terra incognita*; we had never before seen it, nor could we recognise any object, so as to guess at our whereabouts. There appeared to be no outlet through the woods by which the field was environed. In one part was the skeleton of an old log-house without a roof, and a portion of the field was planted with potatoes. We at length saw a path through to these potatoes, on which we walked till we came to the brow of a hill from whence we perceived familiar objects. It commanded an extensive view: the beautiful and winding Coatacook was at our feet with its bridge, Smith's mills and all that neighbourhood; beyond a broad belt of the forest was visible Tilden's Tavern and the road leading from Hatley to Sterbrooke, and the forest again behind all. We now left the path, taking a short cut over the hill, coming down by Bradley's mill, and so home, much pleased, notwithstanding the little disagreeables, with our little excursion."

In regard to the effects of the work of the beaver, it is remarked by Marsh, "I am disposed to think that more bogs in the Northern States owe their origin to beavers than to accidental obstructions of rivulets by wind-fallen or naturally decayed trees; for there are few swamps in those States, at the outlets of which we may not, by careful search, find the remains of a beaver dam. The beaver sometimes inhabits natural lakelets and even large rivers like the Mississippi, when the current is not too rapid, but he prefers to owe his pond to his own ingenuity and toil. The reservoir once constructed, its inhabitants rapidly multiply so long as the trees, and the harvests of pond lilies and other aquatic plants, on which this quadruped feeds in winter, suffices for the supply of the growing population.

"But the extension of the water causes the death of the neighbouring trees, and the annual growth of those which could be reached by canals and floated to the pond soon becomes insufficient for the wants of the community, and the beaver metropolis now sends out expeditions of discovery and colonization. The pond gradually fills up, by the operation of the same causes as when it owes its existence to an accidental obstruction, and when, at last, the original settlement is converted into a bog by the usual processes of vegetable life, the remaining inhabitants abandon it and build on some virgin brooklet a new city of the waters."

And he adds in a foot note:—"I find confirmation of my own observation on this point (published in 1863) in the 'North West Passage by Land,' of Milton and Cheadle, London, 1865. These travellers observed 'A long chain of marshes formed by the damming up of a stream which had now ceased to exist,' chap. x. In chap. xii. they state that 'Nearly every stream between the Pembina and the Attrabasca—except the large river M'Leod—appeared to have been destroyed by the agency of the beaver,' and they question whether the vast extent of swampy ground in that region 'Has not been brought to this condition by the work of beavers, who have thus destroyed, by their own labour, the streams necessary to their own existence.

"But even here nature provides a remedy, for when the process of consolidation shall have been completed, and the forest re-established upon the marshes, the water now diffused through them will be collected in the lower or more yielding portions, cut new channels for their flow, become running brooks, and thus restore the ancient aspect of the surface.

"The authors add the curious observation that the beavers of the present day seem to be a degenerate race, as they neither fell large trees nor construct great dams, while their progenitors cut down trees two feet in diameter and dammed up rivers a hundred feet in width. The change in the habits of the beaver is probably due to the diminution of their numbers since the introduction of fire-arms, and to the fact that their hydraulic operations are more frequently interrupted by the encroachments of man.

"In the valley of the Yellowstone, which has but lately been much visited by the white man, Hayden saw stumps of trees thirty inches in diameter which had been cut down by beavers. *

"The American beaver closely resembles his European congener, and I believe most naturalists now regard them as identical. A difference of species had been inferred from a difference in their modes of life, the European animal being solitary and not a builder, the American gregarious and constructive. But late careful researches in Germany have shown the former existence of numerous beaver-dams in that country, though the animal, having become too rare to form colonies, has of course ceased to attempt works which require the co-operation of numerous individuals. †

"On the question of identity, and all others relating to this interesting animal, see L. H. Morgan's important monograph, "The American Beaver and his Works," Philadelphia, 1868. Among the many new facts observed by the investigator is the construction of canals by the beaver to float trunks and branches of trees to his pond. These canals are sometimes 600 or 700 feet long, with a width of two or three feet, and a depth of one to one and a-half."

It may be considered by some of my readers that the natural history of beavers can scarcely be considered the meteorological effects of forests. The same may be alleged of all that is being advanced in this chapter relating to the effects of forests on the humidity of the ground. I deem it proper to treat the subject thus freely, partly with a view to anticipating and obviating objections which may suggest themselves to conclusions drawn, and partly

* "Geological Survey of Wyoming" (p. 135).

† Schleiden: "*Für Baum und Wald.*" Leipzig, 1870 (p. 68).

because it is the effect on the soil of the meteorological effects of forests which chiefly concerns us at present in the discussion of these.

SECT. IV.—*On the Desiccating Effects produced on Marshes by Forests in Prolonged Periods.*

Reference is made by Marsh to a recuperative operation, whereby even the bog produced by the destruction of a forest regains, after a time, its former aspect, and in this the desiccating effect of vegetation comes again into play, promotes the work, and expedites the result. In Denmark we see what may thus be accomplished. We there meet with a land, which, at one or more periods of its existence as land, must have been over a great extent of its surface covered by morasses and marshes, and peat bogs, but which is now so dry as to be habitable, and cultivated by man, giving him in return for his labours fields of increase; and the peat bogs supply extensive indications that forests must have played an important part in producing the change.

From *Bögens Indrandring i de Danske Skove*, by Chr. Vaupell, we learn that a careful examination of the peat mosses in North Sjælland, which are so abundant in fossil wood that within thirty years they have yielded above a million of trees, shows that these trees have generally fallen from age and not from wind. They are found in depressions on the declivities of which they grew, and they lie with the top lowest, always falling towards the bottom of the valley.

The origin of these bogs dates from pre-historic times; but the origin of other bogs has been studied, and the result has been given in part in the preceding section.

Marsh, in his valuable treatise on "The Earth as Modified by Human Action," which I have already cited, says, "Bogs generally originate in the checking of water-courses by the falling of timber or of earth and rocks, or by artificial obstructions across their channels. If the impediment is sufficient to retain a permanent accumulation of water behind it, the trees whose roots are overflowed soon perish, and then by their fall increase the obstruction, and, of course, occasion a still wider spread of the stagnating stream. This process goes on until the water finds a new outlet, at a higher level, not liable to similar interruption. The fallen trees not completely covered by water are soon overgrown with mosses; aquatic and semi-aquatic plants propagate themselves and spread till they more or less completely fill up the space occupied by the water, and the surface is gradually converted from a pond to a quaking morass. The morass is slowly solidified by vegetable production and deposit, then very often restored to the forest condition by the growth of black ashes, cedars, or, in southern latitudes, cypresses and other trees suited to such a soil, and thus the interrupted harmony of Nature is at last re-established."

In continuation of the passage I have cited, Mr Marsh goes on to say, "In countries somewhat further advanced in civilization than those occupied by the North American Indians, as in mediæval Ireland, the formation of bogs may be commenced by the neglect of man to remove from the natural channels of superficial drainage the tops and branches of trees felled for the various purposes to which wood is applicable in his rude industry; and when the flow of water is then checked, nature goes on with the processes I have already described. In such half-civilised regions, too, wind-falls are more frequent than in those where the forest is unbroken, because when openings have been made in it for agricultural and other purposes the entrance thus afforded to the wind occasions the sudden overthrow of hundreds of trees which might otherwise have stood for generations, and have fallen to the ground only one by one, as natural decay brought them down. Besides this, the flocks bred by man in the pastoral state keep down the incipient growth of trees on the half-dried bogs and prevent them from recovering their primitive condition."

Denmark supplies many illustrations of the effect of vegetation, herbaceous and arborescent, in filling up and drying up marshes in prolonged periods extending back into pre-historic times.

By numerous successive growths of aquatic and semi-aquatic plants, herbs, and trees, bogs have there been filled up and dried up in the course of ages, and at length rendered, as now, so dry as to be fit habitation for man. And simultaneously with what has been effected by the abstraction of water by the spongioles, and emission of it by the stomates, an influence modifying the process of desiccation otherwise produced, intensifying or moderating it, may have been going on.

Marsh, citing as his authority a work by Wilhelm, entitled "*Der Boden und das Wasser*," a work published in Vienna in 1861, and a work by Krecke, entitled "*Het Klimat van Nederland*," says:—The relative evaporating action of earth and water is a very complicated problem, and the results of observation on the subject are conflicting. Schuebler found that at Geneva, the evaporation from bare loose earth in the months of December, January and February, was from two and a-half to nearly six times as great as from a like surface of water. In the other months, the evaporation from water was from about one and a-half to six times as great as from the earth. Taking the whole year together the evaporation from the two surfaces was $199\frac{8}{12}$ lines from earth, and $536\frac{1}{12}$ lines from water. Experiments by Van der Steer, at the Helder, in the years 1861 and 1862, showed for the former year, an evaporation of 602·9 millimètres from water, 1399·6 millimètres from grounds covered with clovers and other grasses; in 1862 the evaporation from water was 584·5 millimètres; from grass-ground 875·5." It is these latter observations with which we have to do, and these indicate that from the bog evaporation would proceed more rapidly than it would from a lake of the same extent similarly situated.

Such seem, then, the effects of forests on swamps and of swamps on forests. The moisture withdrawn from the ground and passed into the atmosphere by the trees, if in excess of what is supplied from a higher level, and of what also falls on the spot, as rain, snow, or dew, must render them dry, and to the same extent produce the meteorological effect of increasing the humidity of the air; but at the same time, by shade, and by shelter, and by covering the ground with fallen trees, and broken twigs, and by the humus produced from the decay of these, the forests prevent extreme desiccation. And the occasional appearance of marshes on the destruction of forests, even when attributable to the stoppage of an outlet, may indicate what they have thus accomplished.

CHAPTER IV.

On the Effects of Forests on the Moisture over a Wide Expanse of Country.

The observations which we have had under consideration show that forests, in common with other products of vegetation, withdraw moisture from the ground, and that they do so to such an extent as to carry off the water of swamps and to prevent the formation of these increasing the atmospheric moisture in their immediate vicinity to such a degree that it may be felt, making houses damp, even in their innermost chambers, and that it may be seen in clouds and fogs and drizzling rain; and yet, that they keep the soil moist compared with the soil beyond their shade and shelter, wherever that shade and shelter fall; while the ground is at the same time enriched with vegetable mould, the product of the fallen leaves and other *debris*.

But when we extend our study to the effects of forests on the humidity of soil and climate over a wide expanse of country, we find that observations have been made which seem to show that in some cases the extensive destruction of forests, over a great expanse of country has not perceptibly affected the quantity of the rain and dew, and hail and snow, which has there fallen from heaven; while, on the other hand, there are lands which were once populous and fertile, but are now arid and sterile—the aridity of which is alleged to be the cause of their sterility, and to be a consequence of the destruction of forests.

On thus extending our field of observation we meet with additional facts, which, if all the circumstances and conditions of each were known, might be easily reconciled, notwithstanding apparently antagonistic conclusions to which they sometimes seem to lead.

I shall cite some of the individual or separate facts which are known, illustrative of the general facts now stated; and either as I advance or subsequently, as may appear at the time most important, I shall advert to the *modus operandi* of the means whereby the results observed may have been brought about.

SECT. I.—*Cases in which the Extensive Destruction of Forests does not appear to have Perceptibly Affected the Quantity of the Rainfall over a Wide Expanse of Country.*

The subject of this chapter is the effect of forests on the *moisture* over a wide expanse of country, that of this section is only the apparently negative effect, in certain cases of the extensive destruction of forests, on the *rainfall*. Attention is called to the difference, that it may be noted. The rainfall is treated neither as the source nor as the measure of the moisture, but solely as one of the indications of the humidity of the atmosphere, it being the indication of this to which most importance is generally attached, and that which is most generally referred to in popular discussions on the meteorological effects of forests.

Both Europe and America supply illustrations of apparently little effect having been produced upon the deposit of moisture in the form of rain over a wide expanse of country by the extensive destruction of forests.

There are many indications of Europe having been formerly covered much more extensively and densely with forests than now. In France, the destruction of these forests within the last two hundred years as well as before has been considerable, yet there does not appear to have been within that time any very great diminution of the rainfall over some extensive districts in which observations on the rainfall have been made.

This point has been discussed at considerable length by M. Cézanne, in his *Sequel to Étude sur les Torrents des Hautes Alpes, par* Alexandre Surell. It is mentioned by him that some writers on the subject, to whom he afterwards refers more particularly, in endeavouring to demonstrate the action of forests on the rainfall, have adduced as proof that the destruction of forests, and the extensive plantation of these, have both of them affected the *régime* of the rainfall in France; some, that the rainfall has increased at Viviers contemporaneously with the *deboisement* or destruction of forests on the mountains of the Cevennes; others, that it has increased at Bourdeaux contemporaneously with the *reboisement*, or replanting of forests, on the Landes: facts, if facts they be, which, though not incompatible with each other, point to different conclusions. In reference to these observations, M. Cézanne writes:—"If facts of this kind were clearly established, they would be unanswerable; but before admitting them we must betake ourselves to the records of the rainfall and enquire whether either of these two conflicting assertions have any value.

"In France, the earliest series of pluviometric observations is that of *l'Observatoire*. It was begun in 1689 by Phillippe de la Hire, in accordance with an express order given by Colbert to the Academy, in view of the requirements of the hydraulic works at Versailles, to ascertain what quantity of water the rain falling on the plains around could supply to the projected reservoirs.

"It has been repeatedly interrupted, and again resumed. And a summary of the record is given in the following table, taken from a valuable collection of pluviometric observations published by M. Raulin, Professor of Geology in the Faculty of Sciences at Bourdeaux:—*

TABLE OF MEAN ANNUAL RAINFALLS IN DECADES, ACCORDING TO THE PLUVIOMETRE ON THE TERRACE OF THE OBSERVATORY AT PARIS.

Periods.	Number of Years.	Rainfall.	Difference.	Names of the Observers.
1688–1700	10	517·		Lahire, 1688 to 1718.
1701–1710	10	480·6	– 36·4	
1711–1720	10	464·9	– 15·7	
1721–1730	10	378·3	– 86·6	Maraldi, Grandjean de Fouchy, 1709 to 1754.
1731–1740	10	411·	+ 32·7	
1741–1750	10	425·5	+ 11·5	
1773–1780	8	537·6	+ 114·1	Jeaurat, Alex. Bouvard, 1773–1798.
1781–1790	10	506·9	– 32·7	
1791–1798	8	413·7	– 93·2	
1804–1810	7	518·3	+ 104·6	Bouvard, Arago, Le Verrier.
1811–1820	10	496·5	– 21·8	
1821–1830	10	498·6	+ 2·1	
1831–1840	10	509·3	+ 10·7	
1841–1850	10	529·3	+ 20·	
1851–1860	10	520·3	– 9·	

"The column of difference shows that the variation followed no law of continuity. The long-continued series of observations presents us with three separate periods, and these give respectively for the annual mean, during 65 years, 1688 to 1754, 448·6 millimètres; 26 years, 1773 to 1798, 489·6; 57 years, 1803 to 1860, 512·0.

"Many authors have appealed to these numbers to prove that the rainfall in Paris is now [not less, but] greater than formerly; but this has been met by the following considerations: In pluviometric observa-

* Bourdeaux, Chaumas. 1864.

tions all errors made are errors of deficiency, arising from the escape of water by evaporation, by infiltration, by spilling, and from neglect, etc.; and doubtless the first observers did not attach any great importance to those measures which, in the absence of other corresponding observations made elsewhere, could not lead to any generalization.

"Thus Father Cotte, quoted by M. Raulin, writes in 1804:—'I may observe that the udomètre used at the Observatory of Paris has been found to be so defective that they have been obliged to give up the use of it for some years; they have now set up a new one, which is much more exact. The water is received and measured on the platform of the building, 27 métres [90 feet] above the ground, instead of measuring it, as formerly, in one of the apartments on the first storey, so that it ran through a pipe 63 feet long from the platform where it was received to the reservoir, which necessarily occasioned a loss.'

"From these different causes it is impossible to compare satisfactorily the series of observations from 1688 to 1754 with the series made from 1803 to 1860. It is possible that if the two series of observations had been made with the same instrument, and with the same precision, the latter might have shown a diminished instead of an augmented mean.

"Arago said, on this subject, in 1853*:—'There is no reason to suppose that the climate of Paris is either more or less rainy than it was 150 years ago. The small augmentation presented by the numbers in the later groups do not in fact exceed variations observable in the earlier periods.'

"It is known that in 1817 a second udomètre was placed on the ground of the court, and that ever since it has constantly received quantities of water a little in excess of what was received by that on the terrace, as may be seen from the following numbers:—

Period.	Measurement of Water Annually Received		Proportion.
	On the Terrace.	On the Ground.	
	a	*b*	*a-b.*
	millimètres.	*mm.*	*mm.*
1821-1830	498·6	551·9	1·10
1831-1840	509·3	584·8	1·14
1841-1850	529·3	627·8	1·18
1851-1860	620·3	577·1	1·40

* Arago: "*Œuvres complétes Melanges* (p. 420).

"It was long believed that this difference was owing to this—that the drops of rain increased in bulk by aggregation during their fall; it is agreed now that the relatively lesser amount collected in the pluviomètre on the terrace is attributable to atmospheric eddies. But, if it be so, the topographical modifications to which the vicinity and approaches to the Observatoire have been subjected since 1688 may suffice perhaps to explain the augmentation of the actual means. This idea naturally suggests itself when astronomers are heard complaining that, in consequence of the multiplication of street carriages and other conveyances, of gas lights and of *bells*, certain researches have become impossible in the Observatoire of Paris, so that it is necessary to remove it to the country, and it is imperatively necessary to decentralize the study of astronomy.

"In short, it may be admitted in regard to Paris, that if the rainfall be different from what it was during the last century, the variation is so inconsiderable that doubts are entertained as to what the character of the variation is."

Similar comments are made on observations made at Bourdeaux.

"The observations which we possess for the city of Bourdeaux are summarised in the following table, the numbers given in which are taken, in like manner, from the valuable collection of M. Raulin :—

TABLE OF MEAN ANNUAL RAIN-FALLS AT BOURDEAUX, IN DECADES.

Periods.	Number of Years.	Rain-fall.	Difference.	Names of the Observers.
1714–1720	7	659·1		Sarreau, father and son.
1721–1730	10	737·5	+ 78·4	
1731–1740	10	735·1	– 2·4	
1741–1750	10	693·6	– 41·5	
1751–1760	10	670·0	– 23·6	
1761–1770	10	647·8	– 22·2	
1776–1786	10	641·9	– 5·9	Guyot and De la Mothe.
1842–1850	8	849·2	+ 207·3	Abria.
1851–1860	10	795·2	– 54·8	
1851–1860	10	820		Petit-Laffitte.

General average, 719 millimètres.

"The column of differences here shows still that the variations do not follow a law of continuity. For the first series of 67 years the annual mean is 684·7 millimètres, while for the new series, 1842–1860, this mean rises to 820, an augmentation of 20%.

"And it is remarkable in this table that for the years 1851-1860, two different observers obtained quantities of water notably different."

The work of M. Raulin presents other examples of such anomalies. To these I shall afterwards have occasion to refer in the further prosecution of the study of the subject; but from the recorded observations, the destruction of forests in the districts I named does not appear to have greatly affected the deposit of moisture throughout the districts referred to.

Corresponding results have been yielded by a study of the records of observations made in the United States of America.

In North America we have a country which within comparatively recent times was extensively covered with forests in regions which have now been in a great measure cleared of them. To observations which may indicate any changes upon the rainfall over extensive districts which may thus have been produced attention has been given, and is being given, by the Smithsonian Institution, under the direction of the Secretary, Professor Joseph Henry, at Washington. Under his direction there are being collected, collated, tabulated, and otherwise utilised, meteorological observations made throughout the United States, observations made at sea, and collected at the United States Naval Observatory, observations made by Arctic and Antartic explorers, and observations made at several hundred stations in other parts of the world.

Observations on the winds of North America have been tabulated and published, and have been largely made use of by the English Board of Trade in constructing wind charts of the Northern Ocean. In 1872 Professor Coffin was engaged in the tabulation of observations in parallel zones of latitude 5° in breadth, the whole world over, from the North Pole to the South. And at that time it was reported by Professor Henry :—

"The temperature observations are still in progress of reduction, two computers being engaged upon the work. The progress of their labours has, however, frequently been interrupted by calls from different portions of the country for reports on the climate of different districts.

"The following is an account of the present condition of this part of the general reductions :

"The collection and tabulation, in the form of monthly and annual means, of all accessible observations of the atmospheric temperature of the American continent and adjacent islands, have been completed to the close of the year 1870, and extensive tables representing the daily extremes, or the maximum and the minimum at the regular observing hours, have been prepared.

"An exhaustive discussion of all the observations available for the investigation of the daily fluctuations of the temperature has been made, and this part of the work is now ready for the printer.

"The discussion of the annual fluctuations of the temperature has been commenced and carried as far as the present state of other parts of the discussion would permit.

"The construction of a consolidated table giving the mean results, from a series of years, for each month, season, and the year, at all of the stations, which will probably exceed 2,500 in number, has been begun and completed for that part of the continent lying north of the United States, and also for several of the States. This is perhaps the most laborious, as it is one of the most important parts of the discussion. In many of the large cities there are numerous series, made by various observers, at different hours, all of which have to be brought together, corrected for daily variation, and combined to obtain the final mean. To give some adequate idea of the time and labour involved in the preparation of these tables, it may be mentioned that, in the State of New York alone, there are about three hundred series, which are derived from nearly two million individual observations.

"The principal sources from which the general collection of results has been derived, may be enumerated as follows:—

"1. The registers of the Smithsonian Institution, embracing upward of three hundred large folio volumes.

"2. The publications of the Institution, Patent-Office, Department of Agriculture, and public documents.

"3. All the published and unpublished records of the United States Army, United States Lake Survey, and United States Coast Survey.

"4. The large volume compiled by Dr Hough, from the observations made in connection with the New York University System, the records made in connection with the Franklin Institute, and those obtained from numerous observatories and other scientific institutions.

"5. The immense collection of printed slips, pamphlets, manuscripts, &c., in the possession of the Smithsonian Institution.

"The work has been somewhat retarded by the collection and tabulation of the rain-fall, to the end of 1870, for the Smithsonian stations, and to the end of 1871 for the United States military posts.

"Beside the discussion of the observations on temperature, rain, and wind, there remain those relative to the pressure of the atmosphere, and its humidity; also those which are classed under the head of casual phenomena, such as thunder-storms, tornadoes, auroras, meteors, early and late frosts, progress of vegetation, opening and closing of rivers, &c. These will be put in hand as soon as the funds of the Institution which can be devoted to meteorology will permit the requisite expenditure."

From this statement some idea may be formed of the magnitude of the work, of the extent of the resources provided for the prosecution of it, and of the energy with which it was being carried out.

The documents by Dr Hough, referred to, were published in two large volumes, the first entitled "Results of a Series of Meteorological Observations, made in obedience to instructions from Regents of the University of the State of New York, from 1826 to 1850 inclusive," and the second entitled "Second Series of Meteorological Observations, embracing Observations from 1850 to 1863, with Records of Rainfall, and other Phenomena, to 1867 inclusive."

In 1872 were published "Tables and Results of the Precipitation in Rain and Snow in the United States, and at some Stations in Adjacent Parts of North America, and in Central and South America," collected by the Institution, and discussed under the direction of Professor Henry by Mr Charles A. Schott. And, in an examination of these, I fail to discover any intimation of any change in the quantities of rain falling having followed the clearing of any district from which observations were collected, and the stations were 790 in number.

Simultaneously with the collecting of these observations by the agents of the Smithsonian Institution, special attention was being given by Mr Draper, Director of the Meteorological Observatory in the Central Park of New York, to the alleged effects of forests and of the destruction of these on the rain-fall. And in his report to the Board of Commissioners of the Department of Public Parks for the same year, 1871, he makes the following statement, in reply to the question, Does the clearing of land increase or diminish the fall of rain:—

"Much solicitude is publicly felt as regards the supposed diminished quantity of water which fell last year, a point of the highest concern. There is a general impression that this alleged deficiency was to such an amount as to endanger a due supply to the city for the current year. And not only this, it has also been asserted that, for several years past, there has been a steadily occurring diminution in the rainfall. Whilst the quantity of water has thus been becoming less and less, the demand has been becoming greater. Not only has the population of the city increased, but also that of the suburban districts, which derive their supplies from the same water-gathering grounds that we do.

"I therefore supposed, since our registering rain-gauge furnishes very reliable measures, that it would be useful to examine this subject critically. But since we have had these gauges in operation only about three years, and as the investigation proved to be full of interest, I was led to draw upon other additional sources of information, selecting such as seemed to be of the most trustworthy kind. By the aid of these, the examination has been extended as far back as 1836, and with the following results:—

"1st. As respects the indications given by our own instruments, which may be thoroughly relied on for the years 1869, 1870, 1871.

"For the first of these years, 1869, the total rainfall was 46·82 inches, distributed as follows: During the first quarter, 15·06 inches; second quarter, 10·24; third quarter, 7·72; fourth quarter, 13·80—total, 46·82.

"For 1870, the total rainfall was 42·32 inches, distributed as follows: During the first quarter, 12·86 inches; second quarter, 10·29; third quarter, 9·39; fourth quarter; 9·78—total, 42·32.

For 1871, the total rainfall was 52·06 inches, distributed as follows: During the first quarter, 10·33 inches; second quarter, 14·12; third quarter, 14·21; fourth quarter, 13·40—total, 52·06.

"So far as these years are concerned there does not appear any evidence of a decrease. On the contrary, in the last there is a very considerable excess over either of the others.

"Extending our examination to preceding years as far back as the beginning of 1836, and grouping those years into three periods each of ten, and one of six years, the statement comes to this: First period, from 1835 to 1846, 39·5 inches; second period, from 1845 to 1856, 47·0; third period, from 1855 to 1866, 52·0; fourth period, from 1865 to 1872, 52·0. This would make the annual rainfall throughout these 36 years, 47·62 inches. That of the last three years 47·06.

"These numbers being substantially the same, it may be concluded that, though there are large variations from year to year, as shown by a synoptic table, these, on the whole, will neutralize one another when very long periods of time are considered.

"In the foregoing tables the numbers from 1836 to 1854, inclusive, are derived from the observations made by the Military Officers at Fort Columbus, New York Harbour; those for the next twelve years are from the records of Prof. Morris, in New York City; and the remainder are from the registers of this observatory. It is of course assumed that the rainfall at Fort Columbus, that in New York City, and that in the Central Park are the same, an assumption which is, I suppose, under the circumstances, admissible.

"The amount of rainfall not only influences in a predominant manner the growth of plants, and, therefore, agricultural pursuits determining the profitable cultivation of many different crops, but it also exerts an influence on several manufacturing operations. If, therefore, the above statement be correct, no apprehension need be entertained of a permanent disturbance in these particulars. Although in the last thirty-six years great changes have been made in all those portions of the United States intervening between the Mississippi and the Atlantic Ocean, large surfaces having been cleared of the primeval forests and brought under cultivation, their physical character and aspect having therefore been essentially altered, no corresponding diminution can nevertheless be traced in the mean amount of water that has fallen. On the contrary, as seen in the table given and in the synoptic chart, there has been an actual increase. It appears, therefore, that the wide-spread public impression that the clearing of land diminishes the volume of rain is not founded on fact, and in truth this is no more than might have been expected from a correct consideration of the meteorological circumstances under which rain is produced.

"It is the belief of European Meteorologists that the mean rainfall on the western portion of that continent varies little, if at all, when periods of many years are considered. In England there are rainfall records reaching back to 1677. Since 1725 these records are unbroken; at present there are more than 1,500 rain-gauge stations in that country. The Scotch observations extend to 1731, the Irish to 1791.

"A discussion of the observations made at the Royal Observatory at Greenwich, in 1859, led to the conclusion that the annual fall of rain, as compared with that previous to 1815, was becoming smaller; but more extended observations, taken from gauges at stations widely separated, led to the opposite conclusion, viz., that there was a perfect compensation, the decrease at one place being compensated by the increase at another.

"This conclusion was strikingly illustrated by the Continental observatories. The rainfall at Paris was found not to have altered in 130 years, and though the observations of fifty years at Marseilles gave a decrease, those for fifty-four years at Milan gave an increase.

"Even in the same locality this principle of compensation may be noticed. Thus the rainfall in England, in the ten years from 1850 to 1859, was found by Mr Symons to be five per cent. less than during the previous forty years, but during the following six years it was five per cent. above the mean of the preceding ten.

"It may, however, be supposed that conclusions which apply to the old-settled countries of Europe, in which but few important topographical changes, through agricultural or other operations, have taken place for many years, will scarcely apply to America, wherein the clearing of land and agriculture surface-changes have been occurring on a very extensive scale. The foregoing conclusions, however, show us how insignificant is the meteorological result which these variations produce."

The observations are cited as evidence that there are cases in which the extensive destruction of forests does not appear to have perceptibly affected the quantity of the rainfall over a wide expanse of country; and these observations are brought forward as observations not less necessary to be taken into account, in considering the effects of forests on the humidity of the climate, than are those which have previously engaged our attention.

SECT. II.—*Cases in which the Extensive Destruction of Forests appear to have been followed by a marked Desiccation of Land and Aridity of Climate.*

Lawyers have been credited with the *bon mot* that the case being altered that alters the case, but the principle holds true in science as well as in law; and it seems to be a truth of universal application. Along with the recorded observations which have been cited as cases in which the extensive destruction of forests does not appear to have perceptibly affected the quantity of rain falling over a widely-extended country, there are other cases in which the extensive destruction of forests appears to have been followed by a marked desiccation of land and aridity of climate; and these are so numerous as almost to justify the declaration that, in times past, wherever civilised man has gone, what he found a wilderness he has left a desert, dried up and desolate, through the reckless destruction of the forests and the bush.

In treating of the hydrology of South Africa, of the former hydrographic condition of the Cape of Good Hope, and of the causes of its present aridity, I have given copious details in regard to the destruction of herbage and trees which has been going on in South Africa from the time when it was first visited by Europeans to the present (pp. 167–170), with details of the condition to which forests have been reduced by reckless felling of timber trees (pp. 171–175), with details of the extensive destruction of forests by fire (pp. 175–194), and with details of the consequence of the destruction of herbage and trees on the desiccation or diminution of the water supply in the basin of the Orange River, given by Mr J. Fox Wilson in a paper read before the Royal Geographical Society, with remarks on the same by Dr Livingstone, Sir Roderick Murchison, Dr Kirk, Mr Galton, Colonel Balfour, and Lord Stratford de Redcliffe (pp. 197–207), and corresponding testimony by Dr Rubige, and others, at the Cape of Good Hope.

Of the extreme aridity of South Africa, beyond the colonized portion of it, I have given illustrations in accounts given by Dr Livingstone of his experience at Kolobeng, in accounts given of the great sufferings of Mr Helmore and his family in travelling in the interior, under which the whole of them succumbed and perished, and in accounts given by Mr M'Kenzie of his experience in travelling to Shooseng (pp. 216–223), and in accounts given by Dr Moffat of his experience in a journey to Griqua Town (pp. 253–256); and of the aridity of soil and climate within the colony I have given corresponding illustrations in the same volume (p. 8 and p. 227).

In bringing forward these facts thus detailed I made obvious my belief that though only the sequence of desiccation to the destruction of forests and herbage and grass could be proved, they were connected as cause and effect. Such was also the opinion of, I believe, all whose testimony I thus adduced. To establish this point was the object of the paper prepared for the Geographical Society by Mr Fox Wilson; and thus has Dr Moffat borne testimony to the fact: he relates that on his settlement at Latakoo, "The natives were wont to tell of the floods of ancient times, the incessant showers which clothed the very rocks with verdure, and the giant trees and forests which once studded the brows of the Hamhana hills and neighbouring plains. They boasted of the Kuruman and other rivers, with their impassable torrents, in which the hippopotami played, while the lowing herds walked to their necks in grass, filling their *makukas* (milk sacks) with milk, making every heart to sing for joy." And he mentions that, "Independent of this fact being handed down by their forefathers, they had before their eyes the fragments of more fruitful years in the immense number of stumps and roots of enormous trunks of *acacia giraffæ*, where now scarcely one is to be seen raising its stately head above the shrubs; while the sloping sides of hills and the ancient beds of rivers, plainly evinced that they were denuded of the herbage which once clothed their surface. Indeed, the whole country north of the Orange River lying east of the Kalagari desert, presented to the eye of a European something like an old neglected garden or field." Dr Moffat found no difficulty in accounting for this. "The Bechuanas, especially the Batlapis, and the neighbouring tribes," says he, "are a nation of levellers; not reducing hills to comparative plains, for the sake of building their towns, but cutting down every species of timber, without regard to scenery or economy. Houses are chiefly composed of small timber, and their fences of branches and shrubs. Thus, when they fix on a site for a town, their first consideration is to be as near a thicket as possible. The whole is presently levelled, leaving only a few trees, one in each great man's fold, to afford shelter from the heat, and under which the men work and recline.

"The ground to be occupied for cultivation is the next object of attention. The large trees being too hard for their iron axes, they burn them down by keeping up a fire at the root. These supply them with branches for fences, while the sparrows, so destructive to their grain, are thus deprived of an asylum. These fences, as well as those in towns, require constant repairs, and, indeed, the former must be renewed every year; and by this means the country for many miles around becomes entirely cleared of timber; while in the most sequestered spots, where they have their outposts, the same work of destruction goes on. Thus, of whole forests, where the giraffe and elephant were wont to seek their daily food, nothing remains.

"When the natives remove from that district, which may be after only a few years, the minor species of the acacia soon grows, but the *acacia giraffæ* requires an age to become a tree, and many ages must pass before they attain the dimensions of their predecessors. In the course of my journeys I have met with trunks of enormous size, which, if the time were calculated necessary for their growth, as well as their decay, one might be led to conclude that they sprung up immediately after the Flood, if not before it. The natives have also the yearly custom of burning the dry grass, which on some occasions destroys shrubs and trees even on the very summit of the mountains. To this system of extermination may be attributed the long succession of dry seasons." "To the same cause," says he, "may be traced the diminution of fountains, and the entire failure of some which formerly afforded a copious supply, such as Griqua Town, Campbell, and a great number of others which might be mentioned. It has been remarked that since the accidental destruction of whole plains of the *Olea similis* (wild olive) by fire, near Griqua Town, as well as the diminishing of large shrubs on the neighbouring heights. a gradual decrease of rain has succeeded in that region."

In treating of these, the secondary causes of the desiccation of South Africa, I had occasion to quote, from Marsh's treatise on "The Earth as Modified by Human Action," the following statement, which I followed up with the remarks and quotations from the same and other authors, which follow :—

"'Whenever a tract of country, once inhabited and cultivated by man, is abandoned by him and domestic animals, and surrendered to the undisturbed influences of spontaneous nature, its soil sooner or later clothes itself with herbaceous and arborescent plants, and at no long interval with a dense forest growth. Indeed, upon surfaces of a certain stability, and not absolutely precipitous inclination, the special conditions required for the spontaneous propagation of trees may all be negatively expressed, and reduced to these three :— exemption from defect or excess of moisture, from perpetual frost, and from the depredations of men and browsing quadrupeds. When these requisites are secured, the hardest rock is as certain to be overgrown with wood as the most fertile plain, though for drier seasons the process is slower in the former than in the latter case. Lichens and mosses first prepare the way for a more highly organized vegetation. They retain the moisture of rains and dews, and bring it to act, in combination with the gases evolved by their organic processes, in decomposing the surface of the rock they cover; they arrest and confine the dust which the wind scatters over them, and their final decay adds new material to the soil already half-formed beneath and upon them. A very thin stratum of mould is sufficient for the germination of seeds of the hardy evergreens and the birches, the roots of which are often found in immediate contact with the rock, supplying their trees with nourishment from a soil deepened and enriched from the decomposition of their foliage, or sending out long rootlets into the surrounding earth in search of juices to feed them.'

"But with all the provisions which have been made for the production of forests, and for the restoration of small portions which have been destroyed, it is possible for man to counteract these; and he has done so. But what have been some of the consequences which have followed?

"According to a summary of some of these given by Marsh, 'With the extirpation of the forest all is changed. At one season the earth parts with its warmth by radiation to an open sky; receives, at another, an immoderate heat from the unobstructed rays of the sun. Hence the climate becomes excessive, and the soil is alternately parched by the fervours of summer, and seared by the rigours of winter. Bleak winds sweep unresisted over its surface, drift away the snow that sheltered it from the frost, and dry up its scanty moisture. The precipitation becomes as irregular as the temperature; the melting snows and varied rains, no longer absorbed by a loose and bibular vegetable mould, rush over the frozen surface, and pour down the valleys seawards, instead of filling a retentive bed of absorbent earth, and storing up a supply of moisture to feed perennial springs. The soil is bared of its covering of leaves, broken and loosened by the plough, deprived of the fibrous rootlets which held it together, dried and pulverized by sun and wind, and at last exhausted by new combinations. The face of the earth is no longer a sponge, but a dust heap; and the floods which the waters of the sky poured over it hurry swiftly along its slopes, carrying in suspension vast quantities of earthy particles, which increase the abrading power and mechanical force of the current, and, augmented by the sand and gravel of falling banks, fill the beds of the streams, divert them into new channels, and obstruct their outlets. The rivulets, wanting their former regularity of supply, and deprived of the protecting shade of the woods, are heated, evaporated, and thus reduced in their former currents,—but swollen to raging torrents in autumn and in spring.

"'From these causes there is a constant degradation of uplands, and a consequent elevation of the beds of water-courses, and of lakes, by the deposition of the mineral and vegetable matter carried down by the waters. The channels of great rivers become unnavigable, their estuaries are choked up, and harbours which once sheltered large navies are shoaled by dangerous sand-bars.'

"The earth stript of its vegetable glebe grows less and less productive, and consequently less able to protect itself by weaving a new net-work of roots to bind its particles together, a new carpeting of turf to shield it from wind and sun and scouring rain. Gradually it becomes altogether barren. The washing of the soil from the mountains leaves bare ridges of sterile rock, and the rich organic mould which covered them, now swept down into the dark low grounds, promotes a luxuriance of aquatic vegetation that breeds fever and more insidious forms of mortal disease by its decay, and thus the earth is rendered no longer fit for the habitation of man. . .

"The effect of the destruction of forests upon the climate has been questioned, but the facts remain. And so has it been seen again and again in the history of the nations. The term *savage*, from its etymological derivation, speaks of a sylvan life; and from the sylvan or savage life to that of the civilized or city life, the progress of man may be traced, to some extent, by the destruction of forests. The one has, until attention was given to consequences which have followed the destruction of forests, been the accompaniment or complement of the other, operating sometimes as a cause, manifesting itself sometimes as a consequence—if both be not con-sequences of a common cause. But it is possible that the destruction of forests may be carried too far. According to the testimony of Dr Hooker, cited in the preface, 'In the estimation of an average Briton forests are of infinitely less importance than the game they shelter, and it is not long since the wanton destruction of a fine young tree was considered a venial offence compared with the snaring of a pheasant or rabbit. Wherever the English rule extends, with the single exception of India, the same apathy or inaction prevails. . . . In Demerara the useful timber trees have all been removed from accessible regions, and no care or thought of planting others; from Trinidad we have the same story; in New Zealand there is not now a good Kauri pine to be found near the coast; and I believe that the annals of almost every English colony would repeat the tale of wanton waste and improvidence.'

"In view of this waste, Schleiden, to whom I have already referred, writes, if not in the words, yet following in the train of thought of one of the noblest veterans of our science, the venerable Elias Fries, of Lund: 'A broad band of waste land follows gradually in the steps of cultivation. If it expands, its centre and cradle dies, and on the outer borders only do we find green shoots. But it is not impossible, it is only difficult, for man, without renouncing the advantage of culture itself, one day to make reparation for the injury which he has inflicted: he is appointed lord of creation. True it is that thorns and thistles, ill-favoured and poisonous plants, well named by botanists 'rubbish plants,' mark the tract which man has proudly traversed through the earth. Before him lay original nature in her wild but sublime beauty. Behind him he leaves the desert, a deformed and ruined land; for childish desire of destruction, or thoughtless squandering of vegetable treasures, have destroyed the character of nature; and man himself flies terrified from the arena of his actions, leaving the impoverished earth to barbarous races or animals, so long as yet another spot in virgin beauty smiles before him. Here again, in selfish pursuit of profit, consciously or unconsciously, he begins anew the work of destruction. Thus did cultivation, driven out, leave the East, and the deserts perhaps previously robbed of their coverings; like the wild hordes of old over beautiful Greece, thus rolls this conquest with fearful rapidity from east to west through America, and the planter often now leaves the already exhausted land, the eastern climate become infertile through the demolition of the forests, to introduce a similar revolution into the far west. But we see, too, that the nobler races, or truly cultivated men, even now raise their warning voices, put their small hand to the mighty work of restoring to nature her strength and fulness in yet a higher stage than that of wild nature; one dependent on the law of purpose given by man, arranged according to plans which are copied from the development of manhood itself. All this, indeed, remains at present but a powerless, and for the whole, an insignificantly small enterprise, but it preserves the faith in the vocation of man and his power to fulfil it. In future times he will and must, when he rules, leads, and protects the whole, free nature from the tyrannous slavery to which he now abases her, and in which he can only keep her by restless giant struggles against the eternally resisting. We see in the gray cloudy distance of the future a realm of peace and beauty on the earth and in nature, but to reach it must man long study in the school of nature, and, *before all*, free himself from the bonds of that exclusive selfishness by which he is actuated."'

In 1847 was published *Klima und Plantzen Welt in der Zeit*, by C. Fraas. It was published at Landshut. In this work the writer endeavoured to show, by the history of vegetation in Greece, not merely that clearing and cultivation have affected the climate, but that change of climate had essentially modified the character of vegetable life.

In the same year, 1847, Becquerel published a work, entitled *Eléments de Physique Terrestre et de Mineralogie*, and six years later, in 1853, he published another work, entitled *Des Climats et de l'influence qu exercent les sols Boises et non-boissees*, and in a paper addressed to the Academy of Sciences he examines the subject of forests both as to their commercial importance, and as to their influence on climate. In this paper he casts a rapid glance at the effects produced by the destruction of forests from the remotest ages to our time.

Forests, he shows, existed on the globe long before the appearance of man, a fact proved by the immense coal deposits which are to be found in every part of it, even in the polar regions. These deposits consist of Equisetacea, Sigillaria, &c., particularly also of ferns of the size of trees, instances of which are now only to be met with under the tropics. In most parts of the old continent, the primitive life of man was, as he shows, passed in forests, and increase of population was the cause of the first attacks upon them ; but the greatest devastations only date from the period when great conquerors cut down and burnt the forests in which the peoples they wanted to subdue had taken refuge. From the Ganges to the Euphrates, from that to the Mediterranean, an extent of ground 1,000 leagues in length and several hundred broad, was ravaged by wars during the lapse of thirty centuries. Nineveh and Babylon, so celebrated for their civilization, Palmyra and Balbeck, renowned for their opulence, now offer nothing but ruins to the exploring gaze of the traveller, in the midst of deserts and swamps, once covered by luxuriant forests. From the time of Sesostris to that of Mehemet II., Asia Minor was a constant scene of unrelenting wars leading to similar results. The land of Canaan, so highly praised in the Bible, is now little more than a desert, and the whole coast of Africa along the Mediterranean tells a similar story.

Turning from historical considerations to the present state of forests in France, he shows that similar operations, though not to the same extent, were being carried on there, which could only tend to produce similar effects.

By Mr Marsh, who has himself given much attention to the subject, it is stated that the subject of climatal change, with and without reference to human action as a cause, has been much discussed by Moreau de Jormis, Dureau de la Malle, Arago, Humboldt, Fuster, Gasparm, Becquerel, and many other writers, in Europe, and by Noah Webster, Ferry, Drake, and others, in America, and his work cited is a valuable repository of information, collected by him from their works and other sources, combined with observations made by himself, and conclusions at which he has arrived, all of which are in accordance with those here stated.

Besides the writers now named, Professor Laurent, of Nancy Forest School, has given attention to the subject, and has traced the desolation which has been brought on the former homes of teeming life in the East to the destruction of trees. And a writer in the *Edinburgh Review*, for October 1875, on the subject of forest management, citing the work of Professor Laurent, says, "Babylon, Thebes, Memphis, and Carthage, now waste and even pestilential, were formerly the very hives of human life. The remains of conduits, canals, cisterns, and pools, throughout Palestine, and especially through the now desert country east of the Jordan, are such as to explain the accounts on record of the former population of these regions. So thorough has been not only the change of climate, but the denudation of soil, caused by the cutting down of the olives, palms, and other trees of Palestine during the Roman war, that it would be impossible to attach any credit to the most venerable accounts of the former fertility, beauty, and population of the Holy Land—its brooks and fountains gushing out of valley and hills, being now replaced by bare and solid rock—without the knowledge that we have acquired of the fatal effect of the destruction of timber." This may be considered by others, as it is by me, questionable, but it may be received as indicative of the conviction of the writer, that the connection of the destruction of the forests, eighteen hundred years ago, with the present aridity, as cause and effect, is established beyond all question.

It is alleged by Mr Draper, while reporting his conclusions from an extensive collating of meteorological records in America, which were to the effect that there had been no diminution of the rainfall in the districts in which these observations had been made, that,—"Against this conclusion, which is based essentially on recorded instrumental observations, I cannot admit the force of any alleged historical facts;" and expressing an opinion that the devastation of ancient empires which is attributable in part to drought, is attributable in a great measure to war, and consequences of war other than the destruction of forests, he says,—"It is useless to draw any inference from the present desolate condition of the regions of the Euphrates and Tigris, or of the Holy Land, as contrasted with their amazing fertility in the olden days;" and, "changes such as these have nothing to do with changes of climate." But, with the mass of testimonies which I have piled around me to effects which have followed immediately on the destruction of forests, I cannot assent to the sweeping statement I have quoted. It may be freely admitted that devastations occasioned by war may be followed by drought, without compromise to the allegation that the destruction of forests may be followed by drought. The devastations of war may include the destruction of forests, and it so happens that facts are not awanting illustrative of the devastations of war being followed by an opposite effect, with results corresponding to what might be expected therefrom.

When Humboldt visited South America he was led to consider what could be the cause or occasion of a process of desiccation which was brought under his notice. To quote from a statement by Boussingault, which is cited by Mr Marsh :—" 'The rivers which rise within the valley of the Aragua, having no outlet to the ocean, form, by their union, the Lake of Tacarigua or Valencia, having a length of about two leagnes and a-half [or seven English miles].

" 'At the time of Humboldt's visit to the valley of the Aragua, the inhabitants were struck by the gradual diminution which the lake had been undergoing for thirty years. In fact, by comparing the descriptions given by historians with its actual condition, even making large allowance for exaggeration, it was easy to see that the level was considerably depressed. The facts spoke for themselves. Oviedo, who, toward the close of the sixteenth century, had often traversed the valley of the Aragua, says positively that New Valencia was founded, in 1555, at half a league from the Lake of Tacarigua; in 1800, Humboldt found this city 5,260 mètres [or three and a-half English miles] from the shore.

" 'The aspect of the soil furnished new proofs. Many hillocks on the plain retain the name of islands, which they more justly bore when they were surrounded by water. The ground laid bare by the retreat of the lake was converted into admirable plantations; and buildings erected near the lake shewed the sinking of the water from year to year. In 1796, new islands made their appearance. A fortress built in 1740 on the island of Cabrera, was now on a peninsula; and, finally, on two granitic islands, those of Cura and Cabo Blanco, Humboldt observed among the shrubs, some mètres above the water, fine sand filled with helicites.

" 'These clear and positive facts suggested numerous explanations, all assuming a subterranean outlet, which permitted the discharge of the water to the ocean. Humboldt disposed of these hypotheses, and did not hesitate to ascribe the diminution of the waters of the lake to the numerous clearings which had been made in the valley of Aragua within half a century.'

" Twenty-two years later, Boussingault explored the valley of Aragua. For some years previous, the inhabitants had observed that the waters of the lake were no longer retiring, but, on the contrary, were sensibly rising. Grounds, not long before occupied by plantations, were submerged. The islands of Nuevas Aparecidas, which appeared above the surface in 1796, had again become shoals dangerous to navigation. Cabrera, a tongue of land on the north side of the valley, was so narrow that the least rise of the water completely inundated it. A protracted north wind sufficed to flood the road between Maracay and New Valencia. The fears which the inhabitants of the shores had so long entertained were reversed. Those who had explained the diminution of the lake by the supposition of subterranean channels were suspected of blocking them up, to prove themselves in the right.

"During the twenty-two years that had elapsed, the valley of Aragua had been the theatre of bloody struggles, and war had desolated those smiling lands and decimated their population. At the first cry of independence a great number of slaves found their liberty by enlisting under the banners of the new republic; the great plantations were abandoned, and the forest, which in the tropics so rapidly encroaches, had soon recovered a large proportion of the soil which man had wrested from it by more than a century of constant and painful labour."

In this case war seems to have produced a contrary effect to that attributed to it, in other circumstances, by Mr Draper.

Boussingault proceeds to state that two lakes near Ubate, in New Granada, had formed but one a century before his visit; that the waters were gradually retiring, and the plantations extending over the abandoned bed; that, by inquiry of old hunters, and by examination of parish records, he found that extensive clearings had been made and were still going on.

" He found, also, that the length of the Lake of Fuquené, in the same valley, had, within two centuries, been reduced from ten leagues to one and a half, its breadth from three leagues to one. At the former period the neighbouring mountains were well wooded, but at the time of his visit the mountains had been almost entirely stripped of their wood. He further adds that other cases, similar to those already detailed, might be cited, and he proceeds to show, by several examples, that the waters of other lakes in the same regions, where the valleys had always been bare of wood, or where the forests had not been disturbed, had undergone no change of level."

The following statement is also made by Boussingault :—" In the island of Ascension there was an excellent spring, situated at the foot of a mountain originally covered with wood. This spring became scanty, and at last dried up, after the trees which covered the mountain had been felled. The loss of the spring was ascribed, and rightly so, to the cutting down of the timber. The mountain was therefore planted anew, and a few years afterwards the spring reappeared by degrees, and by and by flowed with its former abundance.

" The metalliferous mountain of Marmato is situated in the province of Popayan, in the midst of immense forests. The stream along which the mining works are established is formed by the junction of several small rivulets, which take their rise in a country thickly wooded.

" In 1826, when I visited the mines for the first time, Marmato consisted of a few miserable cabins, inhabited by negro slaves. In 1830, when I quitted the country, Marmato was covered with workshops, had a foundry of gold, machinery for grinding and amalgamating the ores, and a free population of nearly 3000 inhabitants. In the course of these four years an immense quantity of timber had been cut down, for the construction of machinery and of houses, as well as for fuel and the manufacture of charcoal. But the clearing had scarcely been two years effected before it was perceived that the quantity of water for the working of the machinery had notably diminished. The volume of water was measured by the work done by the machinery; and actual gauging at different times showed the progressive diminution of the water. Now, in the island of Ascension, and at Marmato, it is improbable that any merely local and limited clearing away of the forest should have had such an influence on the constitution of the atmosphere as to cause a variation in the mean annual quantity of rain. Besides, as soon as the diminution of the stream at Marmato was ascertained, a rain-gauge was set up, and in the second year of observation showed a larger quantity than in the first year, though the clearing had been continued, and though there was no appreciable increase in the size of the running stream.

" Two years' observations are insufficient to show any definitive variation in the annual average quantity of rain. But, so far as they go, they show that at Marmato the mass of running water had diminished, in spite of the larger quantity of rain which fell. It is therefore probable that local clearings of forest land, even of very moderate extent, cause springs and rivulets to shrink, and even to disappear, without the effect being ascribable to any diminution in the amount of rain that falls."

These observations are advanced by Boussingualt in connection with the statement that,—" In many localities it has been thought that, within a certain number of years, a sensible diminution has been perceived in the volume of water of streams utilized as a motive-power; at other points, there are grounds for believing that rivers have become shallower, and the increasing breadth of the belt of pebbles along their banks seems to prove the loss of a part of their water; and, finally, abundant springs have almost dried up. These observations have been principally made in valleys bounded by high mountains, and it has been noticed that this diminution of the waters has immediately followed the epoch when the inhabitants have begun to destroy, unsparingly, the woods which were spread over the face of the land.

" And here lies the practical point of the question; for if it is once established that clearing diminishes the volume of streams, it is less important to know to what special cause this effect is due."

In a report by Dr Hough, President of the United States Association for the Advancement of Science, in 1871, are references to climatic conditions there, attributed to the destructions of forests; and, in this connection, referring to the painful accounts which the journals were then giving of the distress in India from famine, he says,—" From a careful study of this subject, with such data as are accessible in late reports, we cannot doubt that this calamity is largely due to the fact that the forests have within recent years been swept off, by demands for railroad and other uses, much more rapidly than formerly, and that the exposure to winds and sun, thus occasioned, may have largely contributed to these painful results."

Mr Marsh, in a foot-note supplying indications of what may be called secular desiccation, in regard to which he had said, " After a district of country has been completely or even partially cleared of its forest growth and brought under cultivation, the drying of the soil under favourable circumstances, goes on for generations, perhaps for ages," says,—"In many parts of New England there are tracts, many square miles in extent, and presenting all varieties of exposure, which were partially cleared sixty or seventy years ago, and where little or no change in the proportion of cultivated ground, pasturage, and woodland has taken place since. In some cases, these tracts compose basins apparently scarcely at all exposed to any local influence in the way of percolation or infiltration of water towards or from neighbouring valleys. But in such situations, apart from accidental disturbances, the ground is growing drier and drier from year to year, springs are still disappearing, and rivulets still diminishing in their summer supply of water. A probable explanation of this is to be found in the rapid drainage of the surface of cleared ground, which prevents the subterranean natural reservoirs, whether cavities or merely strata of bibulous earth, from filling up. How long this process is to last before an equilibrium is reached, none can say. It may be for years; it may be for centuries.

"Livingstone states facts which strongly favour the supposition that a secular desiccation is still going on in Central Africa, and there is reason to suspect a like change is taking place in California. When the regions where the earth is growing drier were cleared of wood, or, indeed, whether forests ever grew there, we are unable to say, but the change appears to have been long in progress. A similar revolution appears to have occurred in Arabia Petræa. In many of the wadis, and particularly in the gorges of the Wadi Feiran and Wadi Esh Sheikh, there are water-worn banks showing that, at no very remote period, the winter floods must have risen fifty feet in channels where the growth of acacias and tamarisks and the testimony of the Arabs concur to prove that they have not risen six feet within the memory or tradition of the present inhabitants. Recent travellers have discovered traces of extensive ancient cultivation, and of the former existence of large towns in the Tih desert, in localities where all agriculture is now impossible for want of water. Is this drought due to the destruction of ancient forests, or to some other cause?

"For important observations on supposed changes of climate in our Western prairie region, from cultivation of the soil and the introduction of domestic cattle, see Bryant's valuable *Forest Trees*, 1871, chapter v., and Hayden, *Preliminary Report on Survey of Wyoming*, p. 455."

Mr Marsh adds:—"Some physicists believe that the waters of our earth are, from chemical or other less known causes, diminishing by entering into new and inorganic combinations, and that the element will finally disappear from the globe." I do not know anything of the facts or the reasonings on which this opinion rests.

If it be necessary, in considering the effects of forests on the humidity of the climate, to take into account cases in which the extensive destruction of forests does not appear to have powerfully affected the quantity of the rainfall over a wide expanse of country, it is no less necessary to take into account other cases in which the extensive destruction of forests does appear to have been followed by a marked desiccation of land, and aridity of climate. They are facts perfectly compatible with each other, and the establishment of either is neither a disproof of the other, nor does it invalidate the testimony on which it is received, though it may prompt to a more strict scrutiny of what is said, and of the credibility of this, than might otherwise have been given to it. Let it suffice here to state that the objections to which such statements are open are these, first, that they are vague and general, and, second, that they relate to effects which may have been otherwise produced than in accordance with the supposition advanced; and what is considered the cause may have been in reality the effect, for anything to the contrary advanced in the statements made.

SECT. III.—*Cases in which the Destruction of Trees has been followed by Desiccation, and the Replanting of Trees followed by the Restoration of Humidity.*

In treating of the Hydrology of South Africa, in a separate volume already referred to, I had occasion to cite St. Helena as a South African Island supplying illustrations of corresponding effects produced on the climate both by the destruction of trees and by extensive sylviculture.

From a note appended by Emsman to his German translation of a work on meteorology in relation to cosmical phenomena by Foissac,* it appears that in the beginning of the sixteenth century the forests of St. Helena must have been extensive, for it is stated by him, on the authority of the introductory chapters in Beatson's *St. Helena*, that it was the goats which destroyed the beautiful forests which,

* *Meteorologie mit Rücksight auf die Lehere vom Kosmos. Deutch von* A. H. Emsman, Leipzig, 1859.

three hundred and fifty years ago, covered a continuous surface of not less than two thousand acres in the interior of the island, not to mention scattered groups of trees.

While I was at the Cape I wrote to St. Helena for information on the subject, and in reply his Excellency, H. R. Janisch, now Governor of the island, at once supplied me with the following information, embodied in notes published on the *Natural History of St. Helena* :—"Viewed from the sea the island offers little or nothing to the eye but an assemblage of lofty and barren hills, intersected in all directions with deep and narrow valleys, in many cases little better than ravines, and generally devoid of vegetation, excepting here and there patches of prickly pear, samphire, and profitless weeds, the wooded peaks in the interior being in most positions hidden from view by the almost perpendicular cliffs running down to the sea. But when first discovered, in 1502, it was in the valleys almost covered with trees right down to the water's edge. These trees appear to have been principally gum-wood, ebony, and red-wood." The gum-wood flourished nearest to the sea; the ebony and red-wood covered the slopes of the mountain; while the hill tops appear to have been covered with the cabbage tree and ferns—the former (*areca oleracea*) presenting from a little distance the appearance of a tree bearing stocks of cabbage, or of brocoli, at the extremities of its branches. While such was the state of vegetation, it must have been an island well watered everywhere.

But the earlier governors and settlers made sad havoc among the trees; and herds of goats and of swine being allowed to run loose on the land, young growing trees, which might have supplied the waste, were destroyed, and the island became almost denuded. All the ebony trees have long since disappeared: the last, a tree remarkable for its excessive hardness, size, and density, was found on Deadwood. The red-wood is now scarce, and, like the ebony, would altogether have disappeared, had not Governor Byefield caused two young trees to be set at Plantation House, from which two all at present on the island have been propagated. And a comparison of the cabbage trees of the present with the remains of those of the past tell of a stunted growth. What was the consequence of this extensive destruction of trees? "Incidentally we find," says my correspondent, "in the records of the last century, accounts of repeated and almost periodical visitations of very severe drought, occasioning ruinous losses of cattle and crops."

Towards the close of the last century, however, the denudation of the island had been carried so far that wiser governors saw it to be necessary to adopt some strenuous measure to restore the vegetation. Nurseries were made, and experienced gardeners were introduced by the Company, and trees from all parts of the world were introduced and flourished. Prizes were given for the number of trees reared, irrespective of their character. The cluster-pine *(pinus pinaster)* was sown very extensively, and several plantations of this tree remain in a thriving condition. But a variety of other forest trees, greatly preferred both for beauty and use, were planted about the same period and have flourished well. In regard to the results, my correspondent writes :—" For many years past, since the general growth of our trees, we have been preserved from this scourge; and droughts, such as were formerly recorded, are now altogether unknown. We have no means, however, of otherwise comparing the rainfall of the two periods, as no tables, or even estimates, of the rainfall can be had for the earlier dates. Our fall of rain now is equal to that of England, and is spread almost evenly over the year. The showers fall more heavily in two or three months of the year. But this period, though called on this account the rainy season, is in no way to be compared to what is understood by an inter-tropical rainy season."

Meteorological observations are or were kept at Longwood and at Plantation. I have at command only the record of the rainfall from 1841 to 1848. The amount of rain which fell in these years was :—

1841,............68·925	1845,............19·509
1842,............90·458	1846,............26·556
1843,............37·189	1847,............42·441
1844, ...20·026	1848,............45·630

The communication I have cited not only tells of the former abundance of vegetation and moisture, and of frequent long-continued droughts having followed the reckless destruction of forests. but it tells of the replenishing of the island with trees under the fostering care of the East India Company towards the close of the last century; and that subsequent to that, droughts such as had been previously recorded had been for a long time altogether unknown. But it was further added :—" Since the transfer of the Island from the Company in 1836 the matter has been much neglected. The liberal expenditure and prizes of the East India Company came to an end. The business men of our population require, whether the profits be large or small, that the returns shall be *quick*; and they have no idea of casting upon waters seed that cannot be found after so many days. The result has been that, for the last thirty years, in place of every score cut down hardly one tree has been planted beyond the supply of self-sown plants. Our Governor has, however, given much attention to this since his arrival; and he is anxiously endeavouring to introduce and propagate the best trees he can obtain, and as yet his experiments have been very successful and encouraging." This was written in 1865.

Blanqui in a volume entitled *Voyage in Bulgarie*, published in 1843, says that,—" In the Island of St. Helena, where the wooded surface has considerably extended within a few years, it has been observed that the rain has increased in the same proportion. It is now in quantity double what it was during the residence of Napoleon." In this we find a corroboration of what was reported by Mr Janisch in regard to the consequence of extensive plantings encouraged by the East India Company previous to 1836.

The Island of St Helena is of volcanic origin. It is said to have been discovered by the Dutch in 1502. " Viewed from the sea, as it is approached, there is nothing inviting in its appearance; one large mass of rock with deep ravines running down into the sea, divested apparently of all vegetation, and presenting inaccessible rugged cliffs, some of great height, is all at first that the eye beholds; but as one nears the shore in the interior at certain places may be seen, peeping from out the rock, a few trees to tell that all is not barrenness within."

In the " Notes on the Natural History of the Island of St. Helena " sent to me, it is stated.

" The greater part of the Island is now bare of trees and verdure, many mountains having little upon them beyond samphire and a few scrubby weeds, which alone save them from absolute sterility, especially in the dry season, when the shallow soil is utterly parched up. Other mountains are capable of affording a very limited supply of food for sheep, which traverse their loftiest peaks and most intricate paths in search of their scanty fare.

" Some few of the hills are tolerably well wooded, and the loftiest of the whole, Diana's Peak, 2700 feet high, is clothed to the very summit. . . . .

" The cultivated parts of the Island, particularly in the neighbourhood of Plantation, as seen from High Knoll, remind the stranger very much of England, especially of parts of Devonshire.

" Illusion or likeness is further carried out by the large quantities of luxuriant furze and scrambling brambles seen in full bloom down the slopes of the hill, along the lanes and bye-roads.

"The furze appears to have been introduced into the Island during the early part of the last century, and has proved very useful to the inhabitants by furnishing them with a plentiful supply of fire-wood. It does not appear to be used here as it is in the north of England, for the purpose of watling in the walls, for making warm and comfortable outbuildings for farms and other purposes.

"When used this way, it is merely twisted between the upright posts supporting the building, and if closely worked it makes a warm building.

"There are several plantations in the Island pretty well stocked with good sized trees, principally pine and fir, which grow very well here, but for timber purposes the wood is too coarse and open in texture, resulting most likely from its rapid growth. The wood will answer for common purposes when protected from the weather, but otherwise it appears soon to decay and to be subject to rot.

"These trees, however, are a great ornament to the Island, and add much to its English appearance, as they are the predominating ones, and give character to the scenery.

"The Scarlet Geranium grows wild and very luxuriantly among the rocks, and in some places may be seen whole hedges of it; the nasturtion also grows wild, and water cresses are found in the valley streams, as well as many other plants common to England.

"Barilla, called here samphire, is very abundant in most parts of the Island; and the true samphire is found in many places, but does not appear to be much used. Fruit of many kinds grows very well here; the pears are large, plump, hard, and juicy, and are seen on the tree at the same time as the blossoms. Peaches are good and plentiful, their beautiful blossoms being often seen in the hedges; the fig thrives pretty well, as also Oranges and Lemons, and the useful Plantain. Coffee has been tried and succeeded, it is considered to be very good in quality and flavour. Cotton grows wild, as well as the castor-oil plant.

"The Port Jackson Willow thrives exceedingly well, and will ultimately be valuable for supplying firewood, as it grows quickly and throws up much underwood; and is a very ornamental tree in all its aspects, especially pleasing to the eye when full of its yellow catkins.

"The Cape Gooseberry is a useful fruit, and forms an excellent substitute for the English Gooseberry which it much resembles in taste when cooked; it is the more useful from the fact that the

English Gooseberry does not thrive well here, but runs into an un fruitful shrub.

"The trees most cultivated in Jamestown are the Margossa and the Banian, neither of which are of any great use except for a little shelter from the sun; the Banian is more curious than beautiful. The Date, Cocoa Nut, and Cypress are seen in some of the gardens, and the long leaf of the Plantain mostly accompanies them wherever water can be obtained.

"A great variety of plants, the natives of different regions, may be seen growing equally well on St. Helena, the configuration of which affords a considerable range of climate. The following list of the exotic trees and shrubs now growing on the island may prove not uninteresting :—

"Common Oak, Mosscup Oak, Evergreen Oak, Cork Tree, Abele Tree, Weeping Willow, Pineaster Fir, Spreading Fir, Dwarf Fir, Norfolk Island Pine, Chili Fir, Cape Yew, Casuarina, Cypress (two kinds), Arbor Vitæ, Eucalyptus, Banian (four kinds), Indian Rubber Tree, Erythrina Cape Coral Tree (three kinds), Sophora, Margossa, Gamboge, Terminalia (Bengal Almond), Pittisporum, Wild Olive, Black Fruited Olive, Magnolia, Liliodendron, Silk-worm Mulberry, China Weeping Birch, Murraya, Sago Palm, Palmetto, Dragon Palm, Fan Palm, Iron Wood, Holy Thorn, Myrtle (three kinds), Bauhinia, Locust, Bois Noir, Teak, Cinnamon, Laurel, Bay, Barberry, Protea, Gum Benzion, Coffee Shade, Wild Fig, Wattle of New Holland, Gelega, Althæa Frutex, Chinese Rose Hibiscus (Shoe Black), Changeable Rose (two kinds), Single Red Hibiscus, Single Purple Hibiscus, White Flowered Hibiscus, Yellow Tahitian Hibiscus, Mimosa (various,) Acacia (various), Port Jackson Willow, Buddlea, Candle Nut Tree, Yansheu, China Rose Apple, Spice Tree, Psoralea, English Privet, Sea Grape, Coral Tree (Jatrapa), Rock Rose, Travellers Joy, Oleander, Fiddle Wood, Pola Gola, Spanish Broom, Velvet Thorn, Cassia, Grewia, Datura Arborea, Scarlet Cordea, Soap Berry, Screw Pine, Date Plum, Sweet Olea, Tea, Coffee, China Privet, Jasmine (2 kinds), Holly, Banksia, (3 kinds), Elder, Cotton (2 kinds), Cytisus, Ash, Barbados Pride, Lion's Tail, Osteospernum, Castor Oil, May, Azalea, Gardenia (Cape Jasmine), Tutsan, Verbena, Furze, Wild Bringal, Bamboo (3 kinds), Bamboo Reed, Plumbago, Camellia, Fuschia, Madagascar Creeper, Passion Flower (5 kinds), Ivy, Woodbine, Melostroma.

"Fruit-bearing Plants :—Peach, Apple, Pear, Cape Plum, Mango, Chirimoya, Orange (Sweet), Orange (Seville), Lemon, Lime, Shaddock, Citron, Quince, Filbert, Grape, Pomegranate, Cocoa Nut, Date, Water Lemon (purple), Rose Apple, Pine Apple, English and Spanish Mulberry, Loquat, Banana, Apricot, Guava, Litchi, Melon, Cherry, Indian Walnut, Chesnut, Fig, Papau Apple, Tamarind, Strawberry, Wild Raspberry, English Raspberry, Blackberry, Cape Gooseberry (Tomatita, vulgarly called Bilberry."

Ships entering the harbour approach it on the eastern side of the Island, to windward, and may sail with safety close on shore, the water in the roadstead being deep, and there they may ride at anchor at all times with perfect safety, there rarely being any wind so strong, or sea so violent as to endanger their security. Opposite the anchorage is the town of St. James. At the extreme end of the town are a few pretty forest and vegetable gardens; and at the termination of James' Valley is a waterfall, beneath which is a beautiful spring whence comes all the water used for the supply of the town and shipping. The water is clear and good. It is calculated that seven thousand tons of water are daily discharged into the sea. The number of springs in the Island are said to exceed two hundred.

I accept with faith the statements made to me, in regard to the changes remarked at St. Helena as following the destruction and replenishing of trees, mainly because of their general accordance with what has been observed elsewhere; but also in a great measure from confidence in popular observations in regard to facts even when I cannot assent to popular expositions of these facts as to cause and effect.

The following remarks are results obtained from observations made by rain gauges kept at St Helena :—

The total amount of Rain which fell at Longwood in the year 1848 was 45·630 inches, which appears to be rather more than the average of eight years previous, which amounts only to 43·8 inches.

The month of October, during 1848, was the driest month of the year, being only 0·126 of an inch. January is the next driest month 0·720, and December 0·758; the two wettest months being June 7·150 and July 9·245 inches.

Upon comparing the Registers kept at Longwood and Plantation for 1847, it appears that the fall of rain was greatest at Plantation, it there being 45·892 inches, and at Longwood 42·364 inches; January and December being the two driest months of the year, June and September being the two wettest months, when the sum of the two months are taken. At Plantation the two wettest months were

June and July; at Longwood the wettest months being June and September.

The amount of Rain which fell for the undermentioned years, was:

1841,......68·925 inches.	1842,......90·458 inches.
1843,......37·189 „	1844,......20·026 „
1845,......19·509 „	1846,......26·556 „
1847,......42.411 „	1848,......45·630 „

giving the mean annual fall, 43·813 inches.

Upon Examining the Monthly Register for these eight years, it appears that October, November, December, and January, give the mean driest months. The four wettest being March, May, June, and July. The December of 1846 being the driest month of the whole 96 months; and the February of 1842 being the wettest month of the whole period.

Professor Playfair states, that when the annual fall exceeds 25 inches, the climate is to be classed as moist: if so, St. Helena must certainly be classed as a moist climate, because this standard, compared with St. Helena's average of eight years, is nearly in the proportion of 25 to 43. The Professor also "supposes" the annual fall of Rain near London at 24 inches; if so, St. Helena far exceeds London in its fall of Rain, this being more than half as much again at St. Helena as it is at London.

The four following observations, being the quantities of Rain received at the respective stations for a period of nine months in 1841, are quoted as a confirmation of the theory that woods and mountains tend to precipitate Rain:—

1, At 2644	feet elevation	22·63 inches.
2, At 1991	„	27·11 „
3, At 1782	„	43·42 „
4, At 414	„	7·63 „

The whole four stations being comprehended within a circle of little more than a mile radius.

These statements I give as I have received them. So much depends on the locality and circumstances in which observations by the rain gauge are made that I am unable to say whether they tend to strengthen or to weaken the conclusion to which I have come.

The Island of Mauritius supplies analogous facts. In a history of that Island, embodied my informant believes in Thornton's History of India, the author observes that when we obtained possession of it our countrymen thought it absurd that the beautiful land on the summits and slopes of the mountains should be abandoned to forests and jungle, and so cut them down, upon which the water supply began to fail. Reflection soon taught the authorities the cause of this failure; upon which the hills were again planted with trees, and the rivers and streams resumed their former dimensions.

Mr Marsh writes:—"The Island of Mauritius lying in the Indian Ocean in about 20° N. L., is less than forty miles long by about thirty in breadth. Its surface is very irregular, and though it consists, to a considerable extent, of a plateau from 1200 to 1500 feet high, there are three mountain peaks ranging from 2300 to 2700 feet in height. Hence, though the general climatic influences are everywhere substantially the same, there is room for a great variety of exposures and of other purely local conditions. It is said that the difference of temperature between the highest and lowest stations does not exceed eight degrees F, while, according to observations at thirty five stations, the rainfall in 1872 varied from thirty-three inches at Gros Cailloux to one hundred and forty six inches at Cluny. *Nature*, September 24, 1874. This enormous difference in measurement is too great to be explained by possible errors of observation or other accidental circumstances, and we must suppose there are, in different parts of this small island, great differences in the actual precipitation, but still much of this variation must be due to causes whose range of influence is extremely limited."

Mr Meldrum, Director of the Mauritius Observatory, read a paper before the Scottish Meteorological Society in July, 1866. In this he stated that for some years before there had been severe droughts in the island, and recently there had been severe outbreaks of fever, which had carried off one-tenth of the population. A careful analysis of meteorological observations that had been made showed that from 1861 to 1866 there had been a great diminution in the rainfall. So far as could be discovered, the rainfall was less than during any similar period since the island was discovered. This could only be explained by the cutting down of large forests in the interior, no less than 70,000 acres having been denuded of trees during the ten years from 1852 to 1862. Mr Meldrum concluded by saying that the calamities which had so seriously affected the people of the Mauritius seemed to be self-inflicted; and that the proper remedy was to restore the forests of which the once salubrious and beautiful island had been deprived. And in a communication published in the Journal of the English Meteorological Society for that year there is given additional information on the subject. In this he states, "That the rainfall in that island during the five years 1862–66 was considerably less than during any previous five years of the whole period since 1853;"—"that during the first five years, from 1853-57, the relative humidity of the air was 72·1, whilst during the last five years, 1862-66, it was only 68·2;"—"that the vapour pressure, which in the earlier of these quinquennials was ·657, had fallen during the latter given quinquennial to ·638."

Notwithstanding these facts, he says:—"In no former year of the period of fourteen years did such floods occur as in 1861 and 1866, or such severe droughts as in 1865 and 1866." And to account for these facts, he says:—"That the decrease of rainfall, humidity, and vapour pressure, and the occurrence of floods and droughts, may in some measure be due to the cutting down of the forests, which commenced on an extensive scale about 1852, was vigorously carried on till 1862, and is being still prosecuted, though to a smaller extent."

One chief cause of the cutting down of the forests in the Mauritius, Mr Meldrum states thus:—"Proprietors of forests in high and remote parts of the island, where the climate was as yet too damp and rainy for the sugar-cane, engaged in the work because they believed that their land would thereby become more fit for such crops; for it was very well known that the climate became drier in proportion as the forests were cut down. Upon the whole, I think, at least 70,000 acres, or about one-sixth of the entire area of the island, have been denuded of forests since 1852, and that, too, on the central and elevated parts of the island, at or near the sources of the rivers."

He points out how, by the lowering of lakes, and the complete desiccation of others, malaria resulted, and a deadly epidemic. And the remedy which he suggests is, "to restore, as far as practicable, certain portions of the forests of which this once salubrious and beautiful island has been deprived."

In 1871, a report was issued by Dr H. Rogers, of Mauritius, "On the Effects of the Cutting down of Forests on the Climate and Health of Mauritius." This report I have not seen; but in a lecture on Forest Culture in its relation to industrial pursuits, delivered in Melbourne on the 22d June, of that year, by Baron von Müller, Government Botanist in Victoria, there was given the following resumé of its contents, with the remarks which follow: So late as 1864 the Island was resorted to by invalids from India, as the "pearl" of the Indian Ocean—it being then one mass of verdure. But when the forests were cleared, to gain space for sugar cultivation, the rainfall diminished; the rivers dwindled down to muddy streams; the water became stagnant in cracks, crevices, and natural hollows, while the equable temperature of the Island entirely changed; drought was experienced in the midst of the ocean, and thunder showers were rarely any longer witnessed. The lagoons, marshes, and swamps, along the sea-board were no longer filled with water, but gave off noxious gases; while the river waters became impure from various refuse. After a violent inundation in February 1865, followed by a period of drought, fever of a low type set in. Against this the remedies employed in ordinary febrile cases proved utterly valueless. From the waterless sides of the lagoons pestilential malaria arose. Exposed to this the labourers fell on the field, and in some instances died within a few hours. Scarcity of food among the destitute classes, and inadequate sewage arrangements, predisposed also to the dreadful effect at the time. It is alleged, and maintained, that marshes should either be drained out completely, or kept constantly submerged. And Dr Rogers insists that, for sanitary reasons alone, the plateaux and high lands of Mauritius must be replanted with trees.

To what extent this may have been done, and with what results, remain to be seen.

In Chambers' Journal it was mentioned in the beginning of 1875, apparently on the authority of the transactions of the Royal Society of the Mauritius, that with a view to check the increasing dryness of the climate 800,000 trees had been planted, and 150,000 seed holes prepared on barren mountain slopes and other waste places. And we have the following statement in regard to what appears to have been a prior application of the remedies proposed :—"The hills were again planted with trees, and the rivers and streams resumed their former dimensions." *

*A letter from Mr A. St. John, who had given attention to the subject, and had been asked by Mr Fox Wilson for testimony which he might adduce in his paper "On the Desiccation of the Basin of the Orange River," in support of views held by them both, has been put into my hands. In this it is said :—"It is Thornton, I believe, in his 'History of India,' who gives an account of the drying up of the springs in the Mauritius; and the Journal of the Indian Archipelago, published by Logan at Singapore, supplies information about the Island of Penang. . . . . . I am confident of the information retained in my memory, though I may not always be able to point out the source from which it was obtained; for example, I am perfectly sure that the writer, who as I have stated I think is Thornton, that gave the history of our conquest of the Mauritius, observes, that, when we obtained possession, our countrymen thought it absurd that the beautiful land on the summits and slopes of the

Reference is made to the Island of Ascension by Boussingault, in his work entitled *Economie Rurale considerée dans ses Rapports avee la Chimie la Physique et la Mineralogie,* in a passage which has been cited, in which he says :—" In the Island of Ascension there was an excellent spring situated at the foot of a mountain originally covered with wood. This spring became scanty, and at last dried up, after the trees which covered the mountains had been felled. The loss of this spring was ascribed, and rightly so, to the cutting down of the timber. The mountain was therefore replanted, and a few years afterwards the spring reappeared by degrees, and by and by flowed with its former abundance."

When I was at the Cape of Good Hope, the Hon. Mr Barrington, of Belvidere, on the Knysna, wrote to me in regard to Ascension, that on that island, the driest of the dry—spoken of sometimes as a heap of cinders, which only could be maintained as a naval station by sending to it water in tanks from England and from the Cape—trees and culinary vegetables had been planted, and had been grown with success, through instructions supplied by Sir Wm. Hooker from Kew; and that, since this had been done, not unfrequently had the island been seen capped with a cloud, and little runnels of water had been seen trickling down the sides of the rock. I have always understood

mountains should be abandoned to forests and jungle ; and so cut them down, upon which the water supply began to fail. Reflectiou soon taught the authorities the cause of this failure ; upon which the hills were again planted with trees, and the rivers and streams resumed their former dimensions."

In the same letter the writer says :—" I have deferred answering your letter in the hope of being able to consult some of the works which supplied a portion of the material for my article 'On the Failure of Springs ;' but I have not been able to do what I intended. What I say of the drying up of four hundred springs in Persia is on the authority of Tavernier ; but as the copy I possess of that traveller has no index, I cannot at once find the passage, though perfectly certain that it occurs in his account of the Northern Provinces. . . . . Formerly, in my 'Manners and Customs of Ancient Greece,' (II. 370), I pointed out the disforesting of the mountains as the cause of the drying up of streams and rivulets in several parts of the country, and of the diminishing of nearly all the rivers. Democritus, many centuries before Christ, had made the discovery that woods and forests are necessary to the maintenance of springs ; and in the last century, Volney contended that the Sahara might be rendered fertile by planting it with such firs as would grow in sand, which would attract and retain moisture. I make not the least doubt that in the Transgariep portions of Southern Africa, to which you refer, the diminution of moisture was occasioned exclusively by the cause you point out, and not by any cosmical changes, as imagined by Livingstone. Should the Government, as far as its authority extends, ordain that whenever trees are cut down others should be planted in their place, and generally encourage the multiplication of woods and forests, I make no doubt that that whole region would be abundantly supplied with moisture."

that the copious supply of water in Capetown was derived, not from rainfall and surface drainage, but from the percolation, through the four thousand feet thick filtering stone, of moisture absorbed from what is called the Table-cloth, often seen on Table Mountain when the south-east wind blows in the summer months; and there seemed to me nothing unreasonable in the information supplied by Mr Barrington. He derived his information from the late Commodore Burnet, who had been stationed at the Island, who stated that for a long time the garrison and the shipping had had a good supply of water; and he (Mr Barrington) stated that when he himself saw it, which was in 1861, the summit was enveloped in mist the whole day.

I subsequently obtained through Dr Hooker, who had succeeded his father as Director of the Royal Gardens at Kew, a copy of the report made in 1862 by Capt. Barnard when in charge of Ascension, with a lithographic plan of the Island, illustrative of what had been then accomplished, which had been published at his suggestion by the Lords of the Admiralty, that the public might know something of the altered "condition of that curious and now important island, due to the encouragement given by the Admiralty, through the instrumentality of Commodore Burnet, and more recently by the intelligence and zeal of Capt. Barnard and his indefatigable assistant, Mr Bell." And he goes on to say, in support of his suggestion :—" I doubt if there is any spot in the world where a comparatively barren rock,—destitute of all natural useful vegetation, exposed to the most terrific and injurious sea breezes,—has been, or could have been, brought into such a state of useful cultivation."

The plan shows a great many patches, measured as many of them by poles as by acres, but measuring in the aggregate twenty-nine acres, covered with furze and shrubbery, and upwards of twenty-seven acres of land under cultivation, bearing crops of potatoes, sweet potatoes, cabbage, carrots, pumpkins, turnips, endive, beans, leeks, grass, pine apples, bananas, guavas, figs, oranges, shaddocks, mulberries, and sugar-cane.

It appears that a number of seeds consisting of acorns, horse chesnuts, Spanish chesnuts, etc., which had been previously sent, had been spoilt, probably by being stowed away on ship-board in a damp hold; but simple measures were adopted to prevent the recurrence of this, and by terracing, excavating, and levelling every little patch capable of cultivation, the most was made of every advantage which could be commanded on the island.

The whole report by Captain Barnard is full of details illustrative of that indomitable energy and contrivance which we proudly allege to be characteristic of our nation.

This I shall immediately quote at some length; but what chiefly concerns us is that, apparently by vegetation, there was secured sufficient humidity to promote vegetation, and this in such abundance that a cloud capped the mountain supposed never to have been seen so capped before, and rills of water ran down rocks supposed never to have been bedewed with such tears within the memory of man. When every allowance has been made for suspected exaggeration of previous aridity, and of humidity attained, there remains still a fact to encourage the hope that by the extension of forests an increased humidity may be secured.

In 1864 there were published by the Government the following observations on Ascension, by Captain F. L. Barnard, R.N. :—

"Ascension is in latitude 7° 56′ S. and longitude 14° 24′ W. It is about 7½ miles in length and 6 miles in breadth, and is within the immediate influence of the S.E. trade wind. The island is entirely volcanic, the surface being broken into mountains, hills, and ravines. It was discovered by the Portugese in 1501, but remained uninhabited until after the arrival of Napoleon at St. Helena, when it was occupied as a post by Sir George Cockburn, and placed on the establishment of a sloop of war, under a lieutenant. In 1822 the naval garrison was relieved by a detachment of marines under Major John Campbell; since which it has gradually been increasing in importance, and I propose tracing its rise, progress, and present capabilities from valuable notes left by my predecessor Captain W. F. Burnett, C.B., and the records in office.

"But little information remains on record between 1815 and 1824, in which latter year Lieut.-Col. Nicolls arrived to take command. The number then victualled was 59. Mules and donkeys were the only draught animals, and sheep and bullocks were then first applied for.

"The supply of water was scanty and precarious, and even in 1829 it depended on drips in the banks, and the rain that was collected in casks and a few old tanks. Three carts, six oxen, and three drivers were employed daily in transporting about 360 gallons a distance of six miles, and even this quantity was liable to a considerable diminution after long droughts. When Dampier's vessel, the 'Roebuck,' foundered near Ascension in 1701, he discovered springs or drips by watching where the goats went to drink; and in 1824 attention was called to three of these, viz., Middleton's, the Mountain or Breakneck, and Dampier's. Iron water pipes were applied for to lay down between the Mountain and garrison, where there were tanks capable of containing 40 tons only.

"In July 1825 a boring machine arrived, and tanks and reservoirs were commenced on a large scale; but the latter, from subsequent accounts, seem to have been mere excavations, from which the water soaked away in a few days.

"Boring was first commenced in 1826 above Middleton's springs, by Colonel Nicolls, without any important results. In 1829, Captain Bate reported the possibility of supplying the African squadron with water, proposing certain measures, and Captain Brandreth, R.E., was instructed by the Admiralty to make a survey and report of the island. He found that the auger of the boring machine had been introduced nearly horizontally in the direction of the substratum, which would merely have the effect of causing the stream to flow more freely without arriving at the source of the spring. Captain Bate had also bored near high-water mark by the advice of a foreign naturalist, and from the wells then made the present supply of salt water is derived. Unsuccessful borings were made in the low lands, and others were recommended in the Mountain district. Captain Brandreth reported favourably on Captain Bate's propositions, and returned to Ascension in 1830. Finding that the stock of water was reduced to 40 tons in consequence of a drought during twelve or fourteen months, he pressed for further experiments in boring, and fixed on a spot high up in the Mountain district, on the weather side, at the bottom of a ravine, the sides of which were 80 feet in height. The strata consist of volcanic matter on beds of clay. The experiment succeeded, and at the depth of 25 feet from the surface a spring was found; the shaft was sunk 60 feet, and still yields (in 1864) from three to four tons daily, even after a long drought. A second shaft was subsequently sunk about 100 yards from the first, and produces an occasional supply only. In the latter end of 1830 the main water pipes were partly laid down.

"Palmer's springs were discovered 500 feet below the drips in Breakneck, and were said to produce 2,000 gallons in 24 hours Two large reservoirs were constructed by building up a deep gorge in terraces, which receive the water from an extensive rocky valley, but there is no spring in my opinion. Drinking troughs have been constructed here and at Middleton's; they supply the island-bred cattle, and wild animals with water, which at the latter is brackish, and does not agree with imported beasts. The marines used to take it medicinally in cases of dysentery. There is a neat cottage at Palmer's, in which a man and his wife reside, and take care of a garden producing chilies and pumpkins.

"In December 1831 the main pipes were finished, being led from Bate's tank at Dampier's, 5 miles distant from the garrison, and 1000 feet above its level, and the same depth below the Mountain tank.

"In January 1832 an octagon iron tank, capable of containing 20 tons, was placed under the drip in Breakneck Valley, and in the same year a tunnel was cut through the mountain about 930 feet long, for pipes to convey the water, which was pumped by horse power, and forced up 140 feet into an iron tank above the level of the reservoir on the other side of the mountain. The tunnel is sufficiently wide and high to admit of people walking through with ease, and is a wonderful proof of the perseverance and skill of the marines, who, under Captain Payne, executed it in the short period between 19th May and 3rd October of the same year. The principal and only certain supply of water is obtained through this.

"In February 1847 there was a great scarcity of water, and distilling was first commenced with Clark's apparatus, but as salt water was obtained from a well sunk in the square, affected by the ebb and flow of tide, the supply was limited and uncertain.

"I found the drips in 1861 much in the same state as they appear to have been in 1832, and shall describe the present water resources of the island, the steps that have been taken to improve them, and the plans I would suggest to ensure an adequate supply.

"The drips and wells in Breakneck Valley are the only sources that never entirely fail, although the yield is considerably less after a long drought; the drips are caused by the rain and wet fogs, arrested by the steep sides of the ravine, and percolating through the cinder to strata of rock, which crop out and form ledges. Under these, lengths of zinc and iron sheeting were placed, conducting the water in driblets to a small cemented trough over the octagon tank, which occasionally overflowed after heavy rains, and at all times the labour of forcing a column of 140 feet of water was very distressing to animals, and absorbed much labour.

"In the latter end of 1863, a wind engine of 1½ horse power, by Bury and Pollard, was erected near the octagon tank; the pipes were connected throughout their whole extent, as they were fonnd to be too much on a dead level to carry off the water forced up, and we had the satisfaction of finding that it worked admirably, and was capable of doing much more when required.

"Extensive troughs lined with Roman cement have replaced the odds and ends of old sheeting, preventing waste and increasing the yield of water.

"The wells which were sunk in the spots selected by Captain Brandreth are worked by hand pumps daily, and produce sufficient water for the consumption of the Mountain after many months of drought. I am, therefore, of opinion that the upper one is supplied by a bonâ fide spring, and without it much inconvenience would be frequently experienced.

"The roofing surface has of late been greatly increased, and iron tanks have been placed in convenient places for the supply of the cow-house and stables, by which both manual and horse labour are saved.

"Finding that a considerable rush of water from the mountain roads found its way into Dampier's tank in a very muddy state, large cisterns have been constructed, with underground drains between them, the last being connected with the main pipes just below the Mountain reservoir. A great mass of mud and cinder is deposited by these means, and the water eventually reaches its destination in a comparatively clean state. In connection with this arrangement all the upper roads, which were composed of soft light cinder, liable to be washed away, are being paved with durable stone.

"The drip at Dampier's is scarcely worth taking into account, as it dries up soon after the rain ceases, and produces nothing when most required.

"To prevent the waste necessarily caused by frequently running down small quantities of water from the main tank at Dampier's (Bate's), drinking troughs have been sunk on the spot and are supplied by means of a small fire engine.

"The cattle that are not being stall-fed are driven in every morning for food and water; and there have been no losses amongst the imported cattle since this system has been adopted.

"In 1861 Dr. Normanby's distilling apparatus arrived in H.M.S. 'Isis,' and in the beginning of 1863 pipes were laid down to it from the sea, affording an ample supply of salt water, which is pumped up a height of 25 feet by means of a simple and ingenious contrivance of Mr Smith, the superintending engineer. A small eccentric on the shaft of the donkey engine works a number of levers which pump the salt water into a tank, and the fresh water into a reservoir when the receiver is full. By attaching a strap to the fly-wheel a chaff cutter is also worked in an adjacent building. The produce of water is about one gallon per minute.

"Such are the water resources of the island, which have not more than kept pace with the increase of the population, from 59 in 1854; to an average of 550 in 1863; and after three years' experience and much painful anxiety, with the necessity of reducing the allowance to a gallon for each person during upwards of six months, I would urge the paramount necessity of ensuring an adequate supply."

The details of hydraulic works proposed by Captain Barnard I do not deem it necessary to quote. After giving them, he proceeds:— "I have found but little reliable information respecting the former cultivation of the island; but with the assistance of memoranda left by Captain Burnett, records, and my own experience, I shall describe its present state and capabilities of improvement.

"Like Captain Brandreth, I shall divide the island into four parts, with reference to its agricultural capabilities.

"The first, consisting of about 200 acres, on the highest lands round the Peak.

"The second, of about 800 acres, lying below the Peak, from 2,200 feet to 1,400 feet above the level of the sea.

"The third part, comprising tracts of cinder and ashes, with intervening watercourses about the lower lands.

"The fourth takes in extensive beds of lava and cinder, not likely to undergo any change, but which produce purslane and other food, on which herds of wild goats feed and keep in good condition.

"This part comprises the Peak of Green Mountain, with all it surrounding ravines and hollows, from a height of 2,820 feet to Elliot's Pass, about 2,200 feet above the level of the sea. At the summit is a small piece of table land, on which the Bermudian cedar, guava, hibiscus, and other shrubs flourish; it is frequently enveloped in mist, and with the exception of a running grass gathered by the Africans for the cows, it is covered with a long wiry sedge used for stable bedding only. Orange trees brought with great care from Rio and the Cape of Good Hope, have been tried on the N.E. side, where the soil is deep and good, but without success; they appeared to flourish for a season, but soon began to droop and wither away; consequently all that retained any signs of life were transplanted into a nursery, where they must remain until the weather is favourable for putting them into sheltered spots in the ravines where lime trees flourish. Numbers of trees and shrubs have been planted by the sides of the path leading to the Peak since Mr Bell's arrival in 1857. They look healthy and strong, and the more tender ones are protected by tree guards. A list of them is annexed. . . . . A tin trough placed under one of the wattles for the pheasants to drink from, has water in it during the driest seasons, affording a proof of how much moisture is attracted by planting. The above is enclosed on the sides accessible to cattle by a fence of cask staves.

"We now come to a second enclosure planted with a double row of pinus excelsa, which are growing well. Buddlea, vitex trifolia, gorse, broom, and brambles, border the path in one thick mass, with the beautiful crimson flower of the hibiscus peeping through the foliage. Between the base of the High Peak and the Little Peak is a bare ridge exposed to the strong trade wind, producing sedge and a few stunted shrubs. The Little Peak is enclosed by a bank and ditch, and is cultivated all over, producing light and uncertain crops of English or sweet potato. To leeward of and below it, shrubs grow luxuriantly, and an excavation has been converted into a nursery, but the soil is dry and porous, and tender plants do not survive even a short drought in it. Pine apples have been planted, and will probably succeed here. There is also a fine lime tree, whose roots have found their way into a fissure in the cinder; it consequently flourishes, whilst every attempt to grow others near it has failed.

"All the first division is planted sufficiently, and nothing is required but attention to the growing trees and shrubs, and keeping the fences in repair. It is surrounded by Elliot's Pass, a road cut out of the solid cinder, and passing horizontally quite round the Mountain, which at several points is tunnelled through. It affords great facilities for planting the sides of the mountain and ravines—is a convenient path for the shepherds, and a pleasant walk of about three miles, lined with blackberry bushes bearing plenty of fruit, and numbers of trees and shrubs.

"The ravines present the appearance of dense thickets, bramble, buddlea, vitex, etc., having completely clothed them. Thousands of small birds flock about the bushes, and are increasing wonderfully; they consist almost exclusively of avadavats introduced by Captain Burnett. This pass was commenced in 1839 by Lieutenant Wade, Royal Marines, and completed in January 1840. In 1861 about 600 yards of the path on the weather side were considerably widened by Captain Barnard.

"The second and most important division commences below Elliot's Pass, adjoining which are the farm buildings, consisting of a a cow-house, fodder store, and stock yards, with slaughtering triangle, and every convenience for stall-feeding oxen, penning sheep, and saving manure for the cultivated lands, a great part of which in 1861 had been constantly cropped with sweet potatoes and its fertilizing powers extracted. The farm buildings were so scattered and ill arranged that no great body of manure could be collected. All the slaughtering was carried on in the garrison, and the offal thrown into the sea. I made a complete change in the system; built a fodder store, demanded chaff cutters and oil-cake crushers, formed large yards, adjoining the cow-house by excavating, did away with detached sheds, and connected a sufficient number of iron tanks to ensure a constant supply of water on the spot.

"All crops are most uncertain excepting sweet potatoes, which, unfortunately, are not generally liked as a vegetable, and cannot be used in soup. Regular and large sowings of English potatoes are now made, and several good crops have been obtained; the arrangement for thoroughly manuring the ground once in two years evidently tending to restore fertility to the soil, for the sweet potatoes even come to perfection in less time than they did before. Great losses must be expected from the ravages of caterpillars and long droughts, but the system should be persevered in, if only for the purpose of introducing something like rotation of crops, not hitherto much studied. The best seed potatoes have been obtained from the Cape of Good Hope; they are red, and about the size of walnuts. Some from Loanda have also turned out very well. Supplies according to demand are sent by the contractors for cattle from Table Bay every two months. The seed saved on the spot is worthless. Pumpkins grow to a large size in the weather gardens, weighing upwards of 80 lbs.; they are propagated from cuttings. Great efforts have been made to grow cabbages in large numbers, but the caterpillars destroy nearly all the seedlings, and there are never sufficient for a general issue. French beans succeed better than any other vegetables whenever the droughts do not last long; about two out of three sowings fail. Now and then a fair crop of turnips may be got, but carrots are a long time in growing, and never attain even a moderate size. The New Zealand spinach grows wild amongst the other crops, and at times is gathered in large quantities. No other vegetables are grown in the sheep walk or weather gardens.

"Guano has been twice obtained from Boatswain Bird Island, and seemed to produce good crops of sweet potatoes, but stable and farm manure is better, and more easily obtained.

"In the Home gardens about the Mountain cottage, leeks are produced plentifully, as well as French beans, lettuce, endive, and herbs.

Pine apples have been propagated successfully of late years, and are well flavoured.

"All the ground available for planting is in detached patches, and I find, on searching the records, that detailed descriptions of that under cultivation, up to the end of 1859, have been forwarded to the Secretary of the Admiralty. Since I took charge in July 1861, I have turned my attention to the possibility of breaking up new ground and cultivating English potatoes, cabbages, and the vegetables usually issued with fresh meat. The difficulty of finding any sufficiently level and sheltered is great, and I have had recourse to excavating on the side of the mountain. One piece now in progress, on the same level with the home gardens, will have a back of 44 feet. I have also converted what was formerly a stock yard into a garden, and have a very promising crop of Jersey potatoes well up. As we can find labour, I purpose terracing a very promising piece of ground under the weather gardens, above a patch on which cabbages have been successfully raised. My predecessor enclosed a space on a rather steep slope, containing about an acre, which will be broken up, if the dry weather lasts; it will be fit only for the sweet potato, which is the staple produce of the island, and flourishes even in the driest seasons, but it is not prized by the men. . . . . . There is no limit to the broken ground available for the planting of shrubs, and during the dry season a party is constantly employed digging holes four feet wide, three deep; there are upwards of 1,000 now open for the reception of the Australian wattle, to be planted between Michaelmas and Lady-day. This shrub has been most successful at Ascension, and in a few years will change the aspect, and probably the climate, of the island, from its rapid growth and facility of propagation. I lately measured one that was planted last November twelvemonths, in the shape of a small layer, and it is now from six to seven feet high, covering a circle with a circumference of 36 feet; about 1,000 of these have been planted within the last three years.

"Mr Bell fortunately hit upon the simple plan of laying the small branches into preserved meat tins, butter firkins, and boxes, in which they can be carried to any distance; they already flourish much lower than any other tree or shrub, and had we not lost our last season from an unusual drought, many more would have been planted lower still; there are upwards of 1,000 now ready. I have entered into the above details to show that the wattle has greatly reduced our requirements, and I constantly receive, from private sources, loquats, guava, orange, lime, and wild fruit trees, from the Cape of

Good Hope and the coast. The date palm, coffee bush, and custard apple look healthy and strong in their seed beds, and thousands of young shrubs and trees, from the Peak down to the level of the home gardens, are making rapid growth, whilst the furze, bramble, and other shrubs fill the deep ravines and fissures with a luxuriant foliage, affording good cover for game. Pine apples have arrived to great perfection under Mr Bell's treatment, and we are making fresh plantations from time to time.

"Of all things we most require conifers, and find that various attempts have been made by my predecessor to obtain seeds. The following advice in a letter from Dr Lindley to the Comptroller of Victualling, dated Acton Green, August 20, 1860, if acted upon would be of great service to the island :—'Mr Bell finds by experience that of all trees the most useful to plant on the mountain slopes are conifers. In this I concur, and I would advise their Lordships to send out a supply of Chilian Araucarian and Norfolk Island pines, most especially the former, which form forests on the southern face of the Chilian Andes in precipitous places, where they bid defiance to storms. Any quantity of the seeds (Chilian Araucarian Pine) could be procured through the English Consul at Valparaiso, Mr Rouse, who, however, should be instructed to take care that the seeds are fresh. The Indians bring them to market, but sometimes so old that they will not grow.'

"I hope to be able to get Norfolk Island pine cones, and Australian trees and plants through my predecessor, Commodore Burnett; they all do well at Ascension.

"The Bermudean cedar grows most luxuriantly at the Peak, and a parcel of the seed would be most acceptable. Scarcely any trees or shrubs bear seed here.

"As Sir William Hooker takes a lively interest in the cultivation of the island, he may like to know what steps have been taken to carry out his valuable suggestions, as well as those of Dr Lindley and Dr J. D. Hooker, which I have found amongst the Records.

"Finding a great scarcity of manure, and no facilities for carting it up from the garrison, I shortly after my arrival commenced stall feeding, and slaughtering the oxen at the Mountain, and have now a most valuable heap of manure ready for our worn land.

"I next procured a quantity of guano from Boatswain Bird Island; this, from its great portability, will be a great boon to us if it succeeds, which I have every hope of its doing from the healthy green and luxuriant foliage of a large breadth of sweet potatoes manured with it.

"Mr Bell frequently accompanies me in searching for eligible spots for establishing fresh patches of vegetable ground, and by the aid of terracing, as we can command labour, I feel confident that an ample supply of cabbages, leeks, and at times potatoes, can be commanded.

"Mr Bell having represented to me that numbers of young shrubs and trees required protection when first planted out, I have caused a large number of guards to be constructed from firewood and the hoops that come off the trusses of hay; they answer most admirably.

"These plans, combined with the system of layering adopted by Mr Bell, and the breaking up of new ground, will, I feel convinced, do all that is possible for the cultivation of the Mountain, which is capable of spade labour only.

"The cones of the pitch pine from the Bahamas ordered by their Lordships to be forwarded to Ascension, upon Sir William Hooker's recommendation, will, in all probability, succeed, and I shall be glad to get them.

"Having described our requirements and plans for the cultivation of the mountain, I think an account of an experiment on a large scale, which we are making on the north-east plains, may be interesting to Sir William Hooker.

"In a document from Mr Bell to Captain Burnett, dated October 1859, I find these plains described as having been cleared and cultivated twenty years before, but in consequence of the loss of horses, and frequent failures of the crops, they were abandoned and considered barren and useless.

"However, on searching the records last year, a letter was discovered bearing date 31st August 1849, from the Secretary of the Admiralty, acquainting the captain in charge that Sir William Hooker intended to forward a case of most excellent grass for fodder, known by the name of 'Para;' accompanying this letter was a description of the grass and its habits.

"At Ascension it is doing wonders, increasing in the most astonishing manner, and growing down all weeds and inferior grasses wherever it is once established. Patches of it were tried on the No. 2 plains, and made not only rapid growth but resisted a drought of several months, though exposed to a tropical sun and the full force of the south-east Trade.

"Ploughs and harrows having been promptly supplied at my request, we took advantage of a spare team, and a colt that required breaking in, to plough and harrow these plains, and, much to our atisfaction, found them to be covered with a rich friable loam.

With protection, crops of every description might be grown here, but, in the absence of horse and manual labour, to collect the rocks and boulders which abound on the surrounding hills, and would form excellent dry walls and well-sheltered enclosures, we are planting from six to eight acres with Para grass in fine showery weather. If it succeeds, we could have fine pasture lands for cattle in a short time, and there is every facility at hand for constructing drinking troughs. I am also trying a small patch with English potatoes, fenced for the purpose. The method Mr Bell is adopting for planting this grass is by cutting turf into junks, which are carried to the spot in bread bags, on the heads of Africans, and trod in at equal distances; the runners grow by inches in one week after rain, and form a perfect mat which no animal can root up. Men are daily employed collecting Para grass for the beasts and cattle, both at the mountain and at the garrison, and it materially saves the expensive oat straw sent from the Cape. If Sir William Hooker could obtain a bag of the seed it would help us greatly. Should it at any time be thought advisable to bring a much larger breadth into cultivation for vegetables than can be obtained at the Mountain, I could fence in many acres on the weather slope of a valley formed by two ridges of these plains for the expense of about four additional rations for donkeys to draw the stones on sleighs, but with our present command of labour I could not attempt it. If the Para grass succeeds, there are other large plains, containing hundreds of acres, capable of being converted into pasture land.

"In conclusion, I think it due to Mr Bell to state that the whole of the farming and gardening operations under his care are carried on in a most systematic and skilful manner. He combines the experience of three years with considerable tact in managing the Africans.

"I dwell upon this more particularly, as there appears to be a growing interest in the cultivation and general improvement of the establishment at Ascension, and operations might be more readily and economically undertaken at present than with a new gardener, who would have everything to learn; and, on my part, I am quite willing to devote as much attention to this branch of my duties as I can possibly spare."

There was appended the following Table, showing the quantity of cultivated ground on the island of Ascension, in what way laid out, and present crop:—

Name of garden and Enclosure.	In what way laid out. Furze and Shrubbery. Acres.	Roods.	Poles.	Yards.	Cultivated. Acres.	Roods.	Poles.	Yards.	Present Crop in the Cultivated Land.
The High Peak	6	3	29	—	—	—	—	—	
Little Peak	—	3	38	15	—	3	8	—	English potatoes; seed obtained from Jersey.
Weather Gardens	1	3	9	20	7	—	10	—	Sweet and English potatoes, Cabbage, carrots, pumpkins, and turnips; three acres fallow.
Sheep Walk	—	—	—	—	12	2	21	—	Sweet potatoes, and two small grass paddocks, pine apples, bananas, &c., endive, French beans, and carrots.
Home Gardens	—	—	—	—	1	—	12	—	Leeks, herbs, seedling date palm and coffee, &c., &c. ; one acre fallow.
Outer boundary of the Home Garden	—	1	16	17	1	1	9	8	Turnips and English potatoes.
Hospital Garden	—	2	4	—	—	—	24	—	Cuttings of shrubs.
Sugar Cane Patches	—	—	—	—	—	—	29	12	Sugar cane.
Caldwell's Fruit Ravine	—	—	—	—	1	2	1	13	Guavas.
Jumper's Ravine	—	—	—	—	—	—	13	13	Bananas.
Broad Ravine	—	—	—	—	—	—	23	8	Bananas, oranges, and shaddocks.
Narrow Ravine	—	—	—	—	—	—	20	5	Bananas, shaddocks, and large pandanus.
Black Rock Ravine	—	—	—	—	1	2	16	10	Bananas (the principal banana ravine).
Tobacco Garden Ravine	—	—	—	—	—	-	3	—	Bananas and fig bushes.
Hospital Ravine	—	—	—	—	—	—	—	3	Bananas.
Weather Patches	—	—	—	—	—	—	4	19	Bananas and mulberries.
Mulberry Run	—	—	—	—	—	—	3	16	Bananas and sugar cane.
Cane Ravine	—	—	—	—	—	—	38	—	Bananas and sugar cane.
Palmer's Springs	2	3	3	12	—	—	34	8	Bananas and pumpkin.
Detached patches and Elliot's Pass	15	2	19	—	—	—	9	—	Bananas.
Totals	29	—	—	4	27	1	0	25	

June 16th 1862. (Signed) F. L. BARNARD, Captain in charge of Ascension.

In the observations published in 1864, it is stated, "Much might be done to improve and add to the area of the cultivated land. . . . I consider that the cultivation of the mountain has reached a new stage; the buddlea, vitex, and quick-growing underwood have done their work as pioneers, and made good soil where coffee and the various ornamental and useful trees and shrubs that are ready for transplanting should be put.

"Already a large piece of ground adjoining the cattle yards is being enclosed with a strong fence formed of branches of Ascension trees and underwood. It is planted with Para grass, and will be most valuable for sick cattle, as well as the sheep, at the half-yearly musters, when they invariably suffer greatly from running at their noses, after being kept a day or two on dry food. The yearly saving in fodder will be at least £50."

There is given the following table of observations :—

"Rain Fall and corresponding Produce of Vegetables on the Green Mountain, Ascension, for Six Successive Years.

	1858.		1859.		1860.		1861.		1862.		1863.	
	Rain fall.	Vegetables.	Rain fall.	Vegetables.	Rain fall.	Vegetables.	Rain fall.	Vegetables.	Rain fall.	Vegetables.	Rain fall.	Vegetables.
	in.	lbs.	in.	lbs.	in.	lbs.	in.	lbs.	in.	lbs.	in.	lbs.
Lady Day - -	No acct.	No acct.	6·17	10·009	3·93	20·417	7·35	23·249	2·19	12·329	4·03	8·528
Midsummer - -	3·51	21·098	5·94	7·384	3·62	18·761	5·04	22·288	7·66	12·254	6·12	21·416
Michaelmas - -	1·76	19·882	5·35	16·891	4·69	19·567	6·76	23·946	10·21	18·966	9·11	24·790
Christmas - -	4·91	18·422	7·17	19·839	11·65	22·039	4·05	20·637	5·88	28·880	5·85	20·823
Total - -	10·18	59·402	24·63	54·123	23·89	80·784	23·20	90·120	25·94	72·429	25·11	75·557

"This Table does not in any way represent the comparative quantity of water caught for consumption, as a heavy fall is required to cool the ground before it will run, and light rain is absorbed immediately."

There is appended also the following list of botanical names of trees and shrubs growing on the Peak:—Juniperus Bermudiana, Podocarpus sp., Brugmansia suaveolens, Brugmansia sanguinea, Ficus (four species), Casuarina (two species), Acacia, four species, including the Wattle, Ilex sp., Alpinia nutans, Pinus excelsa, Pinus pinea, Vitex trifolia, Bignonia (Stoniby sp.), Hibiscus (five varieties), Clerodendron fragrans, Coffea Arabica, Buddlea (Ascension gum bush), Eriobotrya Japonica (the loquat), Quercus robur (English oak), Cedrus Deodara (one plant), Cupressus torulosa, Widdringtonia juniperoides, Fourcroya gigantea, Hakea sp., Virgilia Capensis, Eucalyptus (four species), Nerium oleander, splendens, Phytolacca decandra, Myrica cordifolia, Leucodendron argenteum, Melaleuca hypericifolia, Rhus lævigata, Schottia latifolia, Pandanus odoratissimus. Fruits—The banana, peach, lime, orange, fig, loquat, and guavas, the latter being the only kind that produces fruit. Respecting the natural grasses on the Peak, it is said,—"What appears to be grass is in reality not grass at all, being only sedges, near relations to the English rush."

I consider that the preservation of the water under the wattle, to which reference is made, may be accounted for otherwise than by supposing that the moisture is *attracted* by vegetation; but the fact of the connection between plantations and moisture, resulting in an increase of the former being accompanied by an increase of the latter, remains the same whatever theory or hypothesis may be entertained in regard to the *modus operandi*.

In the Report of Kew Garden, for 1864, it is stated, "that from Ascension there continued to be received encouraging accounts of the increased fertility and moisture of the island, consequent on the extension of the plantations." And in the Report for 1865, it is stated,—"Of once sterile Ascension Island, which we continue to supply with plants, Captain Barnard reports that it now possesses thickets of upwards of forty kinds of trees, besides numerous shrubs and fruit trees, of which, however, only the guava ripens. These already afford timber for fencing cattle-yards. When Mr Hooker visited the island in 1843, owing to want of water, but one tree existed on it, and there were not enough vegetables produced to supply the Commandant's table; whereas now, through the introduction of vegetation, the water supply is excellent, and the garrison and ships visiting the island are supplied with abundance of vegetables of various kinds." Later reports I have not seen.

It is remarked by Marsh, that "it has long been a popularly settled belief that vegetation and the condensation and fall of atmospheric moisture are reciprocally necessary to each other, and even the poet sings of

Afric's barren sand,
Where nought can grow, because it raineth not,
And where no rain can fall to bless the land,
Because nought grows there." *

Here we have an illustration of the converse fact: one measure of humidity promoting vegetation, and vegetation not only arresting the desiccation but so reversing the process that an increased humidity is the consequence.

SECT IV.—*Cases, Illustrative of Effects of Forests on Humidity, correspondinng to such as have been adduced.*

Besides the cases which have been brought forward as indicative of the effects of forests upon the humidity of a country, there are others which point to the same conclusion, which may be adduced, not as corroborative testimony, but as independent facts, which are in accordance with what has been alleged. Continuing observations made on the Islands and Continent of Africa, I cite first the case of Madeira.

Madeira does not, like St. Helena and Ascension, supply evidence of a restored or newly produced humidity following the planting of trees; but it supplies testimony to the effects of trees on the humidity of the atmosphere and soil, which is of importance.

Washington Irving, in his "History of Columbus," refers to an ancient document which is believed to have been drawn up by one of the first discoverers of Madeira, about the year 1378. According to this document,—"The country was delightful. The forests were stately and magnificent. There were trees laden with excellent fruits. *The waters were cool and limpid.* On penetrating a little distance they found a beautiful sheltered meadow, the green bosom of which was bordered by laurels and refreshed by a *mountain stream, which ran sparkling over pebbles.*"

In accordance with this statement is the following glowing descrip-

* "——Det golde Strög i Afrika.
Der Intet voxe kan, da ei det regner,
Og; omvendt, ingen Regn kan falde, da
Der Intet voxer."
PALUDAN-MUELLER, *Adam Homo*, ii, 408.

tion of wood and waters, given in an unpublished ancient manuscript, cited by Dr Graham in a work entitled "Climate and Resources of Madeira," published in 1870:—"The island of Madeira at the period of its discovery presented a most lovely picture of nature: a vegetation truly astonishing covered it with trees, reaching to a prodigious height,—the majestic cedar, laurel, til, besides others, forming one continuous and impenetrable forest. Evergreens and creeping plants wove their festoons from branch to branch, giving new shade to a land all clothed with vegetation, and new force to *inumerable springs of pure and salubrious water.*" But tradition tells of a great forest fire having swept over a great extent of the island; and after that, it was alleged, all was changed.

Mr Milne Home, Chairman of the Council of the Scottish Meteorological Society, in a paper submitted to this Society, entitled "Suggestions for Increasing the Supply of Spring Water at Malta, and Improving the Climate of the Island," says,—'Some valuable facts are supplied from the island of Madeira. It has been shown that the annual fall of rain there is, on an average, thirty or thirty-two inches, being about thirteen inches more than at Malta. Can one reason be that, whilst Malta is treeless, Madeira is still partially wooded? Dr Graham says,—'The north side of Madeira is still well clothed; and, although there are perhaps few trees which can aspire to the dimensions handed down to us in the relics of former days, the dark and ancient foliage still covers both hill and valley.'

"Dr Graham refers to the dimensions of the trees of a bygone age in Madeira. There can be no doubt that when first colonized the island had been completely covered with wood. Its name, as given by the Portuguese, was originally *Materia,* in allusion to the inexhaustible materials it supplied for ship-building and the construction of houses."

Dr Graham quotes from an unpublished ancient manuscript the glowing description of its woods and waters, which has been given above; and referring to those statements of an old date, he goes on to say,—"It seems evident, from these descriptions, that Madeira when first colonized was much better supplied with both wood and water than at present; and the conclusion seems not unreasonable, that the better supply of water was in consequence of the larger extent of wood." Citing these passages, Mr Milne Home goes on to say,—"Dr Graham expresses a decided opinion to that effect. He condemns unsparingly the selfishness and folly of the first colonizers, who, in order to get land for the culture of the sugar-cane and vine, set fire to the woods, and produced a conflagration which lasted seven days."

Dr Graham says,—"The forests of Madeira have been continually receding with the increase of fuel requirement, and the replanting of the land thus laid waste has been long and culpably neglected. Recently, however, the introduction of the pine tree has to a very great extent stemmed the progress of reckless destruction. The pine grows easily and rapidly, occupying lands ill-suited to other kinds of cultivation." And in another connection he says,—"The recession of nature's woods has been *in late years compensated* by the advance of the introduced species."

He reports his observations on the arrest of the water of fogs and clouds by the leaves of the coniferæ, and other trees, which act almost like a sieve, draining it out; and he remarks, "when the hills were completely wooded, at the time of the colonization, it is quite probable that the humid mists, continually passing over the mountains, were intercepted, and that the rivers which now, soon after rain, dwindle down to tiny streams were then more constantly full." And he further remarks:—"On the eastern side of the basin of Funchal, the upper lands have been almost entirely cleared of trees. The rain water descends impetuously in a torrent, leaving a tiny stream, which flows steadily so long as the sky is overcast, but ceases altogether after one day of sunshine. I do not think the rains are now heavier or more fitful than in former times; but there are now no woods on the south side to restrain the drops, which unite to denude the rocks of their soil, and to form the mighty torrents witnessed every winter. I do not doubt that the planting of trees in the villages at the head of the main ravines would lead rapidly to a nearly constant supply of water in a region where it would be useful.'

The facts reported and the conclusions drawn from them are all in accordance with what has been reported in regard to St Helena and Ascension.

By Blanqui, in his *Voyage en Bulgarie*, already cited, it is alleged that "the terrible droughts which desolate the Cape Verd Islands must be attributed to the destruction of the forests." And he says that, "in Egypt, recent plantations have caused rains which hitherto were almost unknown."

I have repeatedly met with a reference in different forms to observations which have been made, or are alleged to have been made, in Alexandria and Egypt, in accordance with those which have been brought forward in this and in the preceding section of this chapter; but I consider them open to question.

A writer in the "Edinburgh Review" whom I have already cited, after making some remarks on the desiccation of Palestine, as a consequence of the destruction of the olives, palms, and other trees, during the Roman war, goes on to say:—"Even as to that country, of which it was said, two thousand four hundred years ago, that the family of Egypt have no rain, the United States Commission of Agriculture, for 1871, reports:—'In Upper Egypt, the rains which eighty years ago were abundant, have ceased since the Arabs cut down the trees along the valley of the Nile towards Lybia and Arabia. A contrary effect has been produced in Lower Egypt, from the planting of the Pacha. In Alexandria and Cairo, where rain was formerly a rarity, it has since that time become more frequent." But this statement appears to be open to question.

It is stated by Cézanne that Clot Bey has, in his work entitled *Aperçu géneral sur l'Egypte* (vol. i. p. 22), shown that the plantations in Egypt have not rendered rains more frequent. And he states that at Cairo, the mean number of days on which it rains in the course of the year is twelve, and the rain-fall 34 millimétres.

On this subject Mr Marsh remarks:—"The alleged augmentation of rain-fall in Lower Egypt, in consequence of large plantations by Mehemet Ali, is very frequently appealed to as a proof of this influence of the forests, and this case has become a regular commonplace in all discussions of the question. It is, however, open to the same objection as the alleged instances of the diminution of precipitation in consequence of the felling of the forest.

"This supposed increase in the frequency and quantity of rain in Lower Egypt is, I think, an error, or at least not an established fact I have heard it disputed on the spot by intelligent Franks, whose residence in that country began before the plantations of Mehemet Ali and Ibrahim Pacha, and I have been assured by them that meteorological observations, made at Alexandria about the beginning of this century, show an annual fall of rain as great as is usual at this day. The mere fact that it did not rain during the French occupation is not conclusive. Having experienced a gentle shower of nearly twenty-four hours' duration in Upper Egypt, I inquired of the local governor in relation to the frequency of this phenomenon, and was told by him that not a drop of rain had fallen at that point for more than two years previous.

"The belief in the increase of rain in Egypt rests almost entirely on the observations of Marshal Marmont, and the evidence collected by him in 1836. His conclusions have been disputed, if not confuted, by Jomard and others, and are probably erroneous. See FOISSAC, *Météorologie*, German translation, pp. 634–639."

The Imperial Academy of Science has expressed a wish that the Government of Austria would apply to the Viceroy of Egypt for extracts from the observations which have been made on the rise of the Nile gauge above Cairo for 3000 years and more, especially for extracts from the records of the last 200 years. Should these be supplied, we may hope that some light may be incidentally cast upon some of the questions at issue.

South Africa has also its tale to tell. Mr Tuck, superintendent of the Botanic Garden at Grahamstown, in writing to me before I left the colony, communicated the following notice of what he had observed in the course of the summer, that of 1864–1865 :—"This season has been unusually hot and dry along the coast ; and all arouud Grahamstown we have been unable to grow anything all this summer for want of rain. The springs are all failing.

"You may perhaps know the place of Mr J. J. Stone, on the top of the hill on the Cowie road, towards the sea, marked out by a quantity of Gum trees, on the ridge of the high hills to the south-east of Grahamstown ; well, all through the summer we have had only light misty rain, just enough to damp the grass, and not enough to wet the ground, but these trees of Mr Stone's have there converted the mist into rain. They have scarcely felt any effects of the dry weather ; the vegetables and flowers have there grown all the summer without watering ; there the tanks have always been full : and that is the only place of which I have heard that it has been so within five and twenty or thirty miles of Grahamstown."

I have had occasion to cite the statements made by Boussingault (ante p. 113) in regard to changes in the Lake of Tavarigua, in the vicinity of New Valencia, in South America, otherwise they also might have found a place here, as they show that a destruction of forests had been followed by a lowering of the waters of the lake, and the reproduction of the forests, consequent on the abandonment of cultivation, had been followed by a replenishing of the lake.

By Dr Hough, who has given much attention to the subject in America, it is stated, that "some twenty-five years ago the Danish sland of Santa Cruz was a garden of freshness, beauty, and fertility.

Woods covered the hills, trees were everywhere abundant, and the rains profuse and frequent. A recent visitor who sought the Island, with which he had been familiar in the time of its greatest beauty, for the sake of botanical study, a year or two since, found a third part of it reduced to a desert. The short copious showers had ceased, and the process of desiccation was gradually extending over the island. An attempt to restore the former fertility, by means of planting, was made too late. One planter had set a thousand trees, but every one of them failed."

"The island of Curacoa," again says he, "was, within the memory of living persons, a garden of fertility. But now whole plantations, with their once beautiful villas and terraced gardens, are nothing but an arid waste; and yet, sixty miles away, along the Spanish Main, the rankest vegetation covers the hills, and the burdened clouds shower down abundant blessings."

A writer in the Edinburgh Review, whom I have already had occasion to quote, citing as his authority, I presume, Dr Robert Brown, says, "'By the destruction in France of a great extent of forest,' writes Dr Brown, 'in order to replace them by cultivated fields, the temperature has become very irregular; heavy rains, storms, and dryness, have each done their work upon the soil, and made crops every year more and more uncertain.' In the Vosges, the destruction of forests has gone so far that agriculture has suffered, the soil has become arid, and inundations are frequent. In the Department of the Gard, in 1837, no rain fell for nine months.

"Nismes, named from the forests which once surrounded it, is now amid an arid waste. At Beziers, the Agricultural Society reported in 1797 that the forest which once sheltered the place having been destroyed, the loss of the olive crop was the consequence. The authorities of the Izère reported, in 1793, that the destruction of the forests had altered the temperature, augmented dryness, and seriously affected the crops. From Provence, from the valley of the Moselle, from that of the Haute Garonne, from the Hérault, and from the Eastern Pyrenees, come complaints of the same nature. The regular rain-fall has been diminished, the temperature has changed and become uncertain, and partial and irregular storms have proved curses rather than blessings wherever the forests have been ruthlessly swept away."

These statements also are all of them in accordance with what has been reported with greater detail in regard to St. Helena and Ascension.

CHAPTER V.

Local Effects of Forests on the Rainfall.

In preceding chapters the principal subject has been the effect of forests on humidity, and any mention made of rain has been only incidental. In this chapter that prominence is given to this; and it is the local effects in contradistinction to the effects of forests, or of the destruction of these over a wide expanse of country, which is brought under consideration.

In these preceding chapters oftener than once mention has been made of the rainfall as supplying indications of humidity, or of comparative aridity; and looking at these we have found that though the desiccation of some countries has followed the destruction of forests, in others no appreciable effect has been produced on the quantity of rainfall over a wide expanse of country. But we have found marked effects on the humidity of both soil and climate produced over a more limited range, both by the destruction of forests and by the planting of trees where they were not before, or where they had been destroyed. And by further limiting and localising our observations we may be able, with advantage, to follow up the observations which have been made, and ascertain more satisfactorily the meteorological effects of forests in relation to moisture. As a preliminary to the consideration of the effect of forests on the rainfall, it may be well to consider how rain and rivers are produced.

It may be hundreds are prepared, if asked, Whence comes the rain? and, Whence come the rivers? to tell that the rain comes from the clouds, and the rivers, from springs among the hills. But we require to go a little further in our consideration of the matter before we can determine the effects of forests and of the destruction of forests on the rainfall and on rivers. Whence come the clouds? Oh, from the sea. And how do they spring from the sea?—And how are they formed?—And how can the formation of them be affected by forests, or by land denuded of forests, as in some cases both the rainfall and the rivers appear to be?—And why is it so in these cases and not in others?

These and a hundred other questions suggest themselves on our entering on this new phase of enquiry. And in view of these, it seems expedient to begin at the beginning; and by anticipating, prevent the questionings which might have no end if a different course were followed.

SECT. I.—*On the Production of Rain.*

In consequence of the comparative heat in the tropics the air there expands, and colder air of greater density flowing in over the surface of the earth or sea, the expanded air is borne upwards from below, till, cooled at a higher elevation, it begins to descend, to the north and to the south of the equatorial region; but, excepting in exceptional circumstances, it reaches not the earth again until it has been cooled down to the temperature of the air at that lower level. This process going on continuously, there are produced two sets of currents in the atmosphere: one from the Northern Artic regions, sweeping along, over earth and sea, towards the equator, occasioning the north-east Trade Winds, and the north winds and east winds so dreaded by the sufferers from rheumatism in the northern hemisphere; and another from the Southern Antartic regions, sweeping along in like manner, on or near the surface of the globe, towards the equator, occasioning the south-east Trade's and the famous South-easter of the Cape of Good Hope. But though these two sets of currents intermingle, it may be, at the equator, they can scarcely be said to combine; for, ascending there in a conjoined mass, each portion curves over almost in its entirety towards the region whence it comes, but with a tendency from west to east, instead of that from east to west with which it came. This is accounted for thus: the earth rotates from west to east, carrying with it not only the water of the sea but the air of the atmosphere; being a sphere, or spheroid, each spot in the polar regions is carried through a more limited space in the twenty-four hours than is any spot nearer to the equator; its motion per hour, minute, or second, is less rapid than is that of any spot over which the air may pass in its course to the equator; and at this spot, the wind, moving onward, without diminishing its velocity, may be dragged forward a little; but at last it will be left behind; and thus an apparent current from some easterly point to some westerly point is given to the current flowing from the pole towards the equator. And the returning currents from the equator, carrying with them the velocity from east to west, there acquired when they impinge upon the surface of the globe, having a greater velocity in that direction than that of the spot on which they strike, they seem to come from some westerly point nearer to the equator.

Water in contact with air appears to be absorbed by it in a state of vapour up to a point of saturation, varying with temperature, beyond which it cannot either absorb or retain more. As the air advances from the polar regions towards the equator, its temperature and consequent capacity of absorption are raised, and ere it reaches the equatorial region it may have absorbed a quantity it could retain where it is, but could not retain either at a greater height or in the polar region whence it had come. Accordingly we find that in the equatorial regions, when it is raised to a great elevation, and is thus cooled, the air can no longer retain it all dissolved, and the surplus is deposited in clouds. The moisture thus deposited, attracted by gravitation, passing through lower strata of a higher temperature, not saturated, may be again absorbed; and thus may be explained the phenomenon of a continuously clouded sky unaccompanied by rain, which is seen so frequently at sea, within the tropics, as almost to be the characteristic of the sky in these regions.

The current returning to the polar regions from the equator, in passing over mountains on the summits of which a polar temperature prevails, being thus cooled down, and unable to retain more than a little of the moisture with which they are charged, the surplus is there deposited in the form of rain, or snow, or sleet, or hail.

To this also is attributable the humidity of the climate of England. It may be traced to the prevalence of southerly and westerly winds, which come to us laden, not only with moisture which they may have absorbed in passing over the Atlantic in their passage thither, but with moisture previously absorbed in their passage from the polar towards the equatorial regions.

In England, the southerly and westerly winds are to northerly and easterly winds in the proportion of 196·4 to 135.

There are waves of wind which come sweeping over the Atlantic from the north-west, but these are comparatively rare. Those which come blowing from the south and the west, and more especially those which come blowing from the south-west, have come at a higher level, with an under current, between them and the ocean, flowing in an opposite direction; and these are the most prevalent winds in England. The following are given by Steinmitz, in his little popular work, entitled "Sunshines and Showers," as the mean of several years as the number of days on which the following winds were observed:—

North,.........days,	40·7.	South,.........days,	34·2.
North-east,... ,,	47·6.	South-west,... ,,	104·0.
East,.......... ,,	22·6.	West,.......... ,,	38·0.
South-east,... ,,	19·9.	North-west,... ,,	24.1.

The east wind, cooling down the atmosphere, may occasion rain ; but all our deluges come from the south and west.

The air, when it reaches the polar regions, being greatly cooled down, deposits its moisture in the form of snow; and of this are formed the fields of ice which are characteristic of the Arctic and Antartic regions alike.

By Dr Scoresby, it is reported that in the Arctic regions it snows *nine* days out of ten in the months of April, May and June. With southerly winds near the borders of the ice, where moist air, blowing from the sea, meets with the cold breeze from the ice, the heaviest falls of snow occur. In this case a depth of two or three inches falls in an hour.

In crossing and recrossing the Atlantic, in certain latitudes, frequently are fogs encountered : the cause and occasion is the same. Fragments of Arctic glaciers broken off and floated away by oceanic currents, as icebergs, cool down the ocean and the atmosphere nearer to the tropics, and that to such an extent as to occasion a deposition of moisture wherever they go, and it may be for a hundred miles around them.

As some indication of the immensity of the quantity of moisture brought back to high latitudes by the return currents in the upper regions of the atmosphere, I would remind my reader of the immense body of water composing Lake Superior, Lake Michgan, Lake Erie, and Lake Ontario, in America, pouring over the Falls of Niagara unceasingly, and flowing through the Thousand Isles into the St. Lawrence ; and of the waters poured into the ocean by all the rivers of the world, great and small alike : these are but the drainage of the water precipitated by the way on the valleys through which they flow ; I would remind him of glaciers of the Alps, the product of the comparatively trifling portion arrested by the higher part of that mountain range as it was being borne onwards to the north ; and I would remind him of the immensity of the deposits near to the pole, not frozen sea, but frozen rain.

In a volume lately published, entitled "Under the Northern Lights," by Mr MacGraham,—a correspondent of the "New York

Herald," sent by the spirited proprietor of that paper on a voyage of discovery, made by the *Pandora*, last year to the Arctic regions, the expense being shared with him by the late Lady Franklin, and by Captain Allen Young, who went in command of the vessel,—there is given the following account of Greenland. Speaking of the interior of the continent of Greenland as an icy solitude,— a secret unknown to man, and likely ever to remain such,—he goes on to say:—"Its surface is 4,000 feet above the sea, and when you ascend to it you will probably perceive somewhere on the plain which rises before you in a slight ascent till it touches the sky two or three little sharp conical hills, a few feet high, that pierce through the ice, and you will be astonished to learn that these insignificant mole-hills are in reality the tops of lofty mountains, that have been submerged beneath the mighty inundation of ice. Somebody has said of Switzerland that if it were ironed out it would be a very large country. If Switzerland were about ten thousand times larger than it is, and ice were then poured into it until it should be full up nearly to a level with the highest mountain peaks, it would present just the appearance of the interior of Greenland. And yet the whole of this vast continent was at one period of the earth's history green and fertile. There have been found here forests of carbonised trees and plants, and the fossil remains of many animals that could only have existed in a warm climate. Fossil corals and sponges are often picked up now in Lancaster Sound and on the shore of Beechy Island. It is certain that the climate was soft and mild, and that the country was covered with trees and verdure, and it is equally certain that this terrible inundation of ice came and buried every vestige of it, as Herculanæum and Pompeii were buried beneath the ashes of Vesuvius. But, instead of the two poor little villages, and perhaps a few square miles of the adjacent country, that Vesuvius covered with its fine ashes as with a soft warm blanket, here is a continent larger than the whole of Europe, buried beneath a massive sea of ice. It is as though the waters of the flood had suddenly frozen to the very bottom, and had never thawed."

Such are "the treasures of the snow," and "the treasures of the hail," to be found in the Arctic and Antartic regions of the earth, borne thither from the equator and the tropics, ever in a state of flux, but ever renewed by fresh accessions. Of the evaporation by which this is maintained, the quantity of moisture taken up by the air in its passage over earth and sea to the equator from the poles, I cannot hope to convey either an adequate or a definite idea. It is proportionate to the area, the temperature, the time, the tension, and much besides.

Even from the land the evaporation is great. Maury, in his treatise on the "Physical Geography of the Sea," (p. 274), estimates the annual amount of precipitation in the valley of the Mississippi at 620 cubic miles of water, and the discharge of that river into the sea at 107 cubic miles; and he concludes that "this would leave 513 cubic miles of water to be evaporated from the river basin annually." This is but one basin—a furrow on the dry land; and then there is the sea!

The evaporation from the Mediterranean, the Black Sea, and the Sea of Azov, is reckoned at 50 inches on the whole extent of their surface; this is about 1,500,000 square miles, and a simple calculation shows that from these seas alone must be evaporated upwards of 500 (508) cubic miles of fresh water.

A corresponding estimate and calculation shows that the annual evaporation from the Red Sea must amount to 165 cubic miles of water.

Such are the quantities with which we have to deal in speaking of evaporation from inland seas alone.

Of the whole surface of the earth, three-fourths are covered by sea; that surface measures in round numbers 196 millions of square miles, of which nearly 150 millions are covered by water. What startles me is the consideration of the quantity of water which this implies, and the question arises, What can have been its source? But it is the evaporation from it with which alone we have at present to do. We should probably err were we to reckon the evaporation, over the whole area of the ocean, at the ratio of the evaporation which takes place from the surface of the Red Sea and the Mediterranean. But it is going on everywhere—in an increasing ratio, probably, towards the equator, in a decreasing, towards the poles; and apparently it is not confined there to what is called the open sea. I have already had occasion to refer to the statement by M. Hayes, in a work entitled *La mer liber du Pole*, published in 1868, that thin wet linen exposed to the air dries at the lowest temperature, and that a sheet of ice suspended by a cord evaporates by degrees. He adds, "that evaporation is more restricted near the coast than in the interior districts of a country, and more restricted under an equatorial wind from the south-west, than under a polar wind from the north-east, the former being saturated with moisture, while the latter has been deprived of its humidity."

Of the moisture thus absorbed by the air from the wide ocean and the inland sea, and borne onwards to the tropics, no trace is seen in the atmosphere till the air is cooled below the temperature at which it can keep it so sustained. This happens when it is first raised aloft, and when, on its return towards the poles, it impinges on some mountain range or solitary peak.

But while the course detailed may be considered the normal course of the air in its current to and from the equator, it is liable to many disturbances.

It is not usual for two currents of water flowing in different, and to some extent contrary directions, to glide past each other, each pursuing its own way; there is friction, and as a result of this friction there are eddies and whirlpools. It is so when they flow side by side; it is so when they flow the one over the other; and it is so with these aerial currents: the upper current coming completely through the lower, and producing those westerly winds, of which, otherwise, we should have none in medium latitudes; and it is reasonable to conclude by inference that there may be eddies of the lower current passing into the upper. Every one of these disturbances must affect the temperature, and consequent capacity of a great mass of air to retain the moisture with which it is charged, and that in different ways: for instance, the eddy of the warm upper current may be so cooled down that it must deposit a great quantity of the moisture which it held, or the eddy of the lower current cooling down a portion of the upper current penetrated by it may render it incapable of retaining all the moisture with which it was charged; and in each of these cases rain or snow, or hail, according to circumstances, may be the consequence. The eddy moreover may take a wide sweep, developing into a whirlwind or cyclone, with a radius of a hundred miles or more, and advancing onwards thousands of miles, carrying disturbance of temperature, and of hydrometric conditions wherever it goes. Similar whirlwinds I have seen produced upon a smaller scale, with all the indications of capability of being in like manner developed on a scale as gigantic, simply by the sun beating on arid ground, or on ground from which water has evaporated.

In the centre of such a whirlwind the air of the district over which it passes may be raised to such a height as to be cooled so low that much of its moisture is precipitated, and falls in two parallel lines of rain, or hail, marking the lateral limits of its course; and over the whole area of the ground traversed by it, embracing hundreds of thousands of square miles, and over all the area of the ground traversed by eddies thrown off by it, rain may be a consequence of disturbances of the hygrometric equilibrium beyond what was compatible with the retention of the moisture by the air. A current of cold air so brought into a body of warm air may cool this to a temperature at which it is saturated with a much less quantity than it contains, and the excess will be precipitated as rain; or a current of warm air brought into a body of cold air may be so cooled down that *its* surplus moisture is deposited in the form of rain.

Thus are clouds produced; and a change of wind occasioning a slight rise of temperature may cause the cloud to melt away into transparent air, by the re-absorption of the vapour of which the cloud was formed. The phenomena I have seen at the Cape of Good Hope a hundred times. They are there of constant occurrence.

A correspondent from Sea Point writes :—" On Thursday evening, during the hard south-east gale, some very remarkable and beautiful cloud effects were witnessed. Dark masses of cloud came driving across the Lion's Back at a furious rate, obscuring the brilliant moonlight. But in a few seconds after passing the zenith, their speed became checked, and, at the same time, they began rapidly to dissolve. Some of the cloud masses hung for a few seconds apparently motionless between the opposing currents of wind. Others again yielded to the counter current, and rushed back furiously from the north, meeting the driving masses from the south, and, almost in the moment of apparent meeting, dissolving utterly away. It was like the unavailable charge of a gallant body of light cavalry against a masked battery of artillery,—swept away before the cruel storm. The sudden alternations of clear blue sky, with black thunderous-looking masses of light fleecy clouds, and the changing iridescent hues of the vapours as they drifted across the moon, were very striking, and produced a scenic effect which those who witnessed it will not soon forget."

By the clouds may be traced the aerial currents. Writing on this subject, in connection with the distribution of rain, it is remarked by Cézanne that, " From the elevated summit of a mountain above which shines the sun in a cloudless sky, one may see under his feet a tide of clouds rising up the slopes on one side of the range. It impels its mobile billows into all the anfractuosities of the gorges, lashes and surmounts the buttresses which stop it, in every respect as does the ocean covered with foam the black head of the reef of rock. By all the rocks, by all the depressions of the chasm, the cloudy wave presses on, and pours itself over on the slope on the opposite side: the highest summits alone emerge above the inundation; but down the stream the clouds seem to be falling into an unfathomable void; they are seen to be disappearing, and the slope on this side, lit up with sunshine, offers a smiling contrast to the other, which, immersed in the storm, is shrouded in a thick veil. The rain in such circumstances is invisible to the observer, but he makes its acquaintance a little later, when in his descent he passes through the clouds, or, if the storm have then passed away, when he finds all the streamlets on his road overflowing their banks."

When one is enabled thus to look down upon the clouds he may see the atmospheric current in obedience to the laws of hydraulics. It has its rapids, and its eddies, it strikes with fury against jutting obstacles, and when it is contained between regular sloping hills it abandons the convex mound, and presses itself out against the concave bank. Thus is the aerial current made manifest.

Thus far we have had to do with the production of clouds; the transition to the consideration of the production of rain is easy. This is thus detailed by Sir John Herschel*: "When the sun shines on a cloud which absorbs its heat, the cloud itself is necessarily evaporated, and the vapour by its levity tends to produce an upward current, and thus to counteract the effects of gravity on the globules of which it consists. A globule of water $\frac{1}{1600}$ths of an inch in diameter, in air of 5-6ths the density on the surface, or at the height of about 5000 feet, would have its gravity counteracted by resistance, with a velocity of descent of one foot per second (supposing no friction and no drag); and even if the terminal velocity were reduced to half that quantity by these causes, would still require some upward action to enable it to maintain its level,—a circumstance which sufficiently accounts for the lower level generally observed of cloud during the night. It is more probable, however, that when not actually raining, a cloud is always in process of generation from below and dissolution from above, and that the moment this process ceases, rain in the form of 'mizzle' commences. In a word, a cloud would seem to be merely the visible form of an aerial space in which certain processes are at the moment in equilibrio, and all the particles in a state of upward movement.

In whatever part of a cloud the original ascensional movement of the vapour ceases, the elementary globules of which it consists,

* "Meteorology:" a volume reprinted from the *Encyclopædia Britannica*.

being abandoned to the action of gravity, begin to fall. By the theory of the resistance of fluids, the velocity of descent in air of a given density is as the square root of the diameter of the globule. The larger globules therefore fall fastest, and if (as must happen) they overtake the slower ones, they incorporate, and the diameter being thereby increased, the descent grows more rapid and the encounters more frequent, till at length the globule emerges from the lower surface of the cloud, at the vapour plane, as a drop of rain; the size of the drop depending on the thickness of the cloud-stratum and its density."

From what has been advanced it appears that rain is simply the precipitation from the air of moisture which happened to be held by it in excess of the quantity which it could, at its reduced temperature, hold in solution. It differs from the cloud or fog only in being formed of drops produced by the mutual attraction of smaller drops which are rapidly drawn by gravitation to the ground, instead of floating long suspended, as the constituent lesser drops had been, in the air. And this it may be well to bear in mind in proceeding to the consideration of the local effects of forests on the rainfall.

SECTION II.—*The Effects of Forests on the Quantity of the Local Rainfall.*

I have had occasion in a previous chapter to refer to the existence of an opinion held by many, and widely-diffused, that forests and mountains attract rain. I have otherwise explained the phenomena which have been attributed to some attraction exercised by them upon clouds, alleging and maintaining that the clouds seen in such situations must have been produced there; and I am disposed to allege and maintain something similar in regard to rain.

The effects of trees on the humidity of the earth and atmosphere has received the attention of several men of science and observation in Britain, some of whom—Sir John Herschel and others—have spoken out very decidedly on the subject. But in Britain it has been less of a practical question, demanding attention as a means of avoiding threatening calamities, than it has been in other lands; and while many of those who have given their attention more especially to this subject speak decidedly, they speak with the caution which science demands. Boussingault says: "My opinion is that the felling of trees over a *large* extent of country has always the effect of lessening the mean annual quantity of rain." The deliverance of Becquerel is in accordance with this. He says: "Great clearings diminish the quantity of spring water in a country." But he says, "It has not been ascertained whether this effect should be ascribed to a less quantity of rain which falls annually, or to a greater evaporation from the soil of rain water, or to a new distribution of showers of rain."

The opinions thus expressed are based on observations of facts. But along with these facts there are other facts which have already been referred to, and which require to be taken into consideration, if we would learn the whole truth on the whole of the subject. It has been stated that in the annual report of the Director of the Meteorological Observatory in the Central Park of New York, for 1871, Mr Draper addresses himself to the question—Does the clearing of land increase or diminsh the fall of rain? and in a preceding chapter I have given his answer.

He gives summaries of observations made in each year, and in each quarter of the years 1869, '70, '71; he states that the indications given by the instruments of the observations under his direction may be thoroughly relied on, and he concludes, "so far as these years are concerned there does not appear any evidence of a decrease, on the contrary, in the last, there is a very considerable excess on either of the others."

Citing, then, observations made in England since 1677, and in unbroken continuance since 1725, in Scotland since 1731, in Ireland since 1791, he shows that where a lengthened period and an extensive area are embraced by the observation, there is a perfect compensation, the decrease at one place being compensated by the increase at another, and that even in the same locality this principle of compensation might be seen.

When these facts are taken into consideration along with the other facts which have been cited, the two classes of facts may at first appear to the inconsiderate to be inconsistent and incompatible with each other; but if all be facts they must be compatible and consistent, and a little consideration may suffice to show that they are so.

Harland Coultas, in a work entitled "What may be learned from a Tree," published in New York in 1860, in a passage cited by Marsh says, "The ocean, winds, and woods, may be regarded as the several parts of a great distillatory apparatus. The sea is the boiler, in which the vapour is raised by the solar heat. The winds are the guiding tubes, which carry the vapour to the forests, where lower temperature prevails. This naturally condenses the vapour; and showers of rain are thus distilled from the cloud masses, which float in the atmosphere, by the woods beneath them." All which is true.

By Marsh it is said:—"We cannot positively affirm that the total annual quantity of rain is even locally diminished or increased by the destruction of the woods, though both theoretical considerations, and the balance of testimony, strongly favour the opinion that more rain falls in wooded than in open countries. An important conclusion, at least, upon the meteorological influence of forests, is certain and undisputed: the proposition namely, that within their own limits, and near their own borders, they maintain a more uniform degree of humidity in the atmosphere than is observed in cleared grounds: scarcely can it be questioned that they tend to promote the frequency of showers, and, if they do not augment the amount of precipitation they probably equalize its distribution through the different seasons."

"The strongest direct evidence which I am able to refer to in support of the proposition that the woods produce even a local augmentation of precipitation, is furnished by the observations of Mathieu, sub-director of the Forest School at Nancy. His pluviometrical measurements, continued for three years, 1866-1868, show that during that period the annual mean of rainfall in the centre of the wooded district of Cinq-Franchées, at Belle Fontaine on the borders of the forest, and at Amance, in an open cultivated territory in the same vicinity, was respectively as the numbers 1000, 957, and 853." In an appendix, Mr Marsh inserted a statement that "Fautrat and Sartiaut placed at an elevation of six mètres above a grove of oaks and elms, of twenty years growth and eight or nine mètres height, in the forest domain of Halette, pluviomètres and other meteorological instruments, and like instruments at the same elevation in the open ground three hundred mètres from the forest. In the months February to July inclusive, the rainfall above the trees was found to be 192. 50^{mm} and during the same period 177^{mm} in the open ground. *Comptes-Rendus*, t. LXXIX, 409.

The observations made by Mr Mathieu are thus summed up by himself, in his report to the Director-General of the Forest Administration:—

"In 1868 there fell on cleared spaces within the forest region more rain than beyond the borders of this; on agricultural land the fall was least of all. This result agrees entirely with those obtained in previous years, and tends more and more to present itself as a law. The following table has been prepared to make this apparent :—

	Depth of Sheet of Water Received by the Ground.		
	Cinq-Franches, — Centre of Forest Region.	Belle-Fontaine, — Border of Forest Region.	Ammence, — Agricultural Region.
	Millimetres.	Millimetres.	Millimetres.
9 Last Months of 1866,	691	No observation.	591
11 Do. 1867,	762	716	695
12 Months of 1868,	749	738	631

"If we represent by 1000 the quantity of water which fell each year at the Cinq-Franchées, we obtain for the three years during which the observations were made, the following as the proportions thus indicated :—

1866,	...	1000	—	855
1867,	...	1000	930	913
1868,	...	1000	985	791

The mean of these gives the proportion noted by M. Marsh.

The difference is probably not greater, but less, than is the popular belief; and it is possible it may be represented thus as being greater than it actually is.

M. Cézanne remarks on this report :—" After what we have seen of the so-called caprices of rain, and the variations which they present in one quarter, and in another of the same city, we must acknowledge that the experiments of M. Mathieu, while furnishing on the whole an argument in favour of the supposition of an action of forests on the phenomenon of the rain, are not absolutely demonstrative. How can we satisfy ourselves that the forests have not acted simply as an obstacle to the pluvial wind? If, for example, the agricultural region spread itself out on a level plateau, while the forest region rose on a slope up which crept the pluvial wind, the pluviomètres placed in these two regions are in no way comparable together.

"In order that the experiments might have been conclusive it would have been necessary that, viewed in regard to a great number of points, they should have been always accordant. But of this accordance in condition we have no evidence.

" M. Belgrand, comparing the region of the rainfall in the basin of the Grenetièn, which is wooded, with that of the Bouchat, which is not wooded, has ascertained and established that the former received less water than the latter, and further, that in this case the arrangement of the sides of the mountains exercised a preponderating influence, and one which masked that of the forests."

M. Cézanne has given attention to the effect of the configuration of the land upon the quantity of the rainfall. He has shown that this is determined, not only by altitude, but by the incidence with which a pluvial wind may strike upon any precipice or slope which opposes it, the rainfall being greater in proportion as the atmospheric current arrested by an obstacle is compelled to rise more rapidly. Hence the objection stated by him.

Some, if not all, of the so-called caprices, to which M. Cèzanne refers (while I consider the designation, which originated not with him, not altogether appropriate), I shall afterwards have occasion to cite, and also the experiments made by M. Belgrand. Here it is enough to have established that the popular opinion in regard to the effect of forests on the rainfall has received support from scientific observations, but that it may require considerable modification to bring it into perfect accordance with the matter of fact.

It is with this as it is with many other popular observations on the weather, which may be said to embody correct observations, but which have this solid substratum of truth overlaid with much which is not entitled to be considered such—the confiding trust with which they are received and propounded may be attributable to the confident and explicit expression in which they are couched. The uneducated are often impatient of dubiety, or want of explicitness of thought; and they are ready to impose this upon a vague or ambiguous statement with which they are not satisfied; and the half-educated, again, are prone to generalise rashly, and go far beyond what strict induction would warrant. Education by philosophy may regulate this tendency and make it productive of good; and the study of science may train the educated man to suspend his judgment in regard to the absolute, while resting with full confidence on ascertained facts. The generally received opinions in regard to the effect of trees on humidity, to the extent to which they have been confirmed by observations, are accepted and issued recoined, with a new impress, by such men of science; but the impress on the coin, limits, while it defines its value, and to pass them as equivalent to more than their determined value; were to mislead, though there might be no intention to deceive. The statement made by Mr Marsh, and the testimony of M. Mathieu, seem then to confirm and limit, the popular opinion in regard to the effect of forests upon the rainfall, and what is thus certified is in accordance with all that has been advanced in preceding chapters.

Rain has been spoken of as the precipitation from the air of moisture in excess of what could be sustained in solution at the temperature at the time. The increased moisture passed into the atmosphere by evaporation through the stomates of the leaves must render the air surmounting and surrounding a forest more liable to be affected by any change of wind than air in the open field. This it will do irrespective of any other means whereby the quantity of moisture in the air there may be increased; and thus may the increase of rainfall in question be accounted for.

There may also be an increase of rainfall occasioned by the repeated evaporation and precipitation of the same moisture: it is not the source of the moisture but the measure of the precipitation occurring in the locality which is alone in question here.

Besides this, it is alleged, and I believe correctly, that the heated air passing over a forest becomes cooled, and may thus be led to deposit the moisture with which it is charged.

While it is thus that trees generally act in maintaining the humidity of the district in which they grow, it is not impossible that they may act also in a way much more like what may be called attracting rain, by their acting as lightning conductors.

If a small pan with a perforated bottom be filled with water, and suspended from the prime conductor of an electrical machine, on the cylinder being put in motion, the water, instead of slowly dropping as it did before, pours in torrents through the perforations in the bottom of the pan, an electric attraction as well as an attraction of gravitation drawing it downwards. And this experiment has been employed to illustrate the thunder shower. Tapering points are found to have the effect of drawing off a surcharge of electricity from a body towards which they are directed; and thus, it may be, do trees occasionally act as lightning conductors, attracting the electric fluid, and thus bringing the water charged with it.

Observations have been reported to me which are in accordance with this supposition.

The Rev. J. Thomas, of Capetown, writes to me that when occupying a station of the Wesleyan Missionary Society on the West Coast of Africa, on one occasion when on a journey from the interior in 1848, he and his fellow-travellers came one evening to a forest where they spent the night under the shelter of some large and lofty trees. About two A.M. it began to rain, and it rained about three hours, when it poured in torrents, and continued to do so till they left the place. On mentioning the circumstance they were informed that just in that place it frequently rained in the manner they had described.

I accept the statement because I have no reason to question the correctness of the observation. I suspend my judgment, and lie open to light, as our fathers were wont to say, in regard to the occasion of the down-pour. My prejudices are in favour of the supposition that it was a passing thunder-shower, unaffected by the trees one way or another to a perceptible extent; but it is in accordance with views such I have stated, and which I know to be held by others; and I cite it as a case which, having been communicated to me, I ought not to ignore because it is at variance with more general views which I entertain.

SECT. III.—*Effects of Forests and of the Destruction of these on Rivers, and Streams, and Springs.*

It is a somewhat prevalent opinion that as rain proceeds from the clouds, rivers have their primary source in springs; and along with this opinion it is held by many that the primary function of rivers is to carry moisture to lands which otherwise would be barren, and there to diffuse fertility. But, in point of fact, no water springs from the ground which has not previously been deposited from the atmosphere; and the primary function of streams, brooklets, and rivers is simply to carry off surplus moisture in excess of what the soil can retain.

As rain is produced by the gravitation to the earth of surplus moisture in the atmosphere in excess of what the air can contain suspended in a state of invisible vapour at the temperature to which it has been reduced, rivers are produced by the gravitation to a lower level of the surplus water so precipitated in excess of what is absorbed by the earth or evaporated again into the atmosphere.

The popular phraseology in regard to many things is far from being in exact accordance with scientific conceptions. We speak of catching cold, of the rising sun, and of the new moon. And so we speak of the little spring of water at the greatest distance or the highest elevation from the mouth of a river as its source; but no one supposes that the whole of the waters of the river come from this.

It may be that there is not an inch of its course, or of the courses of its numerous tributaries and affluents, which does not pass many of its sources, channels of capillary dimensions, through which, from time to time, such excess of rainfall has drained off, or may drain off, into its bed, by which the accumulated drainings are drained off into the sea, if they be not absorbed or evaporated by the way.

It is under this aspect of springs, and streamletss, and rivers, we should look at them while considering the local effect upon them of forests, or of the destruction of these.

At a conference which I attended in Swartland, at the Cape of Good Hope, after I had given expression to my views on this subject, one gentleman who was present stated that a neighbour of his had planted on his place twelve trees twenty years before, or twenty trees twelve years before, I do not remember which, and that he did not believe one drop more rain had fallen in the district since these trees had been planted than usually fell before! And I think it not impossible that this may have been the case; but there are other ways besides increasing the quantity of the rainfall in which trees may act upon the humidity of a country, and even on the rainfall in a way beneficial to man and beast.

It has frequently been remarked that springs, and streamlets, and rivers, which have flowed permanently in the vicinity of forests have ceased to flow when these forests have been destroyed; nor are cases awanting of their flow having been resumed when, by plantations or natural reproductions, the destroyed trees have been replaced by others; cases have been cited; and, while apparently in certain circumstances even the extensive destruction of forests has not perceptibly affected the deposit of moisture over a widely extended region, facts are not awanting illustrative of what has been referred to occuring on an extended, as well as on a limited, scale.

The observations made by Mr Draper in regard to undiminished rainfall in America must command acceptance. But along with these we must attend also to the following.

In the Report of the Commissioners of Agriculture, for 1869, it is stated:—"From all parts of the State of Maine come up the same complaint of the diminished volume of water in the streams, occasioned by clearing off the forests and denuding the hills of trees. The snows are not so heavy, nor so frequent, as they were twenty or thirty years ago; and there is less rain in the summer. Many of the old trout streams of twenty years ago are now completely dry, and several parts of the State suffer more than formerly from droughts. Snow covers and protects the ground with less regularity."

There is thus brought before us also another of the effects of forests, or rather of the destruction of forests, but the discussion of this cannot be prosecuted here without distracting attention from what more immediately concerns us.

Mr Marsh in his treatise on "The Earth as Modified by Human Action," in writing of the Influences of the Forest on the flow of springs, says:—"It is an almost universal and, I believe, well-founded opinion, that the protection afforded by the forest against the escape of moisture from its soil by superficial flow and evaporation insures the permanence and regularity of natural springs, not only within the limits of the woods, but at some distance beyond its borders, and thus contributes to the supply of an element essential to both vegetable and animal life. As the forests are destroyed, the springs which flowed from the woods, and, consequently, the greater water-courses fed by them, diminish both in number and volume. This fact is so familiar in the American States and the British Provinces, that there are few old residents of the interior of those districts who are not able to testify to its truth as a matter of personal observation. My own recollection suggests to me many instances of this sort, and I remember one case where a small mountain spring, which disappeared soon after the clearing of the ground where it rose, was recovered about twenty years ago, by simply allowing the bushes and young trees to grow up on a rocky knoll, not more than half an acre in extent, immediately above the spring. The ground was hardly shaded before the water reappeared, and it has ever since continued to flow without interruption. The hills in the Atlantic States formerly abounded in springs and brooks, but in many parts of these States which were cleared a generation or two ago, the hill-pastures now suffer severely from drought, and in dry seasons furnish to cattle neither grass nor water."

And in regard to the effect of the destruction of forests on the diminution of springs, he subsequently says there is no want of positive evidence on the subject.

Marchand cites the following instances:—

"Before the felling of the woods, within the last few years, in the valley of the Soulce, the Combe-ès-Mounin and the Little

Valley, the Sorne furnished a regular and sufficient supply of water for the ironworks of Unterwyl, which was almost unaffected by drought or by heavy rains. The Sorne has now become a torrent, every shower occasions a flood, and after a few days of fine weather the current falls so low that it has been necessary to change the water-wheels, because those of the old construction are no longer able to drive the machinery, and at last to introduce a steam-engine to prevent the stopage of the works for want of water.

"When the factory of St. Ursanne was established, the river that furnished its power was abundant, and had, from time immemorial sufficed for the machinery of a previous factory. Afterwards, the woods near its sources were cut. The supply of water fell off in consequence, the factory wanted water for half the year, and was at last obliged to stop altogether.

"The spring of Combefoulat, in the commune of Seleate, was well known as one of the best in the country; it was remarkably abundant, and sufficient, in the severest droughts, to supply all the fountains of the town; but since considerable forests were felled in Combe-de-pré Martin and in the valley of Combefoulat, the famous spring, which lies below these woods, has become a mere thread of water, and disappears altogether in times of drought.

"The spring of Varieux, which formerly supplied the castle of Pruntrut, lost more than half its water after the clearing of Varieux and Rougeols. These woods have been replanted, the young trees are growing well, and, with the woods, the waters of the spring are increasing.

"The Dog Spring between Pruntrut and Bressancourt has entirely vanished since the surrounded forest-grounds were brought under cultivation.

"The Wolf Spring, in the Commune of Soubey, furnishes a remarkable example of the influence of the woods upon fountains. A few years ago this spring did not exist. At the place where it now rises, a small thread of water was observed after very long rains, but the stream disappeared with the rain. The spot is in the middle of a very steep pasture inclining to the south. Eighty years ago the owner of the land, perceiving that young firs were shooting up in the upper part of it, determined to let them grow, and they soon formed a flourishing grove. As soon as they were well grown, a fine spring appeared in place of the occasional rill, and furnished abundant water in the longest droughts. For forty or fifty years this spring was considered the best in the Clos du Doubs. A few years since, the grove was felled, and the ground turned again to a pasture. The spring disappeared with the wood, and is now as dry as it was ninety years ago."

"Siemoni gives the following remarkable facts from his own personal observation:

"In a rocky nook near the crest of a mountain in the Tuscan Appennines, there flowed a clear, cool, and perennial fountain, uniting three distinct springs in a single current. The ancient beeches around and particularly above the springs were felled. On the disappearance of the wood, the springs ceased to flow, except in a thread of water in rainy weather, greatly inferior in quality to that of the old fountain. The beeches were succeeded by firs, and as soon as they had grown sufficiently to shade the soil, the springs began again to flow, and they gradually returned to their former abundance and quality.

"This and the next preceding case are of great importance both as to the action of the wood in maintaining springs, and particularly as tending to prove that evergreens do not exercise the desiccative influence ascribed to them in France. The latter instance, shows, too, that the protective influence of the wood extends far below the surface, for the quality of the water was determined, no doubt, by the depth from which it was drawn. The slender occasional supply after the beeches were cut was rain-water which soaked through the superficial humus and oozed out at the old orifices, carrying the taste and temperature of the vegetable soil with it; the more abundant and grateful water which flowed before the beeches were cut, and after the firs were well grown, came from a deeper source and had been purified, and cooled to the mean temperature of the locality, by filtering through strata of mineral earth."

"The influence of the forest on springs," says Hummel, "is strikingly shown by an instance at Heilbronn. The woods on the hills surrounding the town are cut in regular succession every twentieth year. As the annual cuttings approach a certain point, the springs yield less water, some of them none at all; but as the young growth shoots up, they flow more freely, and at length bubble up again in all their original abundance."

"Dr Piper states the following case: 'Within about half a mile of my residence there is a pond upon which mills have been standing for a long time, dating back, I believe, to the first settlement of the town. These have been kept in constant operation until within some twenty or thirty years, when the supply of water began to fail. The pond owes its existence to a stream that has its source in the hills which stretch some miles to the south. Within the time mentioned, these hills, which were clothed with a dense forest, have been almost entirely stripped of trees; and to the wonder and loss of the mill-owners, the water in the pool has failed, except in the season of freshets; and, what was never heard of before, the stream itself has been entirely dry. Within the last ten years a new growth of wood has sprung up on most of the land formerly occupied by the old forest; and now the water runs through the year, notwithstanding the great droughts of the last few years, going back from 1856.'

"Dr Piper quotes from a letter of William C. Bryant the following remarks: 'It is a common observation that our summers are becoming drier and our streams smaller. Take the Cuyahoga as an illustration. Fifty years ago large barges loaded with goods went up and down that river, and one of the vessels engaged in the battle of Lake Erie, in which the gallant Perry was victorious, was built at Old Portage, six miles north of Albion, and floated down to the lake. Now, in an ordinary stage of the water, a canoe or skiff can hardly pass down the stream. Many a boat of fifty tons burden has been built and loaded in the Tuscarawas, at New Portage, and sailed to New Orleans without breaking bulk. Now the river hardly affords a supply of water at New Portage for the canal. The same may be said of other streams—they are drying up. And from the same cause —the destruction of our forests—our summers are growing drier and our winters colder.'

"Becquerel and other European writers adduce numerous other cases where the destruction of forests has caused the disappearance of springs, a diminution in the volume of rivers, and a lowering of the level of lakes, and in fact, the evidence in suppprt of the doctrine I have been maintaining on this subject seems to be as conclusive as the nature of the case admits. We cannot, it is true, arrive at the same certainty and precision of result in these inquiries as in those branches of physical research where exact quantitative appreciation is possible, and we must content ourselves with probabilities and approximations. We cannot possibly affirm that the precipitation in a given locality is increased by the presence, or lessened by the destruction, of the forest, and from our ignorance of the subterranean circulation of the waters, we cannot predict, with certainty, the drying up of a particular spring as a consequence of the felling of the wood which shelters it; but the general trnth, that the flow of springs and the normal volume of rivers rise and fall with the extension and the diminution of the woods where they originate and through which they run, is as well established as any proposition is in the science of physical geography.

"Of the converse proposition, namely, that the planting of new forests gives rise to new springs, and restores the regular flow of rivers, I find less of positive proof, however probable it may be, that such effects would follow. A reason for the want of evidence on the subject may be, that, under ordinary circumstances, the process of conversion of bare ground to soil with a well-wooded surface is so gradual and slow, and the time required for a fair experiment is consequently so long, that many changes produced by the action of the new geographical element escape the notice and the memory of ordinary observers. The growth of a forest, including the formation of a thick stratum of vegetable mould beneath it, is the work of a generation, its destruction may be accomplished in a day; and hence, while the results of one process may, for a considerable time, be doubtful, if not imperceptible, those of the other are immediately and readily appreciable. Fortunately, the plantation of a wood produces other beneficial consequences, which are both sooner realised and more easily estimated; and though he who drops the seed is sowing for a future generation as well as for his own, the planter of a grove may hope himself to reap a fair return for his expenditure and his labour."

We do not always find all facts in manifest accordance with conclusions towards which we may be advancing, or to which we may previously have come; and though every fact must necessarily be in accordance with every other fact we may often find it necessary to take into account conflicting influences, the effect of which must be determined; and to the preceding statement Mr Marsh has appended the following note :—

"Some years ago it was popularly believed that the volume of the Mississippi, like that of the Volga and other rivers of the Eastern Hemisphere, was diminished by the increased evaporation from its basin and the drying up of the springs in consequence of the felling of the forests in the vicinity of the sources of its eastern affluents. The boatmen of this great river and other intelligent observers now assure us, however, that the mean and normal level of the Mississippi has risen within a few years, and that in consequence the river is navigable at low water for boats of greater draught and at higher points in its course than was the case twenty-five years ago.

"This supposed increase of volume has been attributed by some to the recent re-wooding of the prairies, but the plantations thus far made are not yet sufficiently extensive to produce an appreciable effect of this nature; and besides, while young trees have covered some of the prairies, the destruction of the forest has been continued perhaps in a greater proportion in other parts of the basin of the river. A more plausible opinion is that the substitution of ground that is cultivated, and consequently spongy and absorbent, for the natural soil of the prairies, has furnished a reservoir for the rains which are absorbed by the earth and carried gradually to the river by subterranean flow, instead of running off rapidly from the surface, or, as is more probable, instead of evaporating or being taken up by the vigorous herbaceous vegetation which covers the natural prairie.

"A phenomenon so contrary to common experience, as would be a permanent increase in the waters of a great river, will not be accepted without the most convincing proofs. The present greater facility of navigation may be attributed to improvements in the model of the boats, to the removing of sand-banks and other impediments to the flow of the waters, or to the confining of these waters in a narrower channel, by extending the embankments of the river, or to yet other causes."

A case similar to that occurring on the Wolfspring was reported to me by Mr S. Van Reenan, of Constantia. The site of the celebrated vineyard so long in possession of his family, measuring some 45 acres, or 22½ Morgens, was when granted to his forefather a forest. There was then on it an abundance of water, such abundance that though there was no spring on the property there was a large reservoir and large pond in front of the house, supplied and maintained by a stream of water, at least four inches in diameter. But when the forest was felled, and the vineyard planted in its place, the supply of water gradually diminished till it was reduced to a supply one inch in diameter, and ultimately to a supply measuring only a quarter of an inch.

On the same ground he afterwards formed a plantation, to the destruction of which by fire I have elsewhere had occasion to refer.

In regard to this he informed me that on the abolition of slavery, probably about 1838, he feared he should not be able to keep so much vineyard under cultivation as he had previously done, and he employed several of his slaves in sowing seeds of the Cluster pine and of the Stone pine (*Pinus pinaster*, and *Pinus pinea*). In one night, specified by him to me as the night on which the "Vulcan" entered

Table Bay with the German Legion, the wood thus formed was consumed by a fire, occasioned by one of his neighbours burning the bush on his farm, and I understood him to say that the effects were again the same : a somewhat copious flow of water, which had been re-established during the growth of the trees, was suddenly stopped by the denudation of the soil.

In a preceding chapter I have stated that Dr Moffat follows up the details given by him of the destruction of trees by Bechuanas, which I have cited, with the remark, " To this system of extermination may be attributed the long succession of dry seasons." " To the the same cause," says he, " may be traced the diminution of fountains, and the entire failure of some which formerly afforded a copious supply, such as Griqua Town, Campbell, and a great number of others which might be mentioned. It has been remarked that since the accidental destruction of whole plains of the *Olea similis* (wild olive) by fire, near Griqua Town, as well as the diminishing of large shrubs on the neighbouring heights a gradual decrease of rain has succeeded in that region." And Chapman accompanied information which he gave to me in regard to the destruction of forests in the interior with a similar observation. Moffat relates that on his settlement at Latakoo " the natives were wont to tell of the floods of ancient times, the incessant showers which clothed the very rocks with verdure, and the giant trees and forests which once studded the brows of the Mamhana hills and neighbouring plains. They boasted of the Kuruman and other rivers, with their impassable torrents, in which the hippopotami played, while the lowing herds walked to their necks in grass, filling their *makukas* (milk sacks) with milk, making every heart to sing for joy."

He speaks of that river as issuing from caverns in lime stone hills, full formed, like Minerva fully equipped from the head of Jove ; he writes in 1842 "that it no longer continued to send forth the torrents it once did :" he speaks of it as " once a large river emptying itself into the Gariep, or Orange River, at a distance below the water-fall;" but as then by absorption lost in its bed about ten miles to the north-west of its source.

In my own tours throughout the Colony I found everywhere in the superficial aspect of the country indications that, at a period not very remote, it must have been a land well-watered everywhere. I found that within the memory of the present occupants of the land there has been a remarkable change in the aridity, both of limited and of extensive districts. And I found that in not a few places the change was observed to follow immediately the destruction of bush. Details

I have given in a separate volume on the "Hydrology of South Africa."

By Surell it is mentioned, in a note appended to his *Etude sur les Torrents des Hautes Alpes*, "There has been discovered the existence, in the time of the Romans, of a great corporation of watermen established on the Durance, which proves that there was then a considerable flottage, or transport, of timber in rafts, which has been for a long time given up entirely, and which proves also that this department was then covered with abounding forests, of which there exist now only but meagre shreds." But now, that river has made for itself a bed which in some places exceeds a mile and a quarter in breadth, while the ordinary flow of the river is confined to a current little more than thirty feet in width; and from Young's travels in France it appears that so early as 1789 it was computed to have covered with gravel and pebbles not less than 130,000 acres, "which, but for its inundations, would have been the forest land in the province." Thus have we there land undermined and washed away,—fertile land covered with the debris, and the fertilizing material carried away to the sea.

The fact in regard to the former state of the Durance is mentioned also by Ladoucette in his *Histoire, &c, des Hautes Alpes.*

In the *Ami des Sciences*, of December 11, 1873, there is given the following statement by M. Cantegril, sub-inspector of forests. In explanation of one of the statements in this I may state that, with a view to the conservation and improvement of the forests of France, certain regulations had been laid down for the re-arrangement of the forests of the States, and liberal arrangements made for the extension of these regulations, to the management of forests belonging to communes, where this could be done with their consent.

"Upon the territory of the commune of Labruguière (Tarn) there is a forest of 1,834 hectares, (4,524 acres,) known as the forest of Montant, and owned by the commune. It extends northward on the Montagne-Noire, and the soil is granitic, with a maximum altitude of 1,243 meters, and a slope of from 15 to 60 in 100. A little water-course, the Caunan brook, rises in this forest and drains the waters of two-thirds of its surface. At the entrance of the forest, and along this brook, are located several fulling mills, each requiring eight horse-power, and moved by water-wheels which work the beaters of the machines.

"The commune of Labruguière had long been noted for its opposition to the forest regulations; and the cutting of wood, together with the abuse of pasturage, had converted the forest into an immense waste, so that this great property would hardly pay the cost of guarding it and afford a meagre supply of wood for its inhabitants.

"While the forest was thus ruined and the soil denuded, the waters after each heavy rain swept down through the valley, bringing with them great quantities of gravel, the *debris* of which still encumbers the channel of this stream. The violence of these floods was sometimes so great that they were compelled to stop the machines for some time. But in the summer time another inconvenience made its appearance. Little by little the drought extended, the flow of waters became insignificant, the mills stood idle, or could be run only occasionally for a short time.

"About 1840 the municipal authorities began to give information to the population relative to their true interests, and under the protection of a better supervision the work of replanting has been well managed, and the forest is to-day in successful growth.

"In proportion as the replanting progressed, the precarious use of the mills ceased, and the regime of the water-courses was greatly modified. They now no longer swelled into sudden and violent floods, compelling the machines to stop, but the rise did not begin until six or eight hours after the rains began. They rose steadily to their maximum, and then subsided in the same manner. In short, the mills were no longer obliged to stop work, and the water was always enough to run two fulling machines, and sometimes three.

"This example is remarkable in this, that all the other circumstances had remained the same, and therefore we can only attribute to the reforesting the changes that occurred, namely, diminution of the flood at the time of rain, and an increase in its flow during other times."

From a report made by Henry J. Wisner, United States Consul at Sonneberg, in the Department of State, in November, 1873, the river Elbe between the years 1787 and 1837, a period of half a century, diminished at Attenbruecke, in Hanover, ten feet in depth, as a direct result of the cutting off of forests in the region where the tributaries have their origin.

In 1873, there appeared in the *Zeitschrift des österr. Ingenieur und Architecten Vereins,* a paper by Herr Gustav Wex, Counsellor of State, and Director-in-Chief of works undertaken for the regulating of the flow of the Danube, "On the Diminution of Water in Streams and Rivers, accompanied by Occasional Inundations in

Agricultural districts." In this the author, after having in an Introduction shown the great importance of the subject, invites his colleagues as well as other naturalists to examine his book, and appeals for the support of the Government in favour of his propositions, especially those departments of the Government which are more specially occupied with the care and defence of the economical interests of the public; after which he treats, in the first place, of the diminution of water in the rivers and streams, and consequently the diminution in the out-flow. He proceeds upon personal observations during a period of forty years, made on the Austro-Hungarian great rivers and streams, with relation to the conditions of their out-flow, and he comes to the conclusion that the volume of water at present discharged has decreased considerably during a series of years.

Corresponding facts have been attested also by others, and judging from these they have given their opinion that the volume of water discharged by many streams appears to be diminishing. But the correctness of this conclusion has been disputed, and the author discusses the observations which have been adduced against the views adopted by him, as well as those upon which his conclusions were based.

The author proceeds on data supplied in the Second Part of the *Allegmeine Länder und Völkerkunde*, by Berghaus, in regard to the depth of water in the Rhine at Emmerich, of the Elbe at Magdeburg, and of the Oder at Küstrain, according to which the average and lower depths of water have experienced a diminution by no means inconsiderable, while the floods of greatest depth present, on the other hand, apparently an increase both in frequency of occurrence and in magnitude.

Dr Berghaus became convinced through an examination of the tables of the depth of water in the Elbe and the Oder that on the main streams of both the flow or delivery have been considerably diminished; and he expressed a fear that these two rivers of Germany were threatening to disappear from the number of navigable rivers, which would be the case if the reduction in the depth of water should go on at the same rate at which it had proved to be diminishing since the year 1781.

Herr Wex, by long-continued observations and studies, had come to the same conclusion as Berghaus, and he maintains against objections brought forward on different sides the opinion that there has been a progressive diminution in the quantity of water in these rivers, and not less really so in the Vistula and the Danube.

Amongst the objections referred to:—1. Herr F. Hagen, Royal Prussian *Geheime Oberbaurath*, and *Ober-Landes-Bau-Director*, found by actual measurement of the Rhine, at Dusseldorf, that the diminution of the highest and of the medium floods was but inconsiderable—on an average, the one 2·9 and the other 1·6 lines per annum, about one-fourth and one-eighth of an inch. And he alleges that this may be accounted for by the modifications which have been made in the river's bed, whereby the supplies from the melting of ice have been retarded, and the flowing away of floods promoted.

2. Herr Maass, Prussian Royal Hydraulic Inspector, has found by examination of the observations on the height of the Elbe, made for 143 years in the *Pegel* at Magdeburg, a considerable diminution in the greatest, medium, and lowest heights of the river, amounting to 17, to 35½, and to 34 *zoll*, or inches; but he alleges this reduction to be the consequence of the modification of the bed of the river occasioning a deepening of the bed, and an increased rapidity of flow.

3. A conjecture, which has been expressed, that such considerable quantities of water may be carried away in the more frequent and higher floods of later times as to compensate for the diminution in the medium and lower heights of the flow at other times.

The author shows—1. By the measurements made by the late Herr Grebenau, Bavarian Royal *Bau-Inspector*, at Germersheim, on the *pegel* at Sondersheim, throughout a period of twenty-eight years, which gave not only information in regard to the depth of the river, as ascertained by the said gauge, but also in regard to the delivery or quantity of the flow, that the diminution of the average depth and a diminution in the delivery or flow go together.

2. According to observations made by the *Elbe-Stromschau-Commission*, it appears that there has been indeed a deepening of the bed of the river in its upper part; but, on the other hand, an elevation of the river bed by the silting of sand in the middle and the lower portion of it. So that the diminution in the height of the water at the gauge at Magdeburg cannot be attributed to a deepening of the bed of the stream.

3. That the high floods are no compensation for the diminution of the delivery by the low and medium flow is proved by the author—first, by the before-mentioned measurements by the gauge at Sondersheim, according to which differences in the delivery are found to be nearly proportionate to the depth of the flow; and, further, by

measurements made for thirty-two years on the Danube gauge at Alt-Orsova, according to which is established not only a lowering in the medium and the lowest flows, but also in those of greatest height, which phenomenon, different from what has been seen in other rivers, the author attributes to the circumstance that the floods in each of the large tributaries occur at different times.

"On the occasion of a Commission to prepare a scheme or project for the regulation of the flow of the larger streams and rivers of Austria being entrusted to me by the Government," writes Herr Wex, "I set about, as a preliminary measure, the study of the delivery of water by these rivers, and in doing so I have invariably found that the delivery, measured by such appliances and means of ascertaining this, has of late years greatly diminished.

"Although a corresponding fact had been previously observed by scientific students of natural history, and the phenomenon of a diminution in the delivery of different rivers had been ascertained, the correctness of the conclusion arrived at had been called in question by other scientific men, and more especially by *Hydrotechnikern* [hydrologists and students of hydraulic-engineering ?] I shall therefore state the views advanced by them, and thereafter meet them by observations made during protracted periods on some of the principal rivers of Central Europe.

"Herr F. Hagen, Royal Prussian *Geheime Oberbaurath* and *Ober-Landes-Bau-Director*, has in the last (the third) edition of his *Handbuches der Wasserbau Kunst*, for the year 1871, called in question the correctness of observations hitherto made on the height of water in streams and rivers, and of deductions drawn from these in regard to a diminished flow of water in them, and he bases his opposing views on observations made with the Rhine pegel at Dusseldorf since the year 1800, and on the recorded observations on the height of the level of the river for seventy-one years.

"Herr Hagen has calculated for every separate year the arithmetical *mean* yielded by the daily observed height of the water, and also the average annual height of the water, he has also noted the highest and lowest heights of the water in each year; and he has represented these three conditions of the water in a diagram, by which he makes apparent that no very considerable diminution of the waters has occurred.

"In consequence of the great importance of the matter, Herr Hagen has submitted the former selected observations on the state of the river to a calculation founded on the least common multiple, and thus found that in the course of the last 71 years, on the Rhone at Dusseldorf, there has been a reduction of the highest floods to the extent of 2·9 lines, of the *mean* to the extent of 1·6 lines, while there has been a rise in the lowest of 0·2 lines *per annum*. But on these calculations Herr Hagen himself does not lay particular stress, as there may be errors, he says, in the results obtained to the extent of 2·2‴, 0·9‴, and 0·7‴ respectively.

"Herr Hagen says further: 'It may well be imagined that in the course of time a diminution in the highest and the *mean* levels has taken place; and that for the reason that in later years, through the modifications of the water-course which have occurred, the flotation of ice has been impeded, the flow of water from the higher-lying districts of the river's basin has been promoted; whence the small annual reduction of the calculated *mean* river-height may have followed.'

"Subsequently, Herr Hagen having expressed doubts in regard to the statements of certain Hydrotechnikern, relative to a great diminution in the level and delivery of the Weser, from a comparison of the observations made by the pegel at Minden and at Schlüsselburg, comes to the following conclusion: 'It thence appears that, in so far as observations made up to this time can show, it is as impossible to give with certainty a verdict in regard to any general diminution of its waters in regard to the Weser as in regard to the Rhone.'

"Although the observations made on three gauges on two rivers lead Herr Hagen to express himself thus guardedly on the subject of a lowering of the water-level, yet the greater number of Hydrotechnikern—because observations continued through many years, and comparison of the water-levels at distant periods of other rivers are not at their command, and because they consider Herr Hagen an infallible authority on all that relates to hydraulic engineering—have come to the conclusion that in general there has not taken place any great diminution in the flow and delivery of streams and rivers.

"Herr Maass, the Prussian Royal *Wasserbau-Inspector*, has published, in the *Zeitschrift für Bauwesen von Erbkam*, for the year 1870, observations of the height of the river Elbe for the period of 143 years, extending from 1727 to 1869, with a diagram representative of these observations; and from these he has drawn the conclusions that within this period the waters of the Elbe have gradually diminished in the following arithmetical means: *a*. In the highest levels reached, 17 inches; *b*. In the lowest level observed, 34 inches;

c. In the mean of the whole of the observations made in the several years, 35½ inches.

"According to the views of Herr Maass the lowering of the heights of the water level is not a consequence of any diminution of the quantity of water now flowing into the Elbe, but the result of the rectification of the river bed, an extensive deepening of this as a consequence of that modification, and an increase of the rapidity of the flow or delivery of the river. Herr Maass attaches importance to the effects of these in lowering the level of the streams, and remarks that no further lowering of that level is to be expected, because there are no additional works of modification in contemplation.

"As the observations and views of Herr Hagen and of Herr Maass are diametrically opposed to observations which I have myself made on several rivers during the last 40 years, I have brought together the observations I have made on several rivers and streams, and the conclusions I have drawn from them, for publication as measurements of the water level for many years, upon which reliance may be placed, as it is only in being in possession of these data that I could have been so bold as to come forward with any confidence as the opponent of an authority so distinguished throughout the whole of Germany as is Herr Hagen in matters pertaining to Hydrotechnics.

"In the course of my observations on the subject in question there came into my hands the remarkable work, *Allgemeine Länder-und Völkerkunde*, by Dr Heinrich Bergman,—volume second, *Umrises der Hydrographie*, for the year 1837,—and I found in this work, and in that issued by the same author and by J. Perthes, *Hydro-hystorischen Uebersichten der deutschen Ströme*, for the year 1838, collected together much valuable material relative to the height of the water and to the floating of the ice in the rivers.

"From the observations on the river level made with the pegel at Emmerich, on the frontier of Holland, for the period of 66 years, from 1770 to 1835, and with these the observations made with the pegel at Cologne for the period of 54 years, from 1782 to 1835, and in addition to these the observations made on the Elbe with the pegel at Magdeburg, for the period of 108 years, from 1728 to 1835, and on the Oder with the pegel at Küstrin, for the period of 58 years, from 1778 to 1835, has the distinguished hydrographer Berghaus determined the measurements of the highest and of the lowest levels of these rivers, and from them calculated arithmetically the annual mean levels. He has represented these by diagrams, and given diagrams representative of the average height of the rivers in the different months of the year, and of the movement of the ice and of floods; and finally, he has in addition to these tabulated statements given others illustrative of the influence of the rainfall on the quantity of water carried off by the rivers, and has exhibited this in a way so thorough and efficient as is not equalled in any other work on Hydrotechnics. By which means Berghaus as a precursor has shown to Hydrotechnikern in what way observations on the ever-varying levels of rivers should be brought together and compared, in order to present a distinct picture of the hydrographic phenomena, or of the river life of the stream, and from this correctly to draw inferences and final conclusions.

"From these extremely detailed and deeply interesting investigations by Berghaus I make, amongst others, the following leading deductions :—

"From the 'Hydrographie' of Dr Berghaus I have prepared a diagram, which I have appended to this treatise, in which I have represented what were the highest, and the lowest, and the calculated mean annual water-levels of the Rhône, observed by the pegel at Emmerich, from the year 1770 to 1835. From this diagram it appears at a glance that the water-level of the several years is very far indeed from being regular, but in successive years they rise and fall; and it is consequently difficult to represent by a continuous line, or to calculate a *mean* representative of the diminution or increase of the water-level for a period of some length, as Herr Hagen also states to be the case. I therefore hold to the opinion that the method adopted by Dr Berghaus, comparing the arithmetical *mean* of the water-level during a more lengthened period than two years, is more easy and supplies data upon which more reliance can be placed; and from the data thus procured, inferring or deducing whether there has been any rise or fall in the river-level. If, then, we divide the observations made during the period of 66 years into those made in the first period of 33 years, from 1770 to 1802, and those made in the second period of 33 years, from 1803 and 1835; and if from these two equal periods of 33 years each we calculate and compare the annual average levels of the river in each, the result will be, we shall find that in the second period the average height of that level was 10‴ in excess of the first; but on the contrary, the annual water-level has fallen 1′ 42″ 5‴, and the lowest 1′ 1″ 3‴, when compared with the corresponding earlier period from 1770 to 1802.

"As the arithmetically determined *mean* of the river-level in the first period, from 1770 to 1802, was only taken incidentally for comparison, without reference to the fact whether in the course of these 33 years any rise or fall of the water-level had taken place, it is clear that the above numbers represent the reduction which had taken place in the lowest levels and in the annual mean levels of the river in the second period of 33 years—that is, for the half of the whole period embraced by the observations made.

"And the same remark will also apply to all subsequent comparisons of the water-level in two periods.

"If we consider further the observations made of the pegel on the Rhone at Cologne, from 1782 to 1835 [which was also appended to the treatise], and again divide the period embraced of 54 years into two consecutive periods of 27 years each, and by calculation determine the *mean* annual levels, we find that in the second of these periods, that from 1809 to 1835, the mean height of highest floods has risen about 0′ 1″ 66‴; while, on the contrary, the mean annual height has fallen about 4·27″, and that of the lowest levels about 7·21″, as compared with those of the first half of the period, that from 1782 to 1808.

"From the foregoing deductions it is apparent that in the two principal pegels on the Rhine at Emmerich and Cologne—during the periods of 66 and of 54 years, embraced by them respectively from 1770, and from 1782 to 1835—there has taken place a not inconsiderable fall both in the lowest levels and in the mean annual levels; and that only the *mean* of the highest levels is found to be somewhat higher in the second as compared with the earlier halves of the periods embraced by the observations.

"As during the period of observation extending from 1770 to 1835, no such works of modification of the river's course as could have produced any deepening of the bed of the stream at Cologne and at Emmerich, or any increase of the rapidity of water-flow, and consequent lowering of the water-level, had been carried on, the fall of that level in the case of the lowest and the *mean* states of the river, during the later halves of the periods embraced by the observations in question, can only be attributed to a diminished quantity of water passing down the Rhine; while the small rise in the annual *mean* of the highest point reached, has to be ascribed to more frequent and higher floods.

"That the fall in the low and *mean* annual proves to be less than it has been in some other rivers is accounted for, by Berghaus, by a reference to the fact that the Rhine is fed, in a great measure, by the confluence of numerous currents from the ice and snow on the Alps;

which explanation I would follow up with the remark that by the Lake of Constance, which receives the waters of the Upper Rhine and afterwards emits them gradually, this river regulates its delivery at lower-lying points; and that, as a consequence of this, the reduction in its delivery at lowest, and in *mean* annual levels, can show itself in but very minute measurements.

"The circumstance that the fall, in these levels, shows itself much more considerable at the pegel at Emmerich than at the pegel at Cologne, is explained, by Berghaus, by the fact that between Cologne and Emmerich there flow into the Rhine the Wupper, the Ruhr, the Emtsche, and the Lippe, which are less uniform in their flow than is the Rhine which is thus fed.

"Adverting now to the diagram and tabulated statement of the level of the Rhine, as indicated by the pegel at Dusseldorf, situated between Cologne and Emmerich, for the period from 1800 to 1871, published by Herr Hagen, let us examine it with some care.

"Herr Hagen found by his method of investigation that the annual *mean* level had fallen upon an average about 1·6 line, which for a period of 50 years gives a fall of 6·66 inches.

"As according to the observations tabulated by Berghaus the fall in the *mean* annual level given above reduced to a like period of 50 years gives at the pegel at Emmerich 24·88 inches, and at the pegel at Cologne 7·91 inches; from this it appears that Herr Hagen's calculation of the fall of the water level at Dusseldorf, amounting to 6·66 inches, although founded on observations embracing a different period of time, comes very near to the calculation made of the fall at the comparatively proximate pegel at Cologne, from which it follows that the calculated fall must be regarded as an actual fact, and not an error in calculation, as Herr Hagen had intimated that it not improbably might be.

"Although according to the older tabulated observations of Berghaus for the period from 1770 to 1835, there appears a somewhat higher rise in the highest floods of the Rhine, amounting to from 10 to 18 lines,—still the calculation of Herr Hagen that the level reached by the high floods had fallen 2·9‴ per annum, and consequently 12″ 1‴ in fifty years, may possibly be correct; and are probably so, since in consequence of the extensive rectification of the river bed between Basle and Manheim since 1830, the rapid flow of the high floods must have been accelerated.

"Herr Hagen has found a very slight rise in the level of the lowest observations at Dusseldorf, about 0·2‴ per annum, consequently only about 10 lines, or five-sixths of an inch, for 50 years. And this is explicable in that the bed of the stream has been at that place reduced in breadth within later decades; and also in that the extensive rectifications of the course of the Rhine, by cuttings above Manheim, has made it possible that by means of sand and fine silt, transported to the lower reaches of the river, the bed of the stream at Dusseldorf may have become somewhat silted up and elevated in a way similar to what has occurred to a still greater degree in the middle and lower sections of the Elbe.

"From the foregoing references it is evident that the conclusions drawn by Herr Hagen, that the observations made up to this time on the Rhine do not indicate any general lowering of the water level, are erroneous. And if he had been acquainted with the older observations at Emmerich and Cologne, published by Berghaus, or if he had more skilfully compared the observations, extending over a period of 71 years, at Dusseldorf, he would probably have come to a conclusion the very contrary to that to which he has come.

"In order to obtain data on which reliance might be placed in regard to the flow of the Rhine above Dusseldorf and Cologne, I addressed myself to the distinguished hydrographer Herr Grebenau, Bavarian Royal *Bau-Inspector* at Gemersheim, who was for many years engaged in the rectification of the new bed of the Rhine, and from him I received not only the details of observations on the river-level at the pegel at Sondersheim for the period of 28 years from 1840 to 1867, but also the results of investigations on the delivery or quantity of water passing each year through the cuttings of the Rhine bed at Gemersheim, which Herr Grebenau had obtained with great care and precision, partly by means of numerous special measurements of vertical sections of the current and the rapidity of the flow, and partly by means of calculations according to the latest formulas of experimentally-obtained co-efficients.

"When these tabulated observations on the water level, and the diagram representative of the quantity of water delivered for the period of 28 years, are divided into two successive periods of 14 years each; and when for each of these there is calculated the *means* both of the levels and of the delivery, there are obtained from these the following results: the *mean* annual water level in the latter period of 14 years is about ·432 mètres, or 17·63 inches lower, and the delivery is about 6966 cubic feet per second less, than in the former.

"Along with this it must be admitted that, to a great extent, the lowering of the *mean* annual level of the river is to be ascribed to a considerable deepening of the bed of the stream, consequent upon extensive rectifications of the river by cuttings.

"Further, although it must not be concealed that the different water-levels measured, and deliveries calculated, cannot be relied on as absolutely correct, and it is unquestionably the case that the deepening of the bed of the stream had a great effect upon the lowering of the level and the reduction of the delivery, still it must be noted that the fall and diminution in the one and the other, which have been determined, have been brought to light by the same method, and are in any case approximately correct; from which it follows as a consequence, that in the latter period (embracing 28 years), at the pegel at Germersheim, the body of water delivered by the Rhine has considerably diminished.

"Along with this must be noted the very remarkable fact, that the beautifully rectified course of the Rhine from Manheim upwards toward Basle, converting it almost into a regular canal, has now become in a great measure unnavigable: in consequence—first, of the numerous persistent and extending beds of silt in the bed of the river, and resting in the concave sweep; and next, of the continually increasing serpentine character of the course of the stream; and finally, of the low depth of water in the many crossings of the stream from one concave bay to another, all which can now be accounted for by the fact that the normal breadth of the river-bed was originally taken to be greater than it actually is, from which it follows that the current, in consequence of the diminished water-flow, has not now the force necessary to remove these masses of silt, and to lodge them only on the convex or projecting shores of the river-bed.

"The foregoing results of observations made on four gauges on the Rhine, serve to strengthen my allegations in regard to this river; and I proceed to the consideration of the information obtained in regard to the other rivers of Central Europe."

There are given in an appendix the several tabulated observations and diagrams referred to. There follow discussions similar to those which have been quoted in detail: 1. Of observations made on the Elbe, with a tabulated statement of observations of the highest, *mean*, and lowest levels of the river at Magdeburg, with the calculated *means*, and a diagram representative of the same, from the year 1728 to 1869, a division of the former of these being made into periods of 50 years; a diagram representative of the calculated delivery of the Elbe in the several months of the year during the two periods from 1731 to 1780, and from 1781 to 1830; and a diagram representative of the depth in mètres at twenty-five different stations on the river on several occasions of very low water.

2. Of observations on the Vistula, with a tabulated statement of the highest and lowest levels, observed at Weichsel near Kurzebrack in each year from 1809 to 1871, with calculated mean annual depth of the river, and a diagram representative of these. It had been alleged that a greater quantity of water was being delivered by the Vistula than previously, and reference is made to these tables as proof that this was unwarranted, and as supplying evidence that the delivery was being diminished.

3. In regard to the Danube at Vienna, with a tabulated statement of the highest and lowest water levels, observed at Vienna in each year from 1826 to 1871, with the calculated mean level; a tabulated statement of similar observations at Orsova, for the years from 1840 to 1871; and a tabulated statement for comparison of the height of the Danube at ten other stations on the river; a diagram representative of the observations at Vienna, in the period 1849–1871; a diagram representative of the delivery or flow in the several months of the year in the two periods 1826–1848, 1849–1871; and a diagram representative of the comparative water levels at the several stations on the Danube mentioned in the tabulated statement.

There is given a similar tabulated statement of observations made at the pegel on the Oder at Küstrin, from 1778 to 1835. And in regard to all of these he writes: "To facilitate the comparison the fall in the level in the five rivers named, I have reduced the recorded observations to their equivalents for a period of 50 years, and I have thus obtained the results embodied in the following table. The measurements are given in Rhenish inches:—

Names of Rivers and location of pegel.	Periods of observation.	Fall in the *mean* level in half of the period observation.		Rise or fall of *mean* in half of period of observation.	Lowering of *mean* level reduced to period of 50 years.	
		Lowest.	*Mean.*		*Lowest.*	*Mean.*
Rhine, at Emmerich,..........	1770–1835, 66 years,....	13·25	16·42	+ 0·83	20·06	24·88
„ at Dusseldorf,..........	1800–1870, 71 years,....	– ·60	4·73	+ 8·58	– 0·83	6·66
„ at Cologne,.............	1782–1835, 54 years,....	7·21	4·27	+ 1·5	13·33	7·91
„ at Germersheim,.......	1840–1867, 28 years,....	unknown	16·63	unknown	unknown	59·39
Elbe, at Magdeburg,...........	1728–1869, 142 years,...	for 29 years 29·	31·	– 9·	15·76	16·85
Oder, at Küstrin,...............	1778–1835, 58 years,....	9·45	10·13	× 1·56	16·27	17·45
Vistula, at Marienwerder,.....	1809–1871, 63 years,....	27·66	16·50	– 1·58	43·90	26·2
Danube, at Vienna,...........	1826–1871, 46 years,....	5·04	8·46	– 10·07	11·39	18·39
„ at Orsova,.............	1840–1871, 32 years,....	14·76	17·62	– 11·08	46·12	55·06

"If we omit from this table the observations made with the pegel on the Rhine at Germersheim,—as the lowering of the water level there, together with the deepening of the river bed, is mainly attributable to the extensive rectifications of the river by cuttings, and only in a comparatively small degree to a diminution of the delivery,—we find that the greatest lowering of the water level is on the Danube at Orsova, amounting to from 46 to 55 inches; on the Vistula at Marienwerder from 26 to 43·9 inches; and on the Rhine at Emmerich from 20 to 24·8 inches; and on the other pegels of the rivers named from 6 to 18 inches.

"In the Elbe the falls of the lowest and of the *mean* water levels are 15·76 and 16·28; and they might indeed have been considerably greater had it not been that since 1842, in consequence of the great silting up of the river bed with sand, the lower water levels have been elevated from 13 to 22 inches.

"The lowering of the water level becomes so much the greater the larger the river is, and the nearer to the mouth of the river in the sea that the pegel is situated, and this for the reason that the region drained by the river is the greater, and that it is the sum of the reductions in the levels of all the brooks and streams and lesser rivers which have flowed into the main stream which is there represented in this greater lowering of the river level.

"In regard to the high floods of the said rivers, we see from the diagrams submitted that, with the single exception of the station at Orsova, in all of them floods have latterly occurred more frequently and reached a greater height than in the earlier years in which the observations were made, from which it appears clear as day that in these rivers at present, at times of high flood, a much greater quantity of water is delivered by them than in the earlier years.

"From the diagrams representative of the high floods, it is further apparent that in the earlier times of observation the rise of water, in consecutive years, was more uniform; whereas, in the later decades of the periods embraced by the observations, in one year there occurred a very great flood, and in the year before or the year after only a very insignificant rise of water; from which it follows that the alternation of very dry with very wet years occurs more frequently and to a much more marked degree now than formerly.

"This is particularly apparent in the tabulated observations on the Elbe and the Vistula.

"The cause of this remarkable phenomenon lies evidently in this, that since the clearing away of many forests, more especially in the mountains, deluges of rain and rain-spouts occur more frequently; further, while the rain-water, in lands devoid of trees, sinks less into the soil, it at the same time more speedily reaches the brooks and streams and rivers, and fills and overflows these water-courses; and finally, the body of water, now tearing along with rapidity, cuts up the mountain sides cleared of forests, and fills up the beds of the brooks and streams and rivers with earth and sand and rubbish, and so raises the bed of the river—whence a higher level is reached by the water-surface.

"The correctness of this allegation is being attested, in a way which it is saddening to contemplate, by the ever more frequently recurring inundations in Italy, in the south of France, in Hungary, in Bohemia, and in many other lands.

"The aforementioned phenomena of high floods led a distinguished meteorologist to express to me the conjecture that the great increase of the body of water passing along our water-courses, in high floods, may be about equal to the diminution observable in the low and *mean* levels.

"This conjecture, however, is not in accordance with the facts of the case, because, as I have already shown, in the case of the Rhine and of the Elbe, the annual delivery is approximately represented by the *mean* water-levels, which, even in all these five rivers named, is on the decrease. But the incorrectness of the conjecture is more particularly manifested by the tabulated observations by the pegel at Orsova, in as much as, from the geographical position of the very extensive basin drained by the Danube, it frequently happens that the high floods of several of the large affluents coincide in time with that of low water level in several other important accessories of the river, and yet there is not an equivalent compensation for the lesser supply coming from the one class of affluents, in the greater supply coming from the other, in as much as, even at Orsova, the average of the floods of the *mean* and of the lowest levels have fallen still more than have these in the four other rivers named.

"But even if, in accordance with this conjecture, in particular years with repeated extraordinary high floods, some such equalisation of the increased and the diminished delivery of a river should occur, this would supply but little consolation for man, as the great evils consequent on the diminution of the delivery of water at the lowest and the *mean* levels are not obviated by the more frequent occurrence of the greater delivery during high floods, but are being more than ever increased in that those high floods now occasion more frequent and more disastrous inundations."

Herr Wex goes on to say:—"Having in foregoing statements given indisputable evidence that in the five principal rivers of Central Europe,—the Danube, the Rhine, the Elbe, the Vistula, and the Oder, the basins of which embrace an area of 26,860 [German?] square miles,*—the lowest and the *mean* annual water levels, and consequently also the quantities of water delivered by these rivers, during a lengthened period of many years, has been continually decreasing, we may from this draw the following conclusions:—

"1. As the aforesaid rivers are fed mainly by the brooks and streams which flow into them, there must have been also in these a continued decrease in the quantity of water delivered by them for a great many years, from which we may further conclude that if observations had been made on the levels of the different feeders, similar to those which have been made on the five large rivers named, and these had been compared, they would have supplied results similar to those at which we have arrived concerning these.

"The correctness of this allegation receives confirmation from the fact that many manufactories, &c., which have been built during the last fifty years, on rivulets and streams, have experienced a marked diminution in the quantity of water coming through their water-leadings, and it has been found necessary to employ steam-engines to meet the deficiency of their water power, which was originally sufficient for the work they had to do.

"2. As it is possible that the causes which have produced the effect of the lowering of the water level, and diminution of the quantity of water delivered in these five river basins, operate equally in the basins of the other rivers and streams in Europe, and not only so but in the most populous and cultivated districts of the other three quarters of the globe—it may be assumed that in most of the streams and rivers on the surface of the earth a similar lowering in the lowest and *mean* levels of the body of water delivered by them has taken place; while the high floods in the same, reaching a higher point, and becoming of more frequency, discharge a greater quantity of water, and produce more extensive devastating inundations than previously was the case.

"3. If the causes which have operated in producing the decrease of the usual water flow of the streams and rivers, with the rapid over-

* A German mile is equal to 4½ English miles.

flowing of them in times of flood, in the course of the last 140 years, were to continue to operate also in the future, it is evident from what has taken place that in brooks, and streams, and rivers, the lowest and the *mean* levels of these may be expected to be lowered still further in the future. And the question forces itself upon every one involuntarily, to what degree may this diminution in the quantity of water thus delivered by the several streams and rivers be carried?

"In the principal rivers, the Danube, Rhine, Elbe, and Vistula, it is scarcely to be supposed that the lowering of the lowest level of the flow will go on till it reach the very ground of the bed of the stream, occasioning the temporary drying up of the river altogether: seeing that the two first named rivers are in part fed by the melting of the masses of ice and snow lying on the Alps; while, further, it is to be hoped that the occasion of the lowering of the water level will not be carried beyond a certain limit; and finally, because the highest and the lowest level of the stream occur in many of these streams and affluents at different times of the year from what they do in others.

"If, however, we look on the other hand to the very considerable lowering of the lowest and the *mean* levels of the rivers mentioned in the foregoing table, which has taken place within the comparatively short period of 50 years, we are brought to the disturbing conclusion that these five rivers, in the course of 100 or of 200 years, may have their lowest and average levels so lowered that they will be no longer navigable if we do not take measures to counteract the cause which is continuously operating to effect the diminution of the water flow in these rivers.

"The brooks and streams, on the contrary, which drain only basins of limited extent, may, by the continuous lowering of the water level; and by the diminution of the delivery in them, be converted into intermittent torrents, which lie dry during many months of the year, and then, on a fall of rain, snddenly fill and deliver immense bodies of water.

That the dread of this is not without foundation is proved by numerous cases in which very large rivers, which in previous centuries, according to historical records, were navigable at all seasons of the year, have become now only *wildbäche* and torrents, such as, for example, are most of the torrents which characterise the southern slopes of the Alps in Italy and in Carinthia. Many other streams and rivers, which not many decades back were of full water, have latterly, and within the memory of man, become torrential streams, which pour down large bodies of water when, and only when, there have been dashes of rain, and from what has been stated it may be seen that the prognostication is not without foundation when I allege that if the causes which have, during the last 140 years, occasioned a lowering of the water-level and diminution of the above-named five European rivers shall go on operating in the time immediately before us, the result will be that the level will be still further lowered and the delivery diminished, until bye and bye they become so reduced as to be unnavigable.

"Although, beyond the results which have been published by Dr Berghaus in his 'Hydrography,' which has been quoted, and which, unhappily, are but little known, we have hitherto been unable to obtain reliable compilations and comparisons of observations continued for many years of the water-level on the larger rivers, there are men of observation and experience who, in consequence of what they have noticed on some few rivers, have called attention to the diminution of the water supply which is going on. An instance of this we have in the following communication, which is well-deserving of consideration, found in an article, by F. Perrot, in *Deutsche Monatschrift für Handel, Schiff-fahrt. und Verkehrswesen* (I. Band, Rostock, 1872).

"A consideration of the three rivers—Weser, Elbe, and Oder—makes clearly manifest a reduction in the quantity of water delivered by them, and a silting up of the river-bed with sand. It has been calculated that if the Elbe continue to diminish in the future at the same rate at which it has been diminishing up to this time, it will soon be impossible for heavily laden ships to pass by it. Nor is it otherwise with the Oder; in the very dry year 1858, there were only *eleven* days in which the navigation of the Oder in Silesia could be carried on with full force. The Weser delivers the smallest body of water of the three. One principal reason for this is the destruction of forests which has taken place on the heights which are found alongside of the river, and which the Government have latterly taken steps to prevent; but still more than what has resulted from the destruction of forests has been the consequence of the rectifications of the river-bed, which it has become a general practice to carry out.

"After weighing fully the collected observations on the water level, and consequences deduced from them in the foregoing treatise, I think no Hydrotechnik will venture to call in question the correctness of the allegations advanced by the distinguished hydrographer Dr Berghaus, in the year 1835, which allegations have been confirmed and established by myself, that in the brooks, streams, and rivers in central Europe, within the period of observations, extending over about 140 years, high floods now appear oftener and attain a greater height; on the contrary, the lowest, and the *mean* levels of the rivers are falling, and consequently the delivery of the water by these streams and rivers is being continuously diminished to a very great degree."

There follows an expression of the views of the author on the great practical importance of the fact brought to light. In the second chapter he describes the reduction observed in the flow of springs and in the quantity of water yielded by them, and after citing numerous facts, illustrative of these points, he thus concludes :—

"In regard to the diminishing of subterranean waters, we can adduce the following evidence :—

"As we have in the preceding chapter shown, from observations on the water level continued through long series of years, that there has been seen in later decades a lowering of the level of the lowest and of the *mean* annual flows, while the high floods, consequent on storms of rain, have become of more frequent occurrence—from which it comes to pass that a greater quantity of water is thus carried away at such times than formerly—it follows as a consequence that if the quantity of the rainfall remains the same, the proportion of this flowing away on the surface of the earth in such circumstances has increased. On the other hand the proportion sinking below the surface must be less; and from this it comes to pass that the quantity of the subterranean water supply, the drainage and superficial waters, and with them the springs which are fed by them must have been reduced; and the correctness of this conclusion can be established by the following facts:

"From these long continued observations on river levels we have further proved that on brooks, streams, and rivers in these later times, the lowest and the *mean* levels, and also the quantity of water delivered, have been being continuously reduced, and that to a marked degree; and that in the very months during which the water courses have been fed almost exclusively from subterranean flows of water and from springs the diminution of the water delivered has been greatest. Whence it may with all justice be concluded that in these later times the water supplies in subterranean reservoirs and in the water bearing strata have decreased, and also that drainage waters and the springs in a river basin in their collective contributions now furnish smaller water supplies to the feeding of the river course than was the case at an earlier period.

"Dr H. Berghaus has in his work on 'Hydrography' which has been cited, advanced on this point (p. 30) the following doctrines:

"In some parts of the world it has been remarked, the springs have suffered a loss in the quantity of their water supplies. Thus it is in France in what was formerly Poitou, and in the department of the lower Charente, where there has been remarked a decided reduction of the springs since 1825.

"The phenomenon is attributable to the desiccation of the land, the cutting of canals, trenches, &c, while Fleuriau of Bellevue has alleged that the cause is to be found in a diminished rainfall.

"It can also be established by manifold evidence that of late years many springs have dried up, and that in a great many others the quantity of water yielded by them has been greatly reduced; further it is generally known that several solidly and skilfully constructed aqueducts which erst while conveyed a rich supply of water have become completely useless in consequence of a permanent deficiency of water which has arisen, and that very many old wells known amongst us as inexhaustible have become, since 1852, in consequence of the lowering of the water level in the subterranean strata by which they were fed, in some cases absolutely dry; and in other cases so impoverished in water supplies that the wells must be sunk some fathoms deeper if they would be made permanent sources to meet the demand.

"From amongst the numerous cases which have become known to me, I shall adduce but a few specimens:

"It is generally known that the city of Rome, in its pristine glory, with its public fountains and baths, and its several aqueducts, was exceedingly richly provided with water; some of these, from the drying up of the springs by which they were fed, have now run dry, and others have lost a large share of their water supply—as, for example the aqueduct *aqua vergine* (some 20,000 metres, or between 60 and 70 feet, long), which it is now in contemplation, at extraordinary expense, to reconstruct.

"The springs and aqueducts which, at one time, provided for the City of Constantinople a very abundant supply of water for drinking and for use, have fallen off to a very considerable extent in their productiveness, so that it has become necessary to seek out more, and more remote, springs.

"The world-wide renowned fountains and water-works of Versailles were formerly so abundantly provided with water from the aqueducts by which they were supplied that they could play almost the whole day long; whereas now, from the great diminution which has taken place in the water coming to them, this must be allowed to accumulate for about twenty-three hours to allow the fountains and other water-works to play a single hour.

"So also with the numerous fountains and artificial cascades in the Belvidere-Schwarzenberg and Lichtenstein-Gardens at Vienna, and those in the palace garden at Schönbrunn, which were abundantly fed by spring-water led to them, they stand now almost quite dry, as a saddening monument of the dried up springs.

"The City of Vienna has, besides, about 10,000 sunk wells, and in addition to these nineteen different aqueducts, with which the springs and drainage waters in the environs of Vienna are intercepted, collected, and brought into the city. After the water in the sunk wells had not only diminished, but, in consequence of the filtration from the canals, had become deteriorated—and also the quantity of water brought in at one time by the aqueducts had become very much reduced; there was constructed, in the year 1836, the Emperor Ferdinand's aqueduct, by means of which were brought into the City of Vienna, from the Vienna *Donaucanale*, near Nussdorf, by long and deep suction pipes, an aggregate of about 100,000 *eimers* of water daily; and now, after this aqueduct also, through a lowering in the water-level in the Vienna *Donaucanale*, and partly through the coincidence with this of a sliming up of the suction pipes, has become insufficient and precarious, the commune of Vienna, after year-long negociations, has seen itself under the necessity to seek to obtain the two million *eimers* per day, required by the city for drinking and necessary uses, from the high springs of the Schneeberg (Kaiserbrunnen and Stixensteinerquelle), by means of a canal about twelve German miles long,* which aqueduct will absorb a capital of about sixteen million of Guldens [or £1,600,000 sterling]."

Herr Wex goes on to say:—"I consider that I have satisfactorily proved, by the foregoing observations, deductions, and examples, that in recent times the supply of water in subterranean reservoirs, and in the water-bearing strata of the earth, is being diminished; further, that many of the drains and springs of to-day have become some quite dry, and others yield a comparatively small supply of water;

* A German mile is equal to about 4½ English miles.

and finally, that through these changes the lowest and the *mean* water-levels in brooks, streams, and rivers are being continuously lowered, and the quantities of water delivered by them continuously diminished.

"If this continuous diminution, which has been going on for the last 140 years, is to go on continuously still, then will these results and changes on the surface of the earth entail on coming generations evils, and evils of incalculable extent and magnitude. Through the lowering of the level, and reduction of the rivers and of the subterranean drainage, and also through the alternation of very wet and very dry years,—such as is shown, by the diagram referred to, to be prevailing,—will the fertility and productiveness of the land be reduced in no inconsiderable degree, and not a few lands now covered with luxuriant vegetation will become veritable deserts, cheerless and desolate.

"After the drying up of many brooks and streams, and after the conversion of streams and rivers into torrents, in consequence of these changes men would have to go for their water supplies for drinking and for domestic use, and for other purposes, either to the deeper-lying water-bearing strata of the earth, or to a greater distance from their dwelling; whereby the cost of the water consumed would be increased, while many industrial establishments and manufactories would be deprived altogether of the supply of water indispensably necessary to their operations, and would have either to adopt expensive means of providing a substitute for what has been lost, or remove to some remote district where brooks and rivers have not as yet been deprived of their water supplies.

"Finally, by the continuous diminution of water in streams and rivers, the former would become quite dry through the greater part of the year, and the latter would become unnavigable.

"As, through the consideration of what has been advanced, it may thus be seen that, through the continuous diminution and lowering of the flowing water on the surface of the earth, there is imperilled—and that to a great extent—not only the prosperity and the health, but also the existence of future generations, it is desirable that numerous students of physical science should be incited to further research into the cause of these intimately connected phenomena, and then to devise measures to avert the impending calamity, in so far as it may be within the scope of man's power to do so."

The author adds:—"I have given myself also to an attempt to a solution of this difficult problem, and I give the results of my researches in this study in the two following chapters, in the hope that distinguished *collaborateurs* in the same calling and men of scientific attainments may prosecute further the researches I have been privileged to commence, and that the results of their study may bring great good to generations yet unborn."

The chapter which follows is occupied with a discussion of the cause or occasion of a diminution having taken place in the quantity of water flowing in streams and rivers, which he thus concludes:—

"When we fully realise what is implied in the opinions expressed by men of science, and practical men expert in such matters, in various countries and in very different parts of the world, after long experience, observation, and research, we find that forests affect to a very great extent the quantities of water coming from springs and flowing in rivers; that they affect the climate; and that they have a great effect upon the fertility of the lands in which they exist; and that thus:—

"1. The deposit of rain from the atmosphere is greatly increased by the amount of woods in a district, in as much as mists and clouds passing along the surface, striking upon the forests, have the moisture of which they are formed condensed and precipitated as rain. Further, the temperature within the woods is cooler by day, and, on the contrary, warmer by night than it is in the open fields and meadows; and by reason of this, there is a continual circulation of air in the vicinity of forests whereby mists and clouds are precipitated and led to discharge themselves of their contents. This happens not through the forests in and for themselves, nor as a consequence of the forests of themselves, but through the difference between the forests and the open fields; and on this depends the abundance of the rain. It is also very manifest that the forests exercise an attractive influence upon the clouds, by their attracting from them electricity with which they are charged, and with this the water of which they are composed, increasing thereby the rainfall. It is also an ascertained fact that a great part of the water precipitated as rain remains on the leaves of the trees, one part of which falls to the ground, but another portion of which evaporates into the atmosphere, and is again precipitated as fog, mist, dew, or rain,—whence it comes to pass that rain water is kept longer within forest lands, and may be precipitated oftener than once, whereby the rainfall is increased.

"2. Through the abundance of forests will the copiousness of the subterranean drainage flow, and springs be increased, while the rain water retained by the foliage of the forest trees, falling slowly to the earth, is kept by the spongy character of the ground in woods from flowing quickly away, and is in part absorbed, or is left to permeate the mineral strata, which is considerably facilitated by the numerous spreading roots of the trees penetrating cracks, fissures, and canals in the superficial ground, by which means the rain water reaches a greater depth, and this in a much greater quantity in forest ground than in the open field. Further, by numerous experiments it has been established that the evaporation of the humidity in the open country is at the least from four to five times as great as it is in woodlands; from all which it appears that the moisture absorbed in forests is not so readily evaporated, but is retained and directed to the feeding of drainages, springs, and brooklets.

"3. If forests be uprooted, more especially in mountainous regions, or even in somewhat hilly country, the rain drops, falling upon the exposed ground with some force, tear it up, and then flowing down the declivity with considerable rapidity carry with them earth and stones towards the brooks and streams and rivers, by which these water courses are suddenly filled up, and experience much higher and more devastating overflowings, and inundations, than was the case while the woods stood, as is explicitly testified by the aforementioned tabulated observations of river levels.

"4. Through the extensive clearing away of forests the heat of the summer months and the desiccation of the ground becomes increased, then, as a consequence of this, the duration of droughts is prolonged, and from this there follows naturally a diminished productiveness of the land.

"These most disastrous effects of the clearing away of forest show themselves in a very marked degree in these countries, once blessed with a luxuriant vegetation, Palestine, Persia, Greece, Sicily, Spain, and the Canary Islands."

It is stated also that "a great cause of the diminution of water supply from springs and subterranean reservoirs in Europe has been the draining of lakelets and ponds, and the draining of bogs and marshes, which has taken place, in various parts, of late years." And "a third cause of the diminution of water in springs and rivers at present going on is to be sought for in the greatly extended, and still from year to year extending, operations to bring under cultivation, to cultivate, and to improve the land." Of both of which statements illustrations are given, with illustrations of the effect of the latter when carried on on hill sides, to increase the violence and the magnitude of torrents and devastating inundations.

There follows a chapter devoted to the consideration of measures proposed with a view, on the one hand, to prevent continued and ever extending devastation occasioned by inundations; and on the other to arrest and prevent the continuous diminution of water in springs and in rivers in their lowest state, and in their *mean* delivery. But it is the facts of the case established in regard to the effects of forests on rivers and springs with which alone we have at present to do.

The paper was subsequently published, and it excited much interest. By several learned Societies Commissioners were appointed to report upon it. Amongst others this was done by the Royal and Imperial Academy of Science of Vienna, and the Imperial Academy of Science of St Petersburg. It was also favourably considered and approved by the Society of Engineers and Architects of Vienna, the Geographical Society of Vienna, the Forest Academy of Mariabrun, by several Polytechnic Schools, and by many men of science.

In regard to the views of Herr Wex relative to the phenomena observed, the Commission appointed by the Academy of Science of Vienna reported :—

"In view of the facts brought forward by the author, the Commission has come to the conclusion *that the diminution seen within the last century, in the medium and lower heights of the rivers made the subject of observation, is attributable to a diminution in the annual delivery of these rivers.*

"The author finds that the diminution of the quantity of water in the river is attributable to a diminution in the quantity of water yielded by springs, of which he finds additional indications in the diminution of water in streamlets, aqueducts, and wells.

"The Commissioners agree with the author in this view, considering the low depth of water in the rivers to be justly attributable to the quantity of water flowing throughout the whole district constituting the basin of the river having been reduced.

"The causes of this general diminution in the flow of water may be found—1. In a diminution of the annual rainfall, connected with the extension of agriculture occasioned by the clearing away of forests; 2. In an increased evaporation from the surface of the soil, consequent on the change of culture spoken of; 3. In such a change in the mode of flow that the rainfall, instead of being, for the most part, retained for a time and percolating through the gravel, flows away quickly, producing brief periods of high floods, alternating with protracted periods of drought."

After reporting their opinion in regard to the effects of forests on the distribution of the rainfall, the Commissioners go on to say :— "The copious flow of springs, and the abundance of water in rivers, however, does not naturally depend solely on the quantity of rain falling in the course of the year; for, on the one hand, a very considerable quantity of the rainfall is returned by evaporation to the atmosphere; on the other hand, the nature of the soil determines, in a great measure, the quantity of the rainfall which sinks into it, forming subterranean reservoirs from which springs are fed.

"In regard to both of these phenomena, forests exercise an influence which can hardly be estimated too highly.

"It is proved by direct observation in France, and in the forest stations for meteorological observations in Bavaria, that the variations in the temperature of the air in the forests are less than in the open country. Especially does this hold good in the hours of the day and in the seasons of the year in which the greatest heat prevails, the degree of temperature being at these times considerably lower than in the open country, and, in accordance with this the temperature of the soil in the forest, is considerably below that of the land unshaded by trees.

"In like manner the degree of humidity in the forest differs from that in the open country; this being, at all seasons of the year, greater within the forest than it is outside.*

"In view of these facts, we need not be surprised that the evaporation in the forest is found to be much less than it is in the open field;† and all the more so that, besides the relation of evaporation to temperature, the strength of the wind or movement of the air constitutes an essential element in the operation, and there is proportionally much less movement of the air in the forest.

"In proportion as it is important to obtain a correct determination of the quantity of the rainfall which is lost by evaporation so is it difficult to do so.

"As the means of making observations on the amount of evaporation from the surface of plants and the surface of the ground are different,—besides which, the comparison between the quantity of the rainfall and that of the evaporation is prejudiced by difference in

* According to Ebermayer, the difference in the four seasons, from spring onwards, amounts to 5·7, 9·3, 5·2, and 5·2 per cent.

† According to Ebermayer, the evaporation from an exposed suface of water in the forest was about 64 per cent. less than from one outside the forest. —*Zeitschrift für Meteorologie*, viii. 253.

the exposure of the instruments, they being in some places exposed to the sunshine and the rain, in others protected from these, by difference in the sizes of the atmometers, and by difference in the materials of which these are made,—it is not impossible, from these causes, that an atmometer of small size, made of metal, and set in the sunshine, may give an annual evaporation which exceeds by far say two or three times, the amount of the rainfall.

"In consequence of the difficulty of determining by direct observation on evaporation the evaporation from the ground, and thereby determining the quantity of the rainfall available for feeding springs and streams, some have sought to determine this directly in part by comparison between the quantity of water delivered by a river in the course of the year, and the rainfall on the whole valley drained by it; or, otherwise, between the quantity of water percolating through a given section and the rainfall over a given range,

"If now there be also in a wood a considerable portion of the rainfall kept by the twigs and leaves from immediately reaching the ground, the difference between that rainfall and the evaporation (amounting, according to Ebermayer, to 72 per cent., *Zeitschrift fur Met. viii.* 274) will also be retained longer in the forest and get time to permeate and feed the springs.

"The remainder of what has not been dispersed by evaporation either penetrates the ground or flows away over the surface.

"In the former case it seems principally to feed the springs; in the latter case it is carried directly to the water-courses, and after a brief time produces a more or less considerable flooding of these.

"It is generally acknowledged that the forest, through the vegetation of lichens, mosses, &c., peculiar to it, is pre-eminently fitted to absorb the rain, to store up the same, and only gradually—little by little—to yield it again.

"In view of this, the aforementioned investigations in regard to the quantity of water which sinks into the ground to certain depths is very instructive, as they give on the one hand the relative effect of different kinds of soil on the absorption of the different plants with which they are covered, and on the other the proportion of the moisture absorbed by the soil in the course of the year. It appears, according to the latest of these, that the absorption of the forest is especially manifested in the warm season of the year.*

"In regard to that portion of the rainfall which does not penetrate

* According to Ebermayer, in the summer the following per centages of the rainfall was found at the depth of one metre :—

the ground, but flows away over the surface, and to which popularly is ascribed the swelling of floods, there exists no difference of opinion in regard to the influence of forests. On all hands it is agreed that with the removal of forests the tributaries to water-courses rush more rapidly to these; and that in mountain regions, on steep precipices, from which woods have been cleared, the fruitful soil is swept away, and water-courses are converted into torrents.

"In the cutting down of forests which present no longer, as previously, a hindrance to the flowing off of the rain-water by their manifold united roots, by lichens and by mosses, may be seen generally the cause of the more frequent and extensive, and ever more threatening inundations.

"With the facts before them of the diminution of the water in the rivers, which diminution is connected with a diminution in the copiousness of springs, the Commission find the cause of these phenomena to lie—1. In the continued extensive destruction of forests, the beneficial effects of which consist in an increased humidity of the air, a reduction in the extremes of temperature, a diminution of evaporation, and the securing a more regular distribution of the rainfall; while the injurious effects of the destruction of them is seen in an alternation of periods of drought at one time, with wasting floods at another.

"2. In the drying up of the lakes, marshes, and bogs, which increased the humidity of the atmosphere, diminished evaporation elsewhere, kept down excessive heat, and finally escaped through rents in the ground, increased directly the formation of springs.

"3. In the breaking up and cultivation of extensive tracts of country, for the watering of which considerable quantities of water are required.

"4. In the increase of population and of domestic animals, although the diminution of the water occasioned by these causes can amount to what must be relatively a small portion of the whole.

	With litter.	*Without litter on the ground.*		
In open ground,	19	—	14	11
In the forest,	52	72	65	36
Difference	33	53	51	25

Earlier experiments come to us from Maurice in Geneva, and Gasparin in Orange. A later one, on a great scale—undertaken by E. Risler at Calève, by Nyon (Canton Wallis), who sowed different experimental fields, of 12·300 square metres, with corn, clover, etc.,—determined the infiltration at 0·35 metres deep, and showed the comparative humidity of the soil with that of the superficial soil under different conditions of culture.—*Annuaire Meteorologique de l'Observatoire de Paris, pour* 1873, *p.* 277.

"5. And, lastly, it appears to this Commission that the view expressed M. S. Saeman, * according to which, in the interior of the earth, water is continually required for the formation of minerals in which it is chemically combined, and from which mineral operation a diminution of water must follow, deserves consideration."

At the instance of the Academy of Science of Vienna, the paper by Herr Wex was brought under the attention of the Imperial Academy of Science in St Petersburg, by which also a Commission was appointed to consider it, to supply information in regard to similar phenomena in Russia, and to report. In a report submitted by the Commission to a meeting of the Academy held on the 27th January 1876, amongst others things it is stated, in reference to what had been said by the author in regard to the effect of the destruction of forests on the humidity of different countries :—"To these examples we may add the districts in Southern Russia, where it is well-known that large forests existed about 150 or 200 years ago in the very spots invaded by the steppes, the higher portions of which are perfectly arid, so that the inhabitants, to prevent their dying of thirst, are obliged to live on the banks of tiny streamlets in the lowest valleys. We may also make mention here of the Volga and Dnieper, where the destruction of the forests, from south to north, has made and is making such progress that these rivers, so indispensable to the commercial prosperity of Russia in the middle and in the lower portions of their course, now flow through regions which are quite cleared of forests. There the floods reach a higher level than they did formerly. And who has not heard serious complaints, annually repeated, with regard to the modifications of river-courses caused by these floods by changing the direction of the navigable channel and hollowing out new beds for the streams? And who does not know that gorges, deprived of water in winter and dry in summer, during spring, in consequence of the rapid melting of the snow on the naked steppes, become, after heavy rains, impetuous torrents, which undermine their banks and carry away large portions of valuable soil? Furthermore, all the affluents of these rivers bring down masses of detritus, which every year contribute to the formation of new river beds. We may state it as our conviction that the injury caused at present by the Volga, the Don, and the Dnieper, would be much

* *Sur l' unité des phénomènes geologiques dans le système du soleil. Bull, de la Société Géologique de France.* 2 *Serie, t. xviii. p.* 322. 1861.

less serious if the land along the banks had been preserved from deboisement."

Thus do abound observations which go to establish it as a fact that, whatever may be the effect of trees on the rainfall, there is an effect produced by them on the humidity and moisture deposited from the atmosphere which is such as to affect the existence of springs, and the flow of rivers. It is the fact alone, and not the way in which it has been brought about, with which we have here to do, and the fact seems to be established beyond question by the observations which have been brought forward.

It is not to be expected that the treatise by Herr Wex should at once command universal unhesitating acceptance of all the observations cited, and reasonings and deductions founded thereon. Since it was published (in 1873) Herr Wex has collected a great many new and interesting observations of facts and experiments in relation to the diminution of water in lands under culture, and in relation to the influence of the extensive destruction of forests; and while these sheets are passing through the press he is carrying through the press a second treatise on the subject, in which he meets all doubts and conflicting observations known to him to have been advanced against the statement made by him in regard to the diminution of water in springs and rivers.

Reference is made by the Commissioners appointed by the Academy of Science of Vienna to report on the treatise by Herr Wex, to observations made by Dr Ernst Ebermayer, professor in the *Central-Forster Lehanstalt*, School of Forest Science, Aschaffenburg. For some seven or eight years he had been engaged in the study of observations on the meteorological effects of forests, made by himself, or under his direction, and corresponding observations made by others. Results have been published from time to time in scientific journals. And the more important were embodied in a volume published under the title of *Die physikalischen Einwirkungen des Waldes auf Luft und Boden und Seine klimatologische und hygienische Bedeutung, begründet dürch die Beobachtungen den forstlich-meteorologischen stationen in Königreich Bayern.*

The following is a *resumé* of facts noted by him, embodied in a report on the Cultivation of Timber and the Preservation of Forests, submitted to the Congress of the United States in 1874. It is given as taken from a report made by H. J. Wiseman, Consul of United States at Sonneberg, to the Department of State, November 1873.

"That the forests of a country are not only of great importance in supplying many necessary productions of ordinary life, but also serve still higher purposes in the domestic economy of nature—to the extent that within certain limits the arability, the inhabitability, and beauty of the land depend upon an appropriate area of woods—has often been declared. Indeed, this fact is now generally acknowledged, at least by all educated persons, and it forms the basis of a series of legislative measures, which have for their object the protection of the forests from destruction and misuse on the part of the ignorant for selfish purposes. But, hitherto, the exact relations between the woods and the fields have not been fixed by the certainty of figures. There has always been a lack of scientific accuracy in connection with a matter of so great importance, simply because no systematic method has been carried out by which, from actual experiment, these relations could be surely determined. The discussions, therefore, which for years past have taken place on this subject, the conflicting opinions which have been advanced in literature and in scientific bodies, have been only valuable to the extent that they served to keep alive interest in a vital question. No argument which has been made has been deemed conclusive, because there has always been a failure to base theories upon the results of scientific researches.

"To obtain this scientific foundation upon which to prosecute future investigations, the kingdom of Bavaria has taken the initiative. Since 1867, under the organization of Dr Ebermayer, professor at the Forest Academy at Aschaffenburg, a series of meteorological observations and experiments have been made at several stations within the kingdom, which were selected as being best adapted for the object in view; and most painstaking and minute investigations have been pursued by competent and experienced observers. These interesting and very important results, which have been obtained by these six years of close inquiry, have just been made public.

"The observations have been made simultaneously at a station within the forest, and at a station corresponding thereto in all respects in the open country. The results which have been reached are as follows:

"1. That the average annual temperature of the atmosphere in the woods is somewhat below that of correspondingly situated areas which are unwooded. (About $1\frac{1}{8}$ to $1\frac{11}{16}$ of a degree Fahrenheit.)

"2. That the average annual temperature at the crowns of the trees is about $1\frac{1}{8}°$ above that which is found in dense woods at a distance of 5 feet above the surface of the ground; while in the former case the average temperature is $\frac{27}{40}$° below that of unwooded lands at a distance of 5 feet above the surface of the ground.

"3. That the average temperature of the spring within the forest was 2·95° below that of unwooded land. This difference was less apparent among shade-trees, than where pines were the growth.

"4. That the average temperature of summer in the day-time, in thick woods, is 3·78° below that of unwooded land.

"5. That the temperature of the atmosphere within the woods, in the summer season, increased 3·94° from the ground to the tops of the trees.

"6. That the average temperature of autumn within the woods was scarcely $1\frac{1}{8}$ below that of the open land; and

"7. That in winter this difference in temperature almost entirely disappeared.

"These briefly mentioned differences between the temperature of the atmosphere within the forests and that of unwooded lands, affect the constant current of air in the day-time. For instance, the stream of air flows from the surface of the ground within the forests toward the periphery of the woods, and thence spreads over the open fields. It afterward passes back again to the crowns of the trees, and by coming in contact with the leaves which, during the day, are colder than the atmosphere, the latter itself grows cooler and heavier, and so gradually descends from the tops of the trees to the surface of the ground.

"At night the conditions are entirely different. The thermometer now is higher in the woods than in the open lands. The Bavarian observations for the month of July show that, while at midday the temperature within the forest is 8·01° below that of the unwooded land, at night it is 4·39 higher, (18 and 29 per cent.); in August, during the afternoon, 7·13° lower, and at night 3·71 higher, (16 and 22 per cent.) During the night, therefore, the colder and denser air of the unwooded land passes into the forest, displaces the warmer air, which rises and is cooled by contact with the leaves, and then radiates.

"The maximum and minimum temperature of the open lands is never reached in the forest. The [*mean ?*] atmospheric temperature of the woods always remains several degrees lower.

"From these data, therefore, it is evident that the thermal effects of woodland are of great moment, and that climatic alterations must result from deforestation on a large scale; that these climatic changes will consist, as a general thing, in increasing the annual temperature, and in sharpening still more the extremes of heat and cold. But these thermal effects are not alone confined to the atmosphere, but have, as well, a particular influence upon the soil. The Bavarian investigations have clearly demonstrated that the average annual temperatures at various depths beneath the surface of the ground are nearly equal; that the average temperature diminishes downward quite slowly and by small degrees, (at a depth of 4 feet never more than 1·12°,) but that the average annual temperature of woodland soil, at all depths, is below that of unwooded land, on an average of 3·37°.

"Further, it has been demonstrated that the temperature of the soil in the spring and summer is highest at the surface and diminishes downward. In spring the difference between the warmth of the soil at the surface and at a depth of 4 feet amounts within the forest to 5·62°. In summer these differences show 7·50° both in the wood and in the open land. But the soil of the woods in summer is 75.0° colder than that of the unwooded land, and the greatest difference has been found at a depth of 2 feet.

"In contrast to spring and summer, the temperature of the soil increases in autumn and winter, from the surface to a depth of 4 feet beneath. In autumn this advance of temperature, according to the Bavarian observations, amounted to 4·50° outside of the forest and to 3·49° within the forest; in winter, relatively 4·21° outside and 4·41° inside the woods. Wooded and unwooded lands have, therefore, in winter, to the depth of 4 feet, very nearly the same temperature; the result of which is that the influence of the woods upon the temperature of the soil is not less than that which they exert upon the temperature of the atmosphere.*

* It cannot be supposed that trees have any vital process by which a degree of heat is maintained above the medium in which they grow. Their trunks, branches, and leaves are heated and cooled in the same manner as inorganic bodies under like conditions of exposure. But wherever evaporation or condensation is taking place, the same change occurs in them as elsewhere, and the universal law of thermal result applies. "The trunks of trees," says M. Becquerel, "only acquire their maximum temperature after sunset. In summer it occurs as late as 9 p.m., while in the air the maximum temperature occurs from 2 to 3 p.m. Changes of temperature take place very slowly in the tree, but in the air they are rapid. When the leaves are cooled by nocturnal radiation they recover from the trunk by radiation the heat they have lost. The temperature of the air above the trees which have been heated by solar radiation, acts on the temperature of the air, and prevents it falling as low as it would otherwise have done."—*Comptes Rendus, Séances de l'Acad. des Sciences*, May 22, 1855, tome ix, p. 1049; also *Jour. of Scottish Meteorological Soc.*, (new ser.,) i, 234. [I give the note as given appended to the text, but I do not homologate what is said in the opening sentence.—J. C. B.]

"Far more important, however, than the thermal effects upon the soil and the atmosphere are the influences inherent to the forests of a country which affect the humidity of the soil and air, the quantity of the rainfall, and the abundance of the springs. In relation to these points the investigations of Ebermayer have produced very valuable results.

"In the first place, it has been discovered that the influence of forest-lands upon the absolute contents of moisture in the atmosphere—the evaporation pressure—cannot be proved, in spite of the fact that the air of the woods is always more humid, relatively, than the air of the open grounds. This is easily explained by the greater coolness of the former. The higher a place is situated, the more marked was the relative difference observed in Bavaria between the humidity of the wooded and unwooded country. Ebermayer assumes that the augmentation of aqueous descents, caused by a larger area of woodland, noticed at many places, is to be attributed merely to the increase of the relative moisture within the forests.

"In close connection with the relative humidity of the atmosphere of wooded and unwooded lands stands the quantity of water which has been discovered to evaporate at given points, during a given interval of time, at a certain temperature, and at a certain pressure of the atmosphere, from an open surface of water.

"The Bavarian observations have proved that in an average of one year less than 64 per cent. of water evaporates within the forest than outside of it. The fact is more remarkable, because the proportion of evaporation was nearly the same at all seasons of the year, although the temperature of the atmosphere of the forests and the open lands is so different in the winter from what it is in summer. This forces us to the conclusion that the *movement of the air*, which is very much less within the woods than outside of them, plays a far more important part in relation to evaporation than has hitherto been supposed.

"But for the abundance of water and the forming of springs in any country, the evaporation from rivers, ponds, and lakes is not so important, by any means, as the evaporation of the water of the soil.

"The amount of evaporation from one square foot (Parisian measurement) of an open surface show, in Parisian cubic inches, as follows :—

	In open land.	*In the woods.*
April, 1869	399	200½
April, 1870	373	226
July, 1869	407	151
July, 1870	394	151
October, 1868	158	73
October, 1869	194	50

"There evaporated, therefore, from the water contained in the soil of wood-lands, as well as from open water-surfaces, far less than evaporated from the water of the soil of the open grounds—about 40 to 50 per cent. in April, 60 per cent. in July, and 70 per cent. in October—and this decrease reaches its maximum in the hottest season. Still more glaring does this difference of exhalation appear when wood-soil, covered with leaves and pine-needles, is compared with wood-soil which is free of litter of this description.

"Under the first-mentioned conditions the evaporation from one square foot (Parisian measurement) amounted, in Paris cubic inches, to the following :—

	From uncovered wood-soil.	*From wood-soil covered with litter.*
April, 1869	200½	78
April, 1870	226	102
July, 1869	151	55
July, 1870	151	55
October, 1869	50	25

"In wood-soil covered by litter, when compared with the bare soil of the fields, the difference in the amount of evaporation per square foot (Parisian measurement) is shown, in cubic inches, by the following figures :—

	From bare soil of the field.	*From litter-covered forest soil.*
April, 1869	399	78
April, 1870	373	102
July, 1869	407	55
July, 1870	394	55
October, 1869	194	25

"From these figures, therefore, it is perfectly apparent how important are the influences of the woods of a country upon the abundance of its springs and the mellowness of its soil; and in this connection how essential are wood-lands which are covered with the litter of fallen leaves, the uprooting of which effects a direct injury to cultivation.

"But it must also be borne in mind that extensive areas of woodland materially increase the quantity of the rain. At Rohrbrunn (Spessart) 62 per cent. more rain falls than at Aschaffenburg, in its immediate neighbourhood, on an average of the years 1867 to 1871. Certainly one-quarter of the gross quantity of the rainfall was caught by the tree-tops and conveyed, by evaporation, again to the atmosphere, (average of the years 1868 to 1871 at all the meteorological stations.) But of the remaining three quarters of the aggregate rain which fell upon the earth, there evaporated during the same interval six times less from the soil of the forest than from that of the open country; and, therefore, a much greater quantity of water is absorbed by the forest, where the leaf-litter is retained, penetrating to the deeper strata of the earth, than is held by the soil of the fields. This fact is of the utmost importance in its relation to the formation of springs to the supply of water to the rivers, and to all the numerous interests of agriculture which stand in so close connection with it.

"The investigations of Ebermayer have also led to very important conclusions in regard to the amount of ozone in the atmosphere.

"The air contains most ozone in situations of great altitude, where there is much humidity. In dense woods, however, the amount of ozone in the atmosphere is somewhat less than in the directly adjoining open land. The most healthy dwelling-places, therefore, are not in the midst of the forests, but at their borders.

"The proportion of ozone, on an average, at the six meteorological stations in Bavaria, on the borders of the forest, relatively to that contained in the atmosphere at Aschaffenburg and Zwickau, was as follows:

In spring,	as	8·20 : 6·80 : 3·20
In summer,	as	7·70 : 3·20 : 3·10
In autumn,	as	8·00 : 5·40 : 2·20
In winter,	as	8·40 : 6·00 : 1·80

"These few data satisfactorily demonstrate the general importance to which these forest meteorological stations may lay claim. A considerable increase of the number of these observations may soon be expected.

"To the six stations now existing in Bavaria will shortly be added ten in Prussia, one in Mecklenburg-Schwerin, and three in Alsace-Lorraine. In Bohemia, at Promenhoff, one observatory is already in operation; also three in Switzerland, Canton-Berne. The erection of a station at Valambrosa, near Florence, in Italy, is also projected."

About the time that Herr Wex's paper was published in 1873, there was held in Vienna an International Congress of distinguished students of forest science. By them was resolved to send to the different governments of the civilized world the following expression of their views :

"1. We recognize the fact that, in order to effectually check the continually increasing devastation of forests which is being carried on, international agreements are needed, especially in relation to the preservation and proper cultivation (for the end in view) of those forests lying at the sources and along courses of the great rivers, since it is known that through the reckless destruction of them, there results a great decrease of the volume of water, causing detriment to trade and commerce, the filling up the river's bed with sand, caving in of the banks, and inundations of agricultural lands along the river course.

"2. We further recognize it to be the mutual duty of all civilized nations to preserve and to cultivate all such forests as are of vital importance to the well-being—agricultural and otherwise—of the whole land, such as those on sandy coasts, on the sides and crowns, as well as on the steep declivities of mountains, and on the sea-coasts and other exposed places, and that international principles should be laid down, to which the owners of such protecting or "guardian forests" should submit in order to preserve the land from damage.

"3. We recognize further that it is the case that we have not at present a sufficient knowledge of the evils (disturbances in nature) which are caused by the devastation of the forests, and therefore that the efforts of legislators should be directed to causing exact data to be gathered relating thereto."

It has been noticed as a singular coincidence, that, at nearly the same time, the American Association for the Advancement of Science had under discussion measures tending to similar results, although not expressly designing to extend its recommendations beyond the limits of the United States, except in the way of correspondence with other associations having similar objects in view. It is not supposed that either of these bodies derived their suggestions from the other, although the proceedings at Portland *antedate those at Vienna only about three weeks in time.*

The coincidence, however, shows the wide and general prevalence of a realizing belief that the time for action *has now come,* and that it is the duty of all Governments to look well to the future, and take early and effectual measures to provide against the injuries that might soon follow a further neglect of interests in this regard.

SECT. IV.—*Immediate Action of Trees in Arresting the Flow and Escape of Rainfall.*

While it is true that the rainfall is only the precipitation from the air of a quantity of moisture which it could no longer hold in solution, it is no less true that thus often a much larger supply of moisture is brought to a locality than it would have obtained in the same time, or in a much longer time, either by deposit of dew, or by the attraction of moisture from the atmosphere by any of the constituents of the soil; and we have now to consider the immediate effect of trees upon it when thus precipitated. Some of these have been adverted to in documents which have been quoted; but they require more detailed consideration.

The testimony which goes to show that the destruction of forests has occasioned the drying up of springs, and that the replanting of woods has been followed by their re-appearance, seems to be incontrovertible; but it has been questioned whether the views which have been advanced and have been generally received in regard to some of the phenomena connected therewith be correct.

Marshal Vaillant, whose experiments on the emission of moisture from the leaves of trees have been cited in a preceding chapter, remarks:—"In the report read by Monsieur Becquerel, at the Academy of Science, it is asserted that *springs generally have their rise in mountains.* It is true, and according to nature, that the causes which formed the mountains have at the same time broken up the impermeable strata in which are stored the water which creates and supplies the springs. That *forests are more usually formed on mountain declivities than in the plains* is generally true, and this is a simple consequence of the superior fertility of the plains and valleys, and of the greater trouble which the agriculturist would have in cultivating such difficult localities where there are often not even forest tracks; but to conclude from this that there is a necessary and intimate relation between the existence of forests and of springs is perhaps a rather far-fetched conclusion; and we think it would be well to examine what the conclusion is really worth.

"The same report states that, 'the roots of the trees by dividing the soil make it more permeable and facilitate infiltration.'

"May we be permitted to make some observations on this point.

Usually there is no ground harder or less permeable than that formed close to the trunks of trees; if required we can bring forward, as a proof, the long and deep trenches which have lately been opened on some of the Boulevards of the capital, the substitution of rich vegetable mould for the exhausted and, as it were, petrified soil, and finally, the drainage works intended to convey air and moisture to the trees on the Boulevards. All these sufficiently prove that these roots would suffer in the soil in which they are condemned to grow, and they are powerless as regards the penetration of water or rain, as well as in imparting the least measure of permeability to the soil which stifles them.

"Monsieur Becquerel, in support of the opinion that forests are favourable to the maintenance of springs, cites two facts the importance of which we do not deny, but which would require a more careful study before being considered incontestable. We allude to the Scamander, which M. de Chouseul-Gouffier found to have disappeared, and the invasion by the lake of Tacariqua of a large tract of land formerly under cultivation. Is it quite certain that the source of the Scamander has dried up, simply in consequence of the destruction of the cedars on Mount Ida? May not the reservoir which supplies this spring have been disturbed by some subterranean convulsion? Have any observations been made regarding the other springs on Mount Ida? And as to the lake of Tacariqua may not the loose soil of such localities so often disturbed by volcanic eruptions have first sunk and then risen, so as to cause in the first place the water to retreat from, and in the second to invade, the shores of the lake? Does not the entire globe, even in its most stable portions, continually present such phenomena? On the western shore of Schleswig and Holstein, in the strata of the ground there are found alternate layers of peat, formed by fresh water, and marine deposits, which sufficiently indicate alternate rises and falls of the land.

"To resume I agree with my honourable friend, M. Becquerel, in saying that forests exercise a complex action. I add that this action has never been studied, specially with regard to the desiccation of the soil which they cover, and the exhaustion of the springs which may be the result. On this point there is work to be done, prejudices to be destroyed, and truth to be revealed."

All that is thus advanced by Marshal Vaillant is entitled to respectful consideration. But along with these theoretic objections may be taken into consideration facts which have been cited above in numbers, and at the same time the following:—

M. Conte-Granchamps, *Ingénieur en Chef des Ponts et Chaussées*, has established by direct experiment, made with precision and with the greatest care in the forests of coniferous trees situated in the regions of the Loire and the Alps :—

"1. That existing sources have ceased to flow on the destruction of forests.

"2. That these identical springs have re-appeared along with vegetation.

"3. That the discharge from a water-course, the *bassin de réception* of which is wooded, varies from one to two; whilst that of another water-course, proceeding from a *bassin de réception* which is devoid of woods, all things else being equal, varies from one to six.

"4. Finally, that the *reboisement* of one hectare, or two and a half acres, will increase the discharge from the spring sixteen cubic metres daily; whilst *gazonnement*, or covering it with herbage, in the same circumstances increases the discharge by four cubic mètres."

And on the other hand, M. d'Arbois de Jubainiville, in reply to an appeal made to its readers by the *Revue des Eaux et Forêts*, for information respecting the influence of forests over the water system, expresses himself as follows :—

"Several forest clearings have been executed in the canton of Vaucouléurs. I have tried to discover what changes have been produced in the springs. All the springs of this territory have their rise in the middle strata of the oolitic system. And the forests above are treated as are usually coppice and timber forests.

"In the territory belonging to the commune of Taillancourt the spring of Vaux-de-Bure had never dried up so long as the plateau which supplied it was shaded by the forest of Vaux-de-Bure, but ever since the half of that forest was cut down every summer the spring has ceased to flow. The clay bed underlying the spring is at no great depth; it lies within a few mètres of the surface throughout the greater part of the basin of supply.

"In the commune of Sauvoy, near the Mayoralty, a perennial spring became ephemeral when a wood was cut down which covered the side of a hill, at the foot of which the spring was situated.

"On the contrary, in the commune of Monsigny-les-Vaucouleurs, the partial clearing of a hill overhanging the spring has not interfered with the outflow, the fountain of supply seeming to be very deep.

"I have also examined the effects of exploitation where felling takes place in the basin of the springs, giving thus free access to to them of sunshine and wind.

"In the reserved quarter, in Maxey-sur-Vaise, the summer flow of the spring of Moymout was much diminished when its basin was exposed by the exploitations. The impermeable bed on which the water is collected lies at no great depth, for during the season of making charcoal the taste of the spring is affected by the smoke.

"The inhabitants of the small town of Void have also noticed a diminution in the summer discharge of water, on the destruction of the woods subject to a right of felling which surmount the springs.

"M. Clavery—who, for a long time, and with such enlightened care, has administered Commercy,—has also made similar observations on the water system which supplies that town. He writes thus on the subject :—

"'Since the exploitation of the woods situated in the basin of the source called Fontaine Royale, which supplies the town, for two or three months every year the inhabitants are deprived of water. Almost all the springs dry up about the month of July. Even before these woods were cut down this scarcity had begun to appear, but only slightly, very few springs being entirely dried up during great heat; but since the exploitations near the Fontaine Royale the greater number are exhausted every year.'

"Cutting down woods has a still greater influence on ponds. Thus the ponds situated in the reserved quarter at Taillancourt was full of water during the growth of the neighbouring woods, but ever since they were cut down it becomes dry during the summer.

"In the same way roads which were muddy and impassable have been rendered dry and good in summer by cutting down the adjoining woods.

"In fine," he remarks in conclusion, "forests increase the summer out-flow of the springs by preventing the ground being dried up, and this influence is all the greater when the water collects on an impermeable bed at no great depth."

From these facts, and the many others which have been adduced, there seems to be no room for doubt, notwithstanding the authority to be attached to anything proceeding from the pen of a man like M. le Marshal Vaillant, that forests exercise a great influence on the water system of a district.

But we can carry our investigations much further, and trace the operation whereby trees arrest and so regulate the flow of and escape of the rainfall in many of its details, and so make manifest what the effect of trees in this operation is.

Herr Wex has expressed his views on this point in a passage I have quoted, and Marsh in his treatise on the "Earth as Modified by Human Action," states in regard to a forest :—

"By its interposition, as a curtain between the sky and the ground, it both checks the evaporation from the earth, and mechanically intercepts a certain portion of the dew and lighter showers, which would otherwise moisten the surface of the soil, and restores it to the atmosphere by exhalation. While in heavier rains the large drops which fall upon the leaves and branches are broken into smaller ones, and, consequently, strike the ground with less mechanical force, or are, perhaps, even dispersed into vapour without reaching it.

"The vegetable mould, resulting from the decomposition of leaves and of wood, seems as a perpetual *mulch* to forest soil by carpeting the ground with a spongy covering which obstructs the evaporation from the mineral earth below, drinks up the rains and melting snows that would otherwise flow rapidly over the surface, and perhaps be conveyed to the distant sea, and then slowly give out by evaporation infiltration, and percolation, the moisture thus imbibed. The roots, too, penetrate far below the superficial soil, conduct water along their surface to the lower depths to which they reach, and then by partially draining the superior strata, remove a certain quantity of moisture out of the reach of evaporation."

The meteorological effects produced thus by forests resolve themselves into the prolongation and consequent increase of the evaporation of water falling in the forms of rain, snow, and hail, effected in two distinct operations, first the absorption and retention of a large portion of the rainfall, and second the retardation of the flow of the remainder towards the great reservoir and source of all, in accordance with the observation of the Hebrew preacher, "All the rivers run into the sea; yet the sea is not full: for unto the place from whence the rivers come thither they return again."

Mr Marsh speaks of the ever-renewed and increasing vegetable mould as a perpetual *mulch*, and in reference to the humidity of forest soil he cites the following passage from *Etudes sur l'Economie Forestière*, by Jules Clavé :—"Why go so far for the proof of a phenomenon which is repeated every day under our own eyes, and of which every Parisian may convince himself without venturing beyond the Bois de Bologne, or the Forest of Meudon? Let him after a few rainy days pass along the Chevreuse road, which is bordered on the right by the wood, and on the left by cultivated fields. The fall of water, and the continuance of the rain, have been the same on both sides; but the ditch on the side of the forest will remain filled with water, proceeding from infiltration through the wooded soil long after the other, contiguous to the open ground, has performed its office of drainage and become dry. The ditch on the left will have discharged in a few hours a quantity of water which the ditch on the right requires several days to receive and carry down to the valley." And but for this drainage into the ditch the water might have remained there for an indefinitely longer time. Thus by an operation, distinct from all that have been mentioned, the humidity of the soil is prolonged and maintained by forests. By continuous exhalations of moisture through the stomates of the leaves—the moisture being obtained in part, and it may be in great part, from what is stored up in these superficial and deeper-lying reservoirs, replenished from time to time by rain—the humidity of the air in a forest is increased; but it is the other phase of the operation with which we have at present more especially to do.

It is this effect of forests which has led to the extensive replanting of the Alps, the Cevennes, and the Pyrenees with trees, herbage, and bush, with a view to arresting and preventing the destructive consequences and effects of torrents. In a separate volume I have given a copious compilation of records of what has been done, of what led to this being done, and of the successful results which have followed. Here I may cite some of the statements made by one of the writers on the subject, M. L. Marschand. I have already referred to remarks by him on the hydroscopicity and capillarity of certain minerals; as a property distinct and different from these which retain moisture, he speaks of the permeability of soils, by which they give passage to moisture and allow of its transmission; and he gives cases of minerals which absorb and retain very little moisture in their structure, but which are very permeable by water.

In general, rocks which are highly hydroscopic are not very permeable, for the molecules, once moistened, cohere and present the appearance of a compact mass impermeable to water, as may be seen in clay.

On a permeable soil or subsoil, trees create and maintain on the surface a layer of humus of considerable hydroscopic and capillary properties, retaining water, and modifying the general permeability. While, on an impermeable rock, the roots break up this and increase the permeability.

The principle which he seeks to establish is, that forests have the effect of modulating the properties of rocks, giving to them what they have not; and he alleges it is in this way, more especially, that their action is salutary in the control of waters on the mountains. Of this view of the subject he gives the following illustration :—" When the rain falls on a denuded brow of a hill, composed of argillaceous earth the water moistens the surface—this absorbs a great quantity of it, through its hydroscopicity and capillarity—but when once this surface is moistened, the transmission of water goes on only very slowly from particle to particle, for the permeability is almost nothing, in consequence of the minute subdivision of the molecules which are brought into the closest contact; and that which is absorbed remains on the surface and dilutes the superficial layer, which is soon thus transformed into a thin clay devoid of cohesion. A layer more or less deep will then detach itself from the surface of the mass, and will flow to the bottom as mud more or less fluid, according as the rain may have been more or less violent. By a very gentle rain, a superficial layer is moistened; but the water falling slowly may be able to penetrate it completely, in virtue of its hydroscopicity and capillarity. In this case there will be only a superficial flow, for the greater portion of the water will penetrate the soil.

" But suppose that this same argillaceous land, or other unstable ground, were wooded, the trees in spreading the fall of the rain over an expanded surface, that of their foliage, would moderate the rainfall, and would at the same time augment the absorbent power of the soil, as well as its permeability, and as a consequence augment the quantity of water retained superficially. The mobility of the surface thus softened would, undoubtedly, be increased, but the roots imprisoning it would retain the softened ground to such a degree that no amount of water falling upon them from the heavens alone could cause it to slip away. Wherever landslips occur on wooded grounds they can be otherwise accounted for.

" If, in conclusion," says he, " we examine a forest situated on a land permeable *en masse*, as are the plateaux of jurassic limestone, the first effect of the forest would be to cover the soil with a thick layer of humus and of moss, which combine in a very high degree hydroscopicity and capillarity. The quantity of water retained thus in the upper layer of the soil will be much greater than it would have been had there been no forest there, for on the rocks referred to the destruction of woods is almost immediately followed by a denudation of these rocks of soil.

" It follows from this that on these lands the forest arrests the descent of the waters to the bottom of the valleys, for it is only very slowly that water retained by hydroscopicity and capillarity quits the substances which they penetrate. Moreover, as the greatest storms of rain never do saturate completely the layer of humus on wooded soils, it is impossible to form torrents on these."

He states that the effect of *gazonnement is* to augment the hydroscopicity and capillarity of the surface of the soil, but that this is not sufficient to secure the absorption of all the water that falls upon it in a storm of rain, and he sites facts in support of the allegation. The same good effects, he states, are produced to a greater extent by *buissonnement*, or the planting of bushes, while a layer of humus of great hydroscopicity, produced by the decay of their leaves, co-operates in the production of these good effects; but he cites evidence that even *gazonnement* and *buissonnement* combined have failed to prevent erosion and the formation of torrents.

But forests produce in a surpassing degree each and all of the effects referred to, as produced in a minor degree by meadows and bush. (1) They form by their detritus a very hydroscopic layer, and in consequence augment the quantity of water retained; (2) They augment the expansion of surface on which the water falls; and (3) They augment the capillarity and permeability of the subsoil.

"I have," says he, "in treating of the permeability of the soil, explained the influence of forests on this. In retaining for some time the water at the surface they augment considerably the quantity which is absorbed, particle by particle, by hydroscopicity and capillarity, for this absorption is slow; and thus, in a word, the forest tempers the action of rain dashed downwards in a storm, and leads the water gently on to the soil, as if it had fallen in a gentle shower; and further, it augments, in fine, the permeability of the soil, by keeping the surface unhardened and in some sort always open to receive the water which comes slowely from the heavens.

"I make no mention of the influence of forests in regard to evaporation—in regard to the direct absorption of water—and in regard to the humidity of the atmosphere, etc. I take up one point of view alone of the torrential management of waters in the high mountains, and these relate to this only indirectly.

"If a storm of rain beat upon a forest the whole of the water which falls is temporarily retained, all penetrates more or less deeply the soil without flowing on the surface; and, it may be objected, if the subsoil is impermeable the result will be the same. But the objection is without foundation. I shall suppose, what is frequently the case, that there is impermeable rock underlying the *humus:* all the water should arrive at this bed of rock and flow down, but the hydroscopicity and capillarity of this *humus*—of the ground—of the foliage—of the branches of the trees—in a word, of the material of which the forest is composed—will arrest the water to such a degree and measure as to regulate temporarily the delivery. . . .

"I have glanced rapidly at the action of forests, in view simply of their effect on the water which falls on their surface; but their function is by no means limited to this, for they serve also to arrest the waters which come from the pastures above them. They constitute in some measure a kind of immense and powerful *barrage*, or barrier placed between the summit and the bed of the valleys.

"In support of this allegation, I shall cite personal observations which seem to me conclusive. Never have I seen, during the most violent storms of rain, superficial flowings of water in the forests situated under pastures, though such flowings may have existed in the meadows at a greater elevation than the forests; all the waters which these supplied were literally absorbed and retained by the forest soil. I except, intentionally, well-marked ravines, which coming from above traverse forests, for the question here is only of *slopes somewhat uniform, or but slightly undulated*; it is evident that the soil of the forest will not absorb the water of a stream which traverses it encased in a bed.

"I take, for example, a valley which rises to a summit line somewhat elevated. The end situated at a great height is formed entirely of pasture lands, which spread out equally on the summits of the brows of the mountains; at a lower level beneath these are the forests. The waters which fall into the cistern formed by the head of the valley rapidly accumulate, and give birth to a torrent which traverses the forest. On the contrary, that which falls on the pasture lands above the brows do not commonly reach the depth of the ravine; descending to the forest zone uniformly extended over the soil, they are there absorbed.

"In a word, the zone of the forest absorbs generally the water flowing from the zone of pasture lands which correspond to it. In support of these observations, I appeal to all who, in the Alps, have observed storms of rain in the forest. I except water accumulated in ravines or depressions, which are in another condition.

"But the beneficent action of the forests does not limit itself to this; the flow in the ravine may also, if it be not completely absorbed, be by them rendered less injurious if it should come to spread itself over a *cone de déjection* in a forest otherwise covered with wood. I have observed, in connection with this, numerous muddy floods in ravines which, spreading themselves out in the middle of a forest, come out thence very limpid, depositing in it their slime, and leaving in it also almost the whole of the water.

"The great forest of the Ofen, in the Grisons has supplied me me with many instances of this. The soil, composed of the dolomite limestone of the triassic period, is somewhat unstable; in the middle, of the pasture lands which surmount the forest there are formed every year numerous torrents, which to an enormous extent carry off the small pebbles, which are characteristic of the dolomite. All these torrents arriving in the forest, then expand and diffuse themselves, and very rarely do they penetrate to the bottom of the valleys. In the upper portion of the Munster-Thal, I have seen on the right-hand side an enormous ravine, the muddy torrents of which are arrested by the forest. And the waters of the Munster, so well enclosed at this point, are a proof of the beneficial action of the forests. In fine, from the moment that the forests begin to retain the mud they retain also temporarily the greater portion of the water in which this was suspended, which are arrested by the enormous absorbent powers they possess."

At the meeting of the Brititsh Association held at Brighton in 1876, M. G. Lemoine, *Ingenieur des Ponts et Chaussées*, read a paper "*Sur les Forets dans leur Rapports avec l'Hydrologie.*" In which he stated that in the basin of the Seine it had been established that, compared with soil covered with grass, or even with other permanent cultivation forests had no special influence on watercourses. The only absolutely certain action of forests was their influence in protecting the soil and preventing it from being carried away; but from this single fact it followed that in mountainous countries they would retard the flow of torrential water. In the Department of the Hautes Alpes the presence of forest vegetation prevented the formation of torrents; re-planting woods led to the drying up of torrents already formed; but in most cases turfing, alone, was sufficient to produce the same effect.

M. Cézanne, in writing of what he calls the *Mécanisme de l'Inondation*, remarks that the rain as soon as it has fallen becomes divided into three portions, the first of which, taken up again by evaporation, returns into the atmosphere to be formed into new showers; the second, after infiltration into the soil, appears again at a lower level in the form of springs, when it loses not itself in the deeper reservoirs, whence it is made to project itself by artisian wells; finally, the remainder flows away by a thousand streamlets towards the thalweg, feeding the brooks, and streams, and rivers.

But these portions do not stand to each other in any definite proportion. Their relative importance varies not only, between one water-course and another, with the nature of the ground, according as this may be more or less favourable to the flow, or to the infiltration, but also in the case of the same water-course according as the season restrains or promotes evaporation. In summer the drier soil and warmer air are more greedy; they drink up or absorb the waters; in winter the moist air and damp ground allow the sheet of rainfall to flow away.

The only general and certain law is that over the area of the river's basin these are complemental to one another, their sum is equal to the quantity of rainfall. And if, for example, after evaporation has taken away its portion, the infiltration be complete, the flow will be nought.

It is the infiltration which is here brought under consideration.

Following out this division he says that it is by springs that the permeability of the soil may be said to be revealed to us, and if their *régime* be connected with meteorology, their existence depends on geological conditions. And in illustration he says:—

"Mount Ventoux—separated from the Alps by deep valleys, and isolated on all sides,—is a mass of very permeable cleft limestone, resting on an impermeable base which slopes toward the south-east. So constructed, the mountain is a veritable filter, through which the rain disappears at once; and excepting in the cases of any violent storms of rain, the superficial ravines are always dry. The subterranean waters protected from evaporation descend slowly by the internal fissures of the rock, and stopped at last by the impermeable bed, they are directed towards the south-east, and flow out in springs and streams sufficiently powerful to give motion to water-mills.

"The fine fountain of Vaucluse owes its origin to analogous circumstances: it is a veritable river, which is formed as other rivers are by the means of a great many imperceptible tributaries; but it presents this peculiarity, that its basin instead of being open to the vault of heaven, is subterranean, and covered by a great thickness of permeable limestone. The area of the basin is nearly 100,000 hectares, * the delivery of the fountain is at low water from 10 to 12

* *Bouvier*, *Annales des Ponts et Chaussées*. (1855, p. 367.)

cubic mètres, 300 to 350 cubic feet, that is almost the sixth part of the Seine.* The Eure, the basin of which is in extent six times that of the fountain of Vaucluse, gives no more water than this at low water.

"What a difference there is between the climate of Provence and that of Normandy! In Provence the evaporation might carry off three or four times as much water as the rain supplies; the greater part of the water-courses there are dried up in summer, and the plains of the Camargue, notwithstanding inundations and irrigation, are covered with saline inflorescence. If then, under this climate, the source of the Vaucluse is so constant and so abundant, it is because its basin being, as is the case with all sources, subterranean, the water which has once penetrated the ground is there sheltered against evaporation."

Now, turning to the consideration of forest lands, we find that, besides the desiccating of swampy land by evaporating through the stomates of the leaves the moisture taken up by the rootlets, another effect of the growth of trees is to desiccate the superficial soil by aiding the water which it receives to descend along its roots to a lower level, whence it is less likely to be carried off quickly by evaporation.

"The roots of vegetables," says d'Hericourt, in a passage which is quoted by Marsh, "perform the office of draining in a manner analogous to that artificially practised in parts of Holland and the British Islands. The method consists in driving deeply down into the soil several hundred stakes to the acre; the water filters down along the stakes, and in some cases as favourable results have been obtained by this means as by horizontal drains."

And by Marsh it is remarked:—"It is an important observation that the desiccation of trees by way of drainage, or external conduction by the roots, is greater in the artificial than in the natural wood, and hence that the surface of the ground in the former is not characterised by that approach to the state of saturation which it so generally manifests in the latter. In the spontaneous wood, the leaves, fruits, bark, branches, and dead trunks, by their decayed material, and by the conversion of rock into loose earth, through the solvent power of the gases they develope in decomposition, cover the ground with an easily penetrable matter extremely favourable to the

* On the 12th August, 1858, the Seine was lower than had been observed for a hundred and fifty-six years before. The gauging that day gave a delivery of 48 cubic mètres per second. The ordinary low water of the Seine is from 75 to 80 mètres. *Belgrand*, *Annales des Ponts et Chaussées*. (1858 t. ii p. 222.)

growth of trees, and at the same time too retentive of moisture to part with it readily to the capillary attraction of the roots.

"The trees, finding abundant nutriment near the surface, and so sheltered against the action of the wind by each other as not to need the support of deep and firmly fixed stays, send their roots but a moderate distance downwards, and indeed often spread them out like a horizontal network almost on the surface of the ground.

"In the artificial wood, on the contrary, the spaces between the trees are greater; they are obliged to send their roots deeper, both for mechanical support and in search of nutriment, and consequently serve much more effectually as conduits for perpendicular drainage."

If attention be given to the mode of growth in roots and rootlets, it may be seen how it comes to pass that the fact is as stated by Mr Marsh.

The root does not bore its way into and through the soil it enters, but it is prolonged, as is the line of dominoes by the players with these. The extreme cells, and probably the extreme cells only, or chiefly, multiply in the spongioles in accordance with the usual mode of cell genesis by the formation of cells within cells, and that in proportion as they are supplied with nutriment; and if this multiplication of cells occasion a pressure in all directions, it tends more to the extension of the root than to what may be called the *up rooting* of the tree. The direction of growth appears to be to whence chiefly come the supplies of nutriment, or material of growth. Where this is found on the level reached the roots extend. Where it is found in the soil below them they descend. Where it is found in the soil above them they ascend. I have had reported to me a case of roots extending towards a ditch, descending by the side of this, changing then their course so as to pass beneath it, ascending then on the further side till they came near the surface, and then spreading horizontally as at first.

I have often heard of roots growing towards a quantity of assimilate-able material as if guided by instinct; and I am given to understand that in willows by a stream there is generally a much more copious growth of roots on the side towards the stream than on the other sides around. Roots of forest trees are often prevented from descending by planting them above a flat stone, which cuts off supplies; and roots of fig-trees growing upon rocks follow and penetrate every crack and crevice where, and where alone, they find nutriment.

Thus may the downward growth of roots of planted trees be accounted for, and the horizontal growth of roots of trees in a forest. when such phenomena are seen; and by this downward growth of the roots of planted trees may the descent of water to the subsoil be promoted, there to be reserved against a day of need, converting the subsoil into a reservoir of water, which, raised by evaporation by heat, would moisten the superincumbent soil, promote vegetation, and pass again through the stomates of the leaves into the atmosphere,—again to be precipitated and absorbed by the soil instead of flowing off to the sea, to be lost in that abyss which never says it is enough!—the springs and fountains and river sources being to us significant of the greatness of the quantity of water which is thus retained.

In view of all that has been advanced, it appears that trees by their growth, the extent of their rootage, and the decay and decomposition of their foliage and debris, tend to increase the proportion of the rainfall which is preserved by infiltration, and to utilise for the promotion of vegetation, a larger portion of what is thus retained than otherwise would be so utilized.

The depth at which evaporation ceases must vary with the temperature, humidity of the atmosphere and character of the soil. Some interesting observatisns on this point are recorded by Johnstrus, in a work entitled *Om Fugtighedens Bevaegelese i den naturlige Jordbund*, published in Copenhagen in 1866. He found in the neighbourhood of Copenhagen that there, at the depth of a mètre and a half (59 inches) the effects of rain and evaporation were almost imperceptible, and became completely so at a depth of from two to three mètres. (6½ to 10 feet.

SECT. V.—*Secondary Effects of Trees in Arresting the Flow and Escape of the Rainfall, and thus equalizing to some extent the Flow of Rivers.*

While rivers in their sources indicate to us that the quantity of water retained by the earth after a copious fall of rain, by the infiltration of a portion of this into the soil, must be very great—even these being composed of what is only the drainage of the quantity in excess of what the ground can retain—rivers in their flood indicate that the portion of the rainfall carried away by *ruissellement*, or by flowing away over the surface of the ground, must also be great.

It may be noted that of what is retained by infiltration a great deal may be utilized by vegetation; and that of what is in excess of this and is carried off, feeding springs and fountains, and streams, the saddest thing that can be said is that it is lost, though this can only be said with a show of truth of that portion of it which is lost in the sea; but of what is carried off by *ruissellement* comparatively little is utilized; a much greater proportion of it finds its way to the sea, and this in rushing thither often carries with it devastation and destruction.

According to the statements I have cited from Surell, evaporation, infiltration, and *ruissellement*, are equal in their sum to the quantity of the rainfall, and if after evaporation has taken up its part the infiltration be complete, the *ruissellement* will be *nil.*

To the negative good which might thus be done, or damage which might thus be prevented, and the effect of trees in doing these, by equalizing to some extent the flow of rivers, would I next draw attention.

In connection with a statement made in the preceding section, relative to the effect of the destruction of forests upon the Durance, reference was made to the important circumstance that while the river is confined to a current little more than thirty feet in width, the bed in some places exceeds a mile and a quarter in breadth, and so far back as 1789 it was computed that it had covered an area of not less than 130,000 acres with gravel and pebbles; and it was intimated that thus was brought before us another of the effects of forests, or rather of the destruction of forests, which would be subsequently brought under discussion.

Mr Marsh, writing on this subject, says: "The traveller who visits the depth of an Alpine ravine, observes the length and width of the gorge, and the great height and apparent solidity of the precipitous walls which bound it, and calculates the mass of rock required to fill the vacancy, can hardly believe that the humble brooklet which purls at his feet has been the principal agent in accomplishing this tremendous erosion. Closer observations will often teach him that the seemingly unbroken rock which overhangs the valley is full of cracks and fissures, and really in such a state of disintegration that every frost must bring down tons of it. If he compute the area of the basin, which finds here its only discharge, he will perceive that a sudden thaw of the winter's deposit of snow, or one of those terrible discharges of rain so common in the Alps, must send forth a deluge mighty enough to sweep down the largest masses of gravel and of rock. The simple measurement of the cubical contents of the semicircular hillock which he climbed before he entered the gorge, the structure and composition of which conclusively show that it must have been washed out of this latter by torrential action, will often account satisfactorily for the disposal of most of the matter which once filled the ravine.

"When a torrent escapes from the lateral confinement of its mountain walls and pours out of the gorge, it spreads and divides itself into numerous smaller streams, which shoot out from the mouth of the ravine as from a centre, in different directions, like the ribs of a fan from the pivot, each carrying with it its quota of stones and gravel. The plain below the point of issue from the mountain is rapidly raised by newly-formed torrents, the elevation depending on the inclination of the bed and the form and weight of the matter transported. Every flood both increases the height of this central point and extends the entire circumference of the deposit.

"Other things being equal, the transporting power of the water is greatest where its flow is most rapid. This is usually in the direction of the axis of the ravine. The stream retaining most nearly this direction moves with the greatest momentum, and consequently transports the solid matter with which it is charged to the greatest distance.

"The untravelled reader will comprehend this the better when he is informed that the southern slope of the Alps generally rises suddenly out of the plain, with no intervening hill to break the abruptness of the transition, except those consisting of comparatively small heaps of its own debris brought down by ancient glaciers or recent torrents. The torrents do not wind down valleys gradually widening to the rivers or the sea, but leap at once from the flanks of the mountains upon the plains below. This arrangement of surfaces naturally facilitates the formation of vast deposits at their points of emergence, and the centre of the accumulation in the case of very small torrents is not unfrequently a hundred feet high, and sometimes very much more.

"The deposits of the torrent which has scooped out the Nantzen Thal, a couple of miles below Brieg in the Valais, have built up a semicircular hillock, which most travellers by the Simplon route pass over without even noticing it, though it is little inferior in dimensions to the great cones of dejection described by Blanqui. The principal course of the torrent having been—I know not whether spontaneously or artificially—directed towards the west, the eastern part of the hill has been gradually brought under cultivation, and there are many trees, fields, and houses upon it; but the larger western part is furrowed with channels diverging from the summit of the deposit at the outlet of the Nantzen Thal, which serve as the beds of the water courses into which the torrent has divided itself. All this portion of the hillock is subject to inundation after long and heavy rain, and as I saw it in the great flood of October, 1866, almost its whole surface seemed covered with an unbroken sheet of rushing water.

"The semi-conical deposit of detritus at the mouth of the Litznerthal, a lateral branch of the valley of the Adige, at the point where the torrent pours out of the gorge, is a thousand feet high and, measuring along the axis of the principal current, two and a half miles long. The solid material of this hillock—which it is hardly an exaggeration to call a mountain, the work of a single insignificant torrent and its tributaries—including what the river which washes its base has carried off in a comparatively few years, probably surpasses the mass of the stupendous pyramid of the Matterhorn.

"In valleys of ancient geological formation, which extend into the very heart of the mountains, the streams, though rapid, have often lost the true torrential character, if, indeed, they ever possessed it. Their beds have become approximately constant, and their walls no longer crumble and fall into the waters that wash their bases. The torrent-worn ravines, of which I have spoken, are of later date, and belong more properly to what may be called the crust of the Alps, consisting of loose rocks, of gravel, and of earth, strewed along the surface of the great declivities of the central ridge, and accumulated thickly between the solid buttresses. But it is on this crust that the mountaineer dwells. Here are his forests, here his pastures, and the ravages of the torrent both destroy his world, and convert it into a source of overwhelming desolation to the plains below.

"I do not mean to assert that all the rocky valleys of the Alps have been produced by the action of torrents resulting from the destruction of the forests. The greater, and many of the smaller channels by which that chain is drained owe their origin to higher causes. There are primitive fissures, ascribable to disruption in upheaval or other geological convulsion, widened and scarped, and often even polished, so to speak, by the action of glaciers during the ice period, and but little changed in form by running water in later eras.

"It has been contended that all rivers which take their rise in these mountains originated in torrents. These, it is said, have lowered the summits by gradual erosion, and with the material thus derived have formed shoals in the sea which once beat against the cliffs; then, by successive deposits, gradually raised them above the surface, and finally expanded them into broad plains traversed by gently flowing streams. If we could go back to earlier geological periods, we should find this theory often verified; and we cannot fail to see that the torrents go on, at the present hour, depressing still lower the ridges of the Alps and the Apennines, raising still higher the plains of Lombardy and Provence, extending the coast still farther into the Adriatic and the Mediterranean, reducing the inclination of their own beds and the rapidity of their flow, and thus tending to become river-like in character.

"We cannot measure the share which human action has had in augmenting the intensity of causes of mountain degradation, and of the formation of plains and marshes below, and we know that the clearing of the woods has, in some cases, produced, within two or three generations, effects as blasting as those generally ascribed to geological convulsions, and has laid waste the face of the earth more hopelessly than if it had been buried by a current of lava or a shower of volcanic sand. New torrents are forming every year in the Alps. Tradition, written records, and analogy concur to establish the belief that the ruin of most of the now desolate valleys in those mountains is to be ascribed to the same cause, and authentic descriptions of the irresistible force of the torrent show that, aided by frost and heat, it is adequate to level Mont Blanc and Monte Rosa themselves, unless new upheavals shall maintain their elevation.

"There are cases where torrents cease their ravages of themselves in consequence of some change in the condition of the basin where they originate, or of the face of the mountain at a higher level, while the plain of the sea below remains in substantially the same state as before. If a torrent rises in a small valley containing no great amount of earth and of a disintegrated or loose rock, it may, in the course of a certain period, wash out all the transportable material, and if the valley is then left with solid walls, it will cease to furnish dèbris to be carried down by floods. If, in this state of things, a new channel be formed at an elevation above the head of the valley, it may divert a part or even the whole of the rain-water and melted snow which would otherwise have flowed into it, and the once furious torrent now sinks to the rank of a humble and harmless brooklet. 'In traversing this department,' says Surell, 'one often sees, at the outlet of a gorge, a flattened hillock, with a fan-shaped outline and regular slops; it is the bed of dejection of an ancient torrent. It sometimes requires long and careful study to detect the primitive form, masked as it is by groves of trees, by cultivated fields, and often by houses, but, when examined closely, and from different points of view, its characteristic figure manifestly appears, and its true history cannot be mistaken. Along the hillock flows a streamlet, issuing from the ravine, and quietly watering the fields. This was originally a torrent, and in the back ground may be discovered its mountain basin. Such *extinguished* torrents, if I may use the expression, are numerous."

The quotation is from *Etude sur les Torrents des Hautes Alpes*, by Surell (Chap. xxiv.), and Mr Marsh adds in a foot-note:—" In such cases, the clearing of the ground, which, in consequence of a temporary diversion of the waters, or from some other cause, has become re-wooded, sometimes renews the ravages of the torrent. Thus, on the left bank of the Durance, a wooded declivity had been formed by the débris brought down by torrents, which had extinguished them-selves after having swept off much of the superficial strata of the mountain of Morgon. 'All this district was covered with woods, which have now been thinned out and are perishing from day to day; consequently, the torrents have recommenced their devastations, and if the clearings continue, this declivity, now fertile, will be ruined, like so many others.' "

And resuming, he goes on to say:—" But for the intervention of man and domestic animals, these latter beneficent revolutions would occur more frequently, and proceed more rapidly. The now scarped mountains, the hillocks of debris, the plains elevated by sand and gravel spread over them, the shores freshly formed by fluviatile deposits, would clothe themselves with shrubs and trees, the intensity of the causes of degradation would be diminished, and nature would thus regain her ancient equilibrium. But these processes, under ordinary circumstances, demand, not years, or generations, but centuries; and man, who even now finds scarce breathing-room on this vast globe, cannot retire from the Old World to some yet undis-covered continent, and wait for the slow action of such causes to re-place, by a new creation, the Eden he has wasted."

In a foot-note he adds:—" Where a torrent has not been long in operation, and earth still remains mixed with the rocks and gravel it heaps up at its point of eruption, vegetation soon starts up and prospers, if protected from encroachment. In Provence, 'several communes determined, about ten years ago, to reserve the soils thus wasted, that is, to abandon them for a certain time to spontaneous vegetation, which was not slow in making its appearance.' "

Mr Marsh next treats thus of two subjects intimately connected, the crushing effects of torrents, and the transporting power of water :—" I must here notice a mechanical effect of the rapid flow of the torrent, which is of much importance in relation to the desolating action it exercises by covering large tracts of cultivated ground with infertile material. The torrent, as we have seen, shoots or rolls forward, with great velocity, masses and fragments of rock, and sometimes rounded pebbles from more ancient formations. Every inch of this violent movement is accompanied with crushing concussion, or, at least, with great abrasion of the mineral material, and, as you follow it along the course of the waters which transport it, you find the stones gradually rounding off in form, and diminishing in size, until they pass successively into gravel, and, in the beds of the rivers to which the torrents convey it, sand, and lastly impalpable slime.

" There are few operations of nature where the effect seems more disproportioned to the cause than in this crushing and comminution of rock in the channel of swift waters. Igneous rocks are generally so hard as to be wrought with great difficulty, and they bear the weight of enormous superstructures without yielding to the pressure; but to the torrent they are as wheat to the millstone. The streams which pour down the southern scarp of the Mediterranean Alps along the Riviera di Ponente, near Genoa, have short courses, and a brisk walk of a couple of hours, or even less, takes you from the sea-beach to the headspring of many of them. In their heaviest floods, they bring rounded masses of serpentine quite down to the sea, but at ordinary high water their lower course is charged only with finely divided particles of that rock. Hence, while near their sources their channels are filled with pebbles and angular fragments, intermixed with a little gravel, the proportions are reversed near their mouths, and, just above the points where their outlets are partially choked by the rolling shingle of the beach, their beds are composed of sand and gravel to the almost total exclusion of pebbles.

" Guglielmini argued that the gravel and sand of the beds of running streams were derived from the trituration of rocks by the action of the currents, and inferred that this action was generally sufficient to reduce hard rock to sand in its passage from the source to the outlet of rivers. Frisi controverted this opinion, and maintained that river-sand was of more ancient origin, and he inferred from experiments in artifically-grinding stones that the concussion, friction, and attrition of rock in the channel of running waters were inadequate to its comminution, though he admitted that these same causes might reduce silicious sand to a fine powder capable of transportation to the sea by the currents. Frisi's experiments were tried upon rounded and polished river-pebbles, and prove nothing with regard to the action of torrents upon the irregular, more or less weathered, and often cracked and shattered rocks which lie loose in the ground at the head of mountain valleys. The fury of the waters and of the wind which accompanies them in the floods of the French Alpine torrents is such, that large blocks of stone are hurled out of the bed of the stream to the height of twelve or thirteen feet. The impulse of masses driven with such force overthrows the most solid masonry, and their concussion cannot fail to be attended with the crushing of the rocks themselves.

"The greatest length of the basin of the Ardèche is seventy-five miles, but most of its tributaries have a much shorter course. 'These affluents,' says Mardigny, 'hurl into the bed of the Ardèche enormous blocks of rock, which this river, in its turn, bears onwards, and grinds down, at high water, so that its current rolls only gravel at its confluence with the Rhone.'

"Duponchel makes the following remarkable statement: 'The river Herault rises in a granitic region, but soon reaches calcareous formations, which it traverses for more than sixty kilomètres, rolling through deep and precipitous ravines, into which the torrents are constantly discharging enormous masses of pebbles belonging to the hardest rocks of the Jurassian period. These débris, continually renewed, compose, even below the exit of the gorge where the river enters into a regular channel cut in a tertiary deposit, broad beaches prodigious accumulations of rolled pebbles, extending several kilomètres down the stream, but they diminish in size and weight so rapidly that above the mouth of the river, which is at a distance of thirty or thirty-five kilomètres from the gorge, every trace of calcareous matter has disappeared from the sands of the bottom, which are exclusively silicious.'

"Similar effects of the rapid flow of water and the concussion of stones against each other in river-beds may be observed in almost every Alpine gorge which serves as the channel of a swift stream. The tremendous cleft through which the well-known Via Mala is carried receives, every year, from its own crumbling walls and from the Hinter Rhein and its mild tributaries, enormous quantities of rock, in blocks and boulders. In fact, the masses hurled into it in a single flood like those of 1868 would probably fill it up, at its narrow points, to the level of the road 400 feet above its bottom, were not the stones crushed and carried off by the force of the current. Yet below the outlet at Thusis only small rounded boulders, pebbles, and gravel, not rock, are found in the bed of the river. The Swiss glaciers bring down thousands of cubic yards of hard rock every season. Where the glacier ends in a plain or wide valley, the rocks are accumulated in a terminal moraine, but in numerous instances the water which pours from the ice-river has force enough to carry down to larger streams the masses delivered by the glacier, and there they, with other stones washed out from the earth by the current, are ground down, so that few of the affluents of the Swiss lakes deliver into them anything but fine sand and slime.

"Great rivers carry no boulders to the sea, and, in fact, receive none from their tributaries. Lombardini found, twenty years ago, that the mineral matter brought down to the Po by its tributaries was, in general, comminuted to about the same degree of fineness as the sands of its bed at their points of discharge. In the case of the Trebbia, which rises high in the Apennines and empties into the Po at Placenza, it was otherwise, that river rolling pebbles and coarse gravel into the channel of the principal stream. The banks of the other affluents—excepting some of those which discharge their waters into the great lakes—then either retained their woods, or had been so long clear of them that the torrents had removed most of the disintegrated and loose rock in their upper basins. The valley of the Trebbia had been recently cleared, and all the forces which tend to the degradation and transportation of rock were in full activity." Of the transporting power of water he writes: "The geographical effects of the action of torrents are not confined to erosion of earth and comminution of rock; for they and the rivers to which they contribute transport the débris of the mountains to lower levels, and spread them out over the dry land and the bed of the sea, thus forming alluvial deposits, sometimes of a beneficial, sometimes of an injurious, character, and of vast extent.

"A mountain rivulet swollen by rain or melted snow, when it escapes from its usual channel and floods the adjacent fields, naturally deposits pebbles and gravel upon them; but even at low water, if, of course, it is long enough for its grinding action to have full scope, it transports the solid material with which it is charged to some larger stream, and there lets it fall in a state of minute division, and at last the spoil of the mountain is used to raise the level of the plains, or is carried down to the sea.

"An instance that fell under my own observation, in 1857, will serve to show something of the eroding and transporting power of streams which, in these respects, fall incalculably below the torrents of the Alps. In a flood of the Ottaquechee, a small river which flows through Woodstock, Vermont, a mill-dam on that stream burst, and the sediment with which the pond was filled, estimated after careful measurement at 13,000 cubic yards, was carried down by the current. Between this dam and the slackwater of another, four miles below, the bed of the stream, which is composed of pebbles, interspersed in a few places with larger stones, is about sixty-five feet wide, though, at low water, the breadth of the current is considerably less. The sand and fine gravel were smoothly and evenly distributed over the bed to a width of fifty-five or sixty feet, and, for a distance of about two miles, except at two or three intervening rapids, filled up all the interstices between the stones, covering them to the depth of nine or ten inches, so as to present a regularly formed concave channel, lined with sand, and reducing the depth of water, in some places, from five or six feet to fifteen or eighteen inches. Observing this deposit after the river had subsided and become so clear that the bottom could be seen, I supposed that the next flood would produce an extraordinary erosion of the banks and some permanent changes in the channel of the stream, in consequence of the elevation of the bed and the filling up of the spaces between the stones through which formerly much water had flowed; but no such result followed. The spring freshet of the next year entirely washed out the sand its predecessor had left, deposited some of it in ponds and still-water reaches below, carried the residue beyond the reach of observation, and left the bed of the river almost precisely in its former condition, though, of course, with the displacement of the pebbles which every flood produces in the channels of such streams. The pond, though often previously discharged by the breakage of the dam, had then been undisturbed for about twenty-five years, and its contents consisted almost entirely of sand, the rapidity of the current in floods being such that it would let fall little lighter sediment, even above an obstruction like a dam. The quantity I have mentioned evidently bears a very inconsiderable proportion to the total erosion of the stream during that period, because the wash of the banks consists chiefly of fine earth rather than of sand, and after the pond was once filled, or nearly so, even this material could no longer be deposited in it. The fact of the complete removal of the deposit I have described between the two dams in a single freshet, shows that, in spite of considerable obstruction from roughness of bed, large quantities of sand may be taken up and carried off by streams of no great rapidity of inclination; for the whole descent of the bed of the river between the two dams—a distance of four miles—is but sixty feet, or fifteen feet to the mile.

"The facts which I have adduced may aid us in forming an idea of the origin and mode of transportation of the prodigious deposits at the mouth of great rivers like the Mississippi, the Nile, the Ganges, and the Hoang-Ho, the delta of which last river, composed entirely of river sediment, has a superficial extent of not less than 96,500 square miles. But we shall obtain a clearer conception of the character of this important geographical process by measuring, more in detail, the mass of earth and rock which a well-known river and its tributaries have washed from the mountains and transported to the plains or the sea, within the historic period."

The whole process of the disintegrating effects of the Po Mr Marsh then details with clearness, and concludes:—"Upon the whole, we shall not greatly err if we assume that, for a period of not less than two thousand years, the walls of the basin of the Po—the Italian slope of the Alps, and the northern and north-eastern declivities of the Apennines—have annually sent down into the lakes, the plains, and the Adriatic, not less than 375,000,000 cubic yards of earth and disintegrated rock. We have, then, an aggregate of 750,000,000,000 cubic yards of such material, which, allowing to the mountain surface in question an area of 50,000,000,000 square yards, would cover the whole to the depth of fifteen yards. There are very large portions of this area, where, as we know from ancient remains—roads, bridges, and the like—from other direct testimony, and from geological considerations, very little degradation has taken place within twenty centuries, and hence the quantity to be assigned to localities where the destructive causes have been most active is increased in proportion.

"If this vast mass of pulverized rock and earth were restored to the localities from which it was derived, it certainly would not obliterate valleys and gorges hollowed out by great geological causes, but it would reduce the length and diminish the depth of ravines of later formation, modify the inclination of their walls, reclothe with earth many bare mountain ridges, essentially change the line of junction between plain and mountain, and carry back a long reach of the Adriatic coast many miles to the west.

"It is, indeed, not to be supposed that all the degradation of the mountains is due to the destruction of the forests—that the flanks of every Alpine valley in Central Europe below the snow-line were once covered with earth and green with woods, but there are not many particular cases in which we can, with certainty, or even with strong probability, affirm the contrary."

There is thus brought under consideration a secondary effect of trees in arresting the flow and escape of the rainfall, and so to some extent equalizing the flow of rivers. How this is affected next demands our attention.

As the evaporation, to which attention has been called, may be considered as only a continuation of evaporation, begun so soon as the rain-drop was formed in the atmosphere, so may the infiltration and *ruissellement* be considered as only a continuation of the descent by which, under the influence of gravitation, it fell; but it is effected under different conditions, and it presents different phenomena.

So soon as it falls part is absorbed by the hydroscopicity of the soil, more, it may be, escapes by infiltration through the soil, and the remainder flows over the surface to a lower level.

It may have been observed that on the footpath, or the rock, it accumulates in pools, but not on the grass or turf of herbage, or field of corn; and on the bare ground, it may be seen flowing off in runnels; but on the grassy turf the phenomenon is somewhat different. Even on the declivity of a knoll, or on the declivity of a mountain side, the grass arrests, divides and subdivides, and so retains the superficial flow of the superabundant rainfall. In accordance with this is the action of forests thereon.

The establishment of this fact has followed the study of the natural history of Alpine torrents. In some of these the whole rainfall in a mountain basin, rushing off impetuously to the sea, and undermining the banks of its channel, carried off the detritus, and buried therewith, it may be, fertile lands, and villages and towns beyond. The destructive effects thus produced in France called attention to the subject nearly a century ago, and in 1793 there was published by M. Fabre, a civil engineer, *Essai sur la theorie des Torrents et des Riviers*, in which he alleges that the destruction of forests in the mountains, and the uprooting of their stumps, had been the primary and the secondary causes of the formation of these torrents, and had thus been the occasion of all the disasters accompanying or following these torrents; and he urged the abandonment or regulation of these proceedings, and the *reboisement* of the mountains, as means of arresting and counteracting the evil.

The commotions occasioned by the revolution prevented full effect being given to these views at that time, but some fifty years later a work was published by M. Alex. Surell, entitled *Etude sur les Torrents des Hautes Alpes*, in which similar and more extended views of the subject were advanced. This work was crowned by the Academy of Sciences; and it led to the commencement of extensive works of *reboisement* on the mountains of France. These have been prosecuted with energy and success at great expense, but ungrudgingly,—the result having proved corroborative of the principles upon which they were undertaken. It is only as illustrative of the soundness of the views upon which these were founded that they are now referred to; and here I can only bring forward statements of these views and principles, with a passing notice of results illustrative of their truth.

M. Surell says: "When we examine the lands in the midst of which are scattered the torrents of recent origin, we see them to be in every case stripped of trees and of every kind of arborescent vegetation. On the other hand, when we look at mountain slopes which have been recently stripped of woods, we see them to have been gnawed away by innumerable torrents of the third class, which evidently can only have been formed in later years.

"See then a very remarkable double fact: everywhere where there are recent torrents there are no more forests: and wherever the soil has been stripped of wood recent torrents have been formed; so that the same eyes which have seen the forest felled on the slope of a mountain have there seen incontinently a multitude of torrents."

And again, "In examining the basins drained by great extinct torrents, there are almost always found there forests, and often dense forests. There may be observed also, along wooded *revers*, a number of small torrents of the third class, which appear as stifled under the mass of vegetation, and are completely extinct. Now this second observation, which can be verified by a multitude of examples, supplies a demonstration of a fact of which the first only permitted us to entertain a suspicion in a vague way:—it is, that the forests are capable of bringing about the extinction of a torrent already formed. Indeed, it is impossible to admit that the small torrents, dug for the most part in mobile and friable ground, can have died of themselves, so to speak, in their very birth, and through the effect alone of that equilibrium to which reference has already been made.

"Stability cannot establish itself so speedily on beds which are scarcely formed, and in the midst of lands which offer still so much food for erosion by the waters; it is a work which demands time, and which is never entirely consummated until the mountain has been gnawed away to the quick, to its last ridge.

"Amongst the great number of extinct torrents, of which the basins are wooded, there are some, the forests of which have been subjected to the commune *régime*, and have fallen in part under the axe of the inhabitants. Very well, the result of this destruction of trees has been to rekindle the violence of the torrents, which only slumbered. There have been seen thus peaceful streams give place to furious torrents, which the fall of the wood had re-awakened from their long sleep, and which vomited forth new masses of *déjection* on beds of deposit, which had been cultivated without suspicion from time immemorial. This is what has been remarked more especially after the excessive destruction of woods which followed the first years of the Revolution; the devastations of many great torrents only date from this epoch."

And once more, "This last fact completes all that need be said in regard to the influence of forests. In seeming these show themselves almost everywhere on the body of extinct torrents, one may suppose that these had first died, and that the woods had then seized upon them when the extinction had been completed, and when the soil of the neighbourhood became stable, permitted vegetation to develop itself in safety: the forest would then only have been one of the effects of the extinction of these, instead of being the cause of it. But then the destruction of the woods would only have restored things to their primitive state, and the torrents ought to have been able to continue extinct after the taking away of the woods as it was before their appearance there—and this is exactly what does not happen. It has sufficed to clear away the woods to see the devastations immediately reappear. It must be then the forests which, by their permanent appearance on the soil, hindered the devastations, and it is the forests, in taking possession of the soil, which have caused them to cease—and the extinction of the torrents is so completely their work that it begins, continues, and disappears with them, the effect ceasing immediately with the cause.

"One sees by this that the action of forests is not confined to preventing the creation of new torrents, but that it is sufficiently energetic to destroy torrents already formed. One sees also that the injurious result of the removal of woods is not only to open every where the soil to new torrents, but that it augments the violence of those which exist, and resuscitates those which appear completely extinct. We may then sum up the influence which forests exercise on torrents already formed on two facts, parallel to those which sum up their influence on lands where the torrents have not yet appeared. (1.) The presence of a forest on a soil prevents the formation of a torrent there. (2.) The destruction of forests leaves them subject to become the prey of torrents. Nor is there in this any thing for which we may find it difficult to account."

He proceeds then to explain the *modus operandi* whereby forests produce such effects: " When the trees fix themselves in the soil the roots consolidate this, interlacing it with a thousand fibres; their branches protect it, as would a buckler, againet the shock of the heavy rains; and their trunks, and at the same time suckers, brambles, and that multitude of shrubs of all kinds which grow at their base, oppose additional obstacles to the currents which would tend to wash it away. The effect of all this vegetation is thus to cover the soil, in its nature mobile, with an envelope more solid and less liable to be washed away. Besides, it divides the currents and disperses them over the whole surface of the ground, which keeps them from going off in a body in the lines of the *thalweg* and meeting there, which would be the case if they flowed freely over the smooth surface of a denuded ground. Finally, it absorbs a portion of the water which is imbibed in the spongy humus, and so far it diminishes the sum of the washing away forces.

" It follows from this that a forest, in establishing itself on a mountain, actually modifies the surface of the ground, which alone is in contact with atmospheric agents, and all the conditions find themselves then modified as they would be if a primitive formation had been substituted for a formation totally different. Whence it is not more astonishing to see the same soil alternately cut up or free from torrents, according as it is despoiled or clothed with forests, than it is astonishing to see torrents cease when we come to primitive formations, or reappear suddenly on friable limestone.

" In accordance with this we find—first, the development of forests brings about the extinction of torrents; second, the destruction ot forests redoubles the violence of torrents, and may even cause them to reappear. And nothing is more easy than to explain these new actions. It will be remembered what are the causes which call forth and maintain the violence of torrents: it is, on one hand, the friability of the soil; and, on the other, the sudden concentration of a great mass of water. Now, we know already that the forests render the soil less liable to be washed away; we know also that they absorb and retain a portion of the rainfall, and prevent instantaneous concentration of the portion which they do not absorb. Consequently they destroy both the one and the other cause. They prolong the duration of the flow, and they render the floods at once more prolonged, less sudden, and less destructive.

"It may be understood from this how forests, in invading the *bassins de réception*, may have contributed powerfully to stifle certain torrents. Whilst the waters were creating for themselves the most convenient slopes, the forests were retaining the soil which was ready to go, were rendering it more solid, were consequently diminishing the mass of earth washed away, and above all were opposing themselves to the concentration of currents. They were augmenting all the resisting, all the existing obstacles, and were diminishing all the motive powers; and they were coming thus to hasten by a double efficacy that epoch of stability in which the force of the waters would find itself in equilibrium with the resistance of the soil. There is one circumstance which ought to render their triumph still more speedy,—it is, that the torrent, in proportion as it is enfeebled, abandons to them a soil more and more stable and favourable to vegetation, in such a way that this augments every day their forces in proportion as the torrent loses force. In fact, if the expression may be allowed, it is reinforced by the effect.

"By this I do not mean to say that the torrents can never become extinct of themselves. That would be in contradiction to what I have said, and at the same time to facts observed, for there are examples of torrents being extinguished without the presence of forests, and solely through the erosion of the mountains—as, for instance, the torrent of Saint Joseph, near Monestier. But I say that the forests expedite the accomplishment of this effect, and that they can produce it where the other circumstances are not yet producing it.

"Thus nature, in summoning forests to the mountains, places the remedy side by side with the evil. She combats the active forces of the waters; to the invasions of the torrents she opposes the aggressive conquests of vegetation. On those mobile *revers* she spreads a solid layer which protects them against external attack, somewhat in the manner that a facing of stone protects an earthen embankment. It is worthy of remark that the little cohesion of limestones, which is opposed to the fixing of grounds, which renders them so mobile, and draws torrents thither, is precisely the quality which renders them favourable to the development of vegetation. The same cause which multiplies the torrents ought then to multiply also the robust forests, and to cause productiveness succeed in the long run to barrenness, and stability to disorder; not that, strictly speaking, there can be in nature anything otherwise than orderly, for there is nothing which is not subject to the rule of immutable laws, but in popular phrase the term disorder has also its meaning.

"One is struck with the illustrations of the observation which has just been made in going over certain forests in these mountains. One sees the vegetation doubling its profusion and energy in grounds torn by ravines, and crumbling on all hands, as if it were mustering its last efforts to retain a soil escaping from it. To cite one example: in the forest of Boscodon may be seen the vigour and tenacity of the vegetation contending against a friable soil composed of schist, tufa, and gypsum. It is, in fact, the lands which are the most mobile which are at the same time the most fertile, and the hard rocks on which vegetation has no hold, brave also the effort put forth by all the causes of destruction. The mountains, if they were abandoned quite naked to external influence, would soon be levelled or cut up into bits, and they would offer to man nothing but a heap of cleft rocks, uncultivated and uninhabited.

"It is vegetation which prevents this ruin; and as there can be no vegetation without water, it is on the mountains that nature has poured out the water in the greatest profusion. We have already called attention to the remark, that there falls more rain on the mountains than on the plains. The mountains attract and retain the clouds [?]. Snows and glaciers crown their summits as immense reservoirs, whence trickles out a perpetual moisture, and whence flow innumerable streamlets which fertilize their sides, and distribute fertility, from brow to brow, down to the very depth of the valleys. Thus, the waters which are the most energetic means of destroying the soil are at the same time the most active in its conservation. In drawing on vegetation, they preserve the soil against their own attacks, and the more they have of power to destroy, the more vegetation they cause to spring up to preserve. It is in this way that nature imposes on all her forces moderators which counterbalance them and keep them from acting always in the same way; and this must end in bringing everything to a state of restored peace."

After dwelling on the thought of self-adjusting provision for the natural extinction of torrents, he, in something like a burst of enthusiasm, gives expression to his feelings in view of the thorough and efficient way in which torrents had naturally become extinct, and of the contrast thus presented to the puny endeavours of man to restrain their ravages: the natural and the artificial; God's way of doing it, and man's way of doing; the work of God and the work of man; and the results: success, perfect and complete; and success, partial and imperfect!

"Let us go back for a moment," says he, "and compare these effects of vegetation with those exercised by the different systems of defence hitherto devised. The result of defences like that of vegetation is to arrest the ravages of torrents; and how powerless appear all embankments by the side of those great and powerful means which nature employs when man ceases to oppose her, and when she patiently prosecutes her work throughout a long series of ages! All our paltry works are nothing but defences, as their name indicates; they do not diminish the destructive action of the waters, they only keep it from spreading beyond a certain boundary. They are passive masses opposed to active forces; obstacles, inert and decaying, opposed to living powers, which always attack, and which never decay. Herein is seen all the superiority of nature, and the nothingness of the artifices devised by man.

"I make not here a barren comparison. I wish to let it be seen that it is better to bridle the torrents than to erect at great expense masonries and earth-works, which will always be, whatever may be done, expensive palliatives, better adapted to conceal the plague than to eradicate it. Why then does not man ask assistance of those new powers, the energy and efficacy of which are so clearly revealed to him? Why does he not command them to do yet again, and that under the directions of his own genius, that which they have already done in times long gone by on so many extinct torrents, and that under the prompting of nature alone?"

In 1872 a sequel to this work by M. Surell was published by M. Cézanne, *Ingeneur des Ponts et Chausées, Representant des Hautes Alpes á l'Assemble Nationale.* Referring to the phenomena of torrents brought under review in that work by M. Surell, and in the Sequel supplied by himself, M. Cézanne says:—

"There may be given in a few words a *résumé* of the whole series of these phenomena.

"The mountains are the result of a series of upheavals following one upon another in the same region. A final agitation gave to the different chains of these the existing elevation; it elevated the summit and opened up deep fissures or divisions, which have become the valleys of the present time. From the time this occurred the waters began to fashion the *thalwegs*, following the line which best suited them; wearing down outlets and filling up basins. It is necessary to admit, or to assume, that the depth or thickness of the alluvial deposits in the bottom of certain valleys—for instance, those of the Isère in the Graisivaudan, or of the Rhine in Alsace,—is to be reckoned by hundreds, and perhaps by thousands, of mètres or yards; for even yet certain lakes existing in depressions of the Alps have their bottom below the level of the sea.

"After a long series of ages the mountains assumed the leading features which they now exhibit, when, the climate changing, great glaciers carried on actively the work of erosion; these have planed away escarpments, and fashioned into something like horizontal lines the rocky belts of the valleys.

"*Débâcles*, or inundations, from the escape of the waters of pent-up lakes, and deluges resulting from the tremendous rains of summers on the extensive fields of ice, have carried away and deposited in the principal valleys in certain favourable places, but more especially at the *débouchés* of lateral gorges, the masses of lœss which have formed cones in the higher plains, and in which the water-courses have subsequently dug out the secondary valleys.

"At a later period, after the melting away of those glaciers, the torrents seized upon the bared mountains; and without restraint they have dug out their basins, and have again taken up the materials disintegrated by the glaciers, and deposited these in the gigantic cones which give to certain regions a physiognomy peculiarly their own

"But after a time the forests, spreading by degrees, stifled the waters under a mantle of verdure; the torrents became extinct,—an era of peace and of comparative quiet supervened in the mountains; then the tribes of men, who during the glacial period rambled over the low-lying plains, in company with the reindeer, the aurochs, and the bears, began to spread themselves in the high-lying valleys. The most ancient settlements were made at the gorges of the torrents, towards the summit of the cone; in point of fact, there are to be found in the mountain valleys very few of these gorges in which we do not meet either with an existing village or with an ancient ruin.

"In this location, which was then one favourable to their pursuits, the primary inhabitants could profit by the exceptional fertility of the cone of deposits; they had nothing to fear from the principal river, which flowed through the lower-lying lands, nor from the torrent, which was then extinct; they commanded the plain, and found themselves at the gate of the mountains; the adjacent gorge supplied them with water, the forest supplied them with wood, the rock supplied them with stone, and their flocks spread themselves over the verdant ridges around them.

"Little by little, a reckless use of the forests and of the pasturage disturbed the equilibrium of the natural forces; and now the old sore is re-opened, and anew, by man's deed, the mountains are inoculated with the leprosy of the torrents. The evil has gone on increasing during prolonged ages of disorder and recklessness; the position of the cultivated grounds, and of the villages established at the *débouché* of the torrents, has now become critical in the extreme; and unless we go back, as we have done; to the olden times, we are unable to account for men having taken up their dwelling in the spots, of all others, which at this day appear to be those which are more immediately threatened.

"But at last an era of reparation begins; and, thanks to the eminent men who have in byegone years given their mind to the work, the next generation may hope to see the final decline of the modern renewed Torrential Era."

In 1874 was published *Les Torrents leur lois, leur causes, lèur effets: Moyens de les reprimeur et de les utiliser: leur action geologique universelle, par* Michel Costa de Bastelica, *Conservateur des Eaux et Forêts.*

This work treats of another aspect or of another department of the subject than any discussed in the treatises already mentioned, which the author designates,—*Le phènomène torrentiel*, or *la torrentialité*; and thus is opened up another chapter of the natural history of torrents.

In speaking of the good done by forests on the face of mountains forming a basin drained by water-courses, he says their beneficial action is manifold; and though this manifold action it may be difficult to unfold, the attempt to do this will place beyond all question that their beneficial action on the water-course is at once most marked and considerable.

"In the discussions which have taken place on this subject," says he, "the point which has engrossed attention to some extent has been almost exclusively the permeability or impermeability of the soil, and the proportion borne by the water absorbed to that which flows off. This is certainly an important question, and no difficulty is found in showing that forests diminish to an enormous extent the amount of water which flows away; but the service which they render is perhaps greater still in regulating, as they do, the flow, and in securing the delivery of only water of perfect fluidity.

"The study of torrents has shown that the evil done consists not so much in the greater or less volume of water discharged as in the disturbances or perturbations of the flow connected with this. The principal causes of these are sudden changes or variations in the delivery and in the degree of fluidity of the flood. And if it be shown that the forests have, in relation to both of these, a regulating power superior to that of any other force operating on the torrent, it will be proved that they are the most potent means of extinguishing torrents.

"If we could expose, by a vertical section, a wooded slope, it would show in the upper portion a layer of varying thickness, but most frequently of from 30 to 40 centimétres (12 or 15 inches) of humus in which the fibrous rootlets are so developed that the whole has the appearance of a woolly material. This layer is at once a sponge and a filter. The large roots of the trees penetrate more or less into the subjacent rock.

"When the rain falls on ground covered with wood a considerable portion of the water is restored to the atmosphere by evaporation; another portion is absorbed by the immense expansion of foliage and boughs. If the rain be prolonged the water comes at length to the ground, which again is capable of absorbing an immense quantity. A flow from this is slow to establish itself; it is necessary, first that the saturation of the sponge-like layer be complete; and when this is effected—when the water has been able to make a passage for itself by an infinite number of imperceptible channels—the flow, like that of a charged syphon, maintains a certain uniformity of flow, and this it continues for a long time after the rain has ceased.

"So much is this the case that opponents have alleged that forests are more hurtful than beneficial, as they tend to prolong floods. The flood is prolonged, it is true, but the delivery is regulated—diminished at the commencement and increased at the close: the total quantity of water drained away takes a longer time to flow; it flows during the whole of that longer time; and, what is of more importance, it flows uniformly and equally, with no sudden variations, and thereby much evil is avoided; and, what is of more importance still, the forest acts at the same time as a filter, delivers no water but what is of perfect fluidity, scarcely even discoloured by the washing away of organic matter, and unable to wash away the earth of the subsoil protected against erosion by its thick covering of humus.

"When, on the contrary, the rain falls on a soil stript of vegetation, it tends to cut this up into ravines, and it does so if the tenacity and resistance of the ground be not sufficient to withstand it; and the flood is subject to great variations in its current, carrying off, here and there the earth and other debris of the soil.

"Forests have, then, a double action; on the one hand they consolidate the soil, on the other hand they reduce and regulate the flow of the current,—acting at once both on the delivery and on the perturbation,—in other words, on the primary cause and on the secondary causes of the overflowing of water-courses.

"It has been tried to subject to experiment and observation the meteorological and hydrological effects of forests. And doubtless studies so interesting are by no means lost to science. They cannot be too much encouraged; but it should be borne in mind that they can have comparatively little value in this question, seeing that they cannot take cognisance of this modulating and regulating action.

"In regard to any flood which we may wish to make the subject of study, it would avail comparatively little to know what quantity of rain falls annually in the basin drained by it. What is necessary to be known is—In what way did the flow of the flood operate during the duration of the flood, taking into account the quantity of water discharged, and all the causes or sources of perturbation operating—which is a much more difficult problem.

"And in resolving the whole qnestion into the permeability of the soil, and its capacity of absorption, it appears importance is attached exclusively to the reduction of the volume of water which flows away. It seems to be forgotten in this that water-courses, if *steadily supplied*, constitute it may be said the principal riches of a country, and the most potent of all instruments of labour.

"By their modulating power forests act as vast reservoirs, not only in preventing sudden variations of delivery during a flood, but in feeding the water-courses and raising their level during the period of exhaustion. In what relates specially to the torrents of the Alps it has been demonstrated that the renewed devastating power which they have exhibited, and which has assumed such portentous magnitude in the course of the last forty years is a consequence of the disappearance of the woods. When one goes over these lands—cut into ravines and despoiled of all vegetation—he meets with numerous stumps of pine and of larch, which testify that at a period as yet still recent they were covered by vast forests.

"M. Surell cites, as an example of the action of forests, the torrent of Savines, now completely extinguished, and the basin of which is everywhere adorned with a magnificent forest of firs and pines. The forest has effectively contributed to the extinction of the torreut, but at this point the following observations may be made :

"This natural extinction of the torrent goes back to ages most remote. The cone is of a perfect geometric regularity. At its base, opposite the Durance, it presents a troncature or section, produced by the erosion of the river, and the escarpment of which is about 30 mètres (100 feet) in height at its culminating point. This section of the ground lays open the interior of the torrential deposit formed of rolled pebbles.

"The whole surface of the cone is cultivated, and on one portion has been built the large village of Savines, the chief place of the canton.

"This enormous heap of deposit is situated at the foot of a high mountain called Morgon, in the flanks of which are dug out a profound gorge surrounded by a vast basin, the work of the water. All the upper slopes of the mountain are hung with a beautiful forest, producing firs more than 30 mètres (100 feet) in height, and 3 mètres (10 feet) in girth.

The lower slopes are deeply ravined, but wooded to the very edge of the *thalwegs.* A pretty strong stream rises from the principal gorge, but it swells but little ; it carries down no material, and it flows into the Durance by a bed deeply enclosed in the left bank of the cone. Extinction and stability are complete ; but it is certain that if the forest should be made to disappear, anew would disorder revive, and this with the same intensity as before.

"In going over the basin with attention, I satisfied myself that everywhere the bed of the *thalwegs* of the gorges and the ravines, formed of the hard rock, were absolutely incapable of being undermined. From this it may be inferred, that during the activity of the torrent, when the basin was being deepened more and more, the surface could not have been wooded. But from the time that the waters had everywhere reached the hard rock, and that they could no more be undermined and washed deeper, their *thalwegs* in the upper slopes tended to consolidate themselves, taking their natural stable declivity ;

and from that time vegetation could begin to take hold and complete the extinction.

"This remark is important in this way, that if the disappearance of a forest always gives birth to torrential disturbances, it does not always hold true that one can put a stop to them by the planting of a forest alone.

"Much as an unstable ground is protected by being wooded—though it maintains itself and behaves, in a hydrological point of view, as do the most solid lands, if the wood come to disappear, if the ground be deeply ravined, if the bottom of the ravine continues to be easily undermined and washed away—it becomes extremely difficult to establish vegetation on the mountains, which continually crumble away, and which with this instability no longer retain any trace of vegetable soil.

"In the Alps there are numerous cases of old mountains which crumble away when the foot of the slope is undermined by the water. And one is thus left, if he desire to effect a radical and prompt extinction of a torrent, to give, artificially, to the bottom of the ravine a power of resistance to undermining and washing away, by appropriate works of consolidation.

"But be this as it may, the potent action of forests is beyond all question. Whatever be the character of the woods—timber forests, coppice-wood, or simple shrubbery—all contribute to give firmness to the soil, to retard and to regulate the flow of the water drained off.

"In comparing the different kinds of woods, it may be said that lofty timber forests, with their vast apparatus of foliage at a great elevation above the soil, are of most use with a view to meteorological and hydrological effects; and that young trees serve perhaps better to insure the consolidation of the soil on steep declivities. But as generally, on poor land, the soil of timber forests covers itself with branches, &c., it follows that a mixture of the two kinds of woods accomplishes best the end which it is sought to effect."

He speaks with similar explicitness in regard to the effect of *gazonnement*; and in reference to artificial structures other than those which he advocated, he remarks: "MM. Scipion Gras et Phillipe Breton have also loudly proclaimed, in a way the most explicit, that the *boisement* of the valley appeared to them the most efficacious measure which could be adopted against torrents, and that it was only in default of proceedings with a view to extinction being adopted—the application of which, when they wrote, was still surrounded with obscurity and uncertainty—that they proposed the measures they did, as means of diminishing, at least provisionally, the danger. The torrents in the Alps which have given occasion for the study of these pheuomena owe their origin to the melting of snow on higher lying mountains in summer, and to *oragès*, or tremendous storms of rain, which fall in spring. These torrents occasioned by the latter are generally the most destructive.

" M. L. Marchand, *Garde General des Forêts*, says on this subject,—" When the torrential rains of the Alps are made a subject of study it is soon seen that they are all of them occasioned by a particular wind called the *fœhn*. These winds are generally violent, and present almost always the character of *orages*, or storms of rain; it follows that great quantities of rain are poured down upon the soil; and to this may be attributed disasters sometimes coming upon spots which seemed to be placed in the best possible situation and circumstances to bear the most persistent rains.

" The *fœhn* is a wind which blows from the south, often with extraordinary force; it is peculiar to the Alps, and is felt throughout their whole extent. Having climbed over Italy, where it is no other than the *sirocco*, the following are its chief characteristics :—It comes from the south, but its direction is modified at every step, either by mountain chains or by valleys. Its origin is still a subject of discussion: according to some it originates in the Sahara, according to others it originates in the Gulf of Mexico. It gives to the sky a strangely-marked, peculiar, heavy, whitish aspect; and the rain falls on the second or third day following its appearance.

" The wind arrives on the Mediterranean coast loaded with vapour; it there encounters that immense calcareous semi-circular wall of the Maritime Alps, and it scales their higher slopes; but in consequence of their covering of forests, and the great heat concentrated by them, in doing so it only attains a higher temperature. It is rarely the case that the moisture is condensed or precipitated on these countries which it rapidly traverses; but it cools by degrees as it mounts the Maritime Alps, and on reaching the upper basin of the Var and its affluents it deposits an enormous quantity of water; then it continues to advance northwards to French Comté, before reaching which latitude it has lost much of its force.

" If a glance be cast over a map of the Southern Alps, it may be observed that from mount Viso there part off great chains running perceptibly from east to west; the *fœhn* comes up the valleys of the basin of the Var, or of the upper sources of the Durance, it strikes upon the first chain parting from the col of the Pas-de-la-Cavale, or of the Grandes-Communes, taking a deviation to the north of Digne. It is against this chain that the first great storms of rain dash themselves. The clouds in passing over these mountains seek the cols or lower parts, and they arrive in the valley of the Ubaye by the openings of Grande-Commune, of Enohastrayes, of the Col d'Allos, of the Lawerq, of the Bas, and in fine, by the great passage of the mountains of the Seyne.

"The *fœhn* forces a passage for itself into the valley of the Durance; goes up this throughout its whole length; it makes its way also by some cols of the chains which separate this valley from that of the Ubaye, and more especially by those which are opposite Embrun.

"If now the forest chart of the country spoken of and the chart of the *fœhn* be compared, it will be seen that the mountains of Seyne have been cleared of woods, and that the whole southern upper slope of the valley of the Ubaye is devoid of forests; in a word, that all the parts which bear the direct attacks of the *fœhn*—those which arrest it—force it to ascend them, and to pour upon them masses of water, are all of them almost entirely cleared of woods. Here we have no longer, as is the case above Menton, a tropical sun to warm the soil; the wind has cooled down as it rose higher from the sea, and it is obliged with fatal effect to precipitate in the form of rain the moisture it has borne thither; and at that place where the forests are an absolute necessity, and where the most considerable quantities of water fall, there it is that they have completely disappeared.

"This summary is incomplete, but it may suffice to render intelligible the general course of the *orages*, or storms of rain in the Alps, and the intensity of these on certain parts, which are generally those at which the *fœhn* is compelled to rise considerably or to change its direction. The celebrated torrent of Riou-Bordoux, near Barcelonette, in face of the opening at Allos, is exactly so situated. The portion of the Alps situated below the department of the Isère almost completely relieves the *fœhn* of its humidity, and this is the classic region of the *orages*.

"The *fœhn* does not confine itself to the production of torrential rains; it is not less terrible in its action on the snow, and on the glaciers. As has been stated, it blows sluggishly and warm for one, two, or three days before the rain appears; if at this time the ground be covered with snow this is not slow to melt rapidly, and absorbing a great quantity of water it becomes like a sponge; then supervenes the rain which expedites the process and brings on a kind of *débâcle*, or breaking up, and the water arrives in great quantities in the valleys. If the rain do not supervene the action of the *fœhn* may suffice to cause all the snow to melt and to produce great consequent disasters. In 1856 the inundations of the valley of Barcelonette had no other cause of production ; the maximum of the flood was attained under a magnificent sky, and all the water came from the melting of the snow which covered the mountain. In Switzerland the terrible inundations of 1868 had in general a double origin—with warm continuous rains were combined the melting of the glaciers. It is always in the spring, or with the first snows of October, that the latter torrents are to be dreaded if the mountains be not covered with glaciers; where this is the case the danger is constant.

"The *fœhn* sometimes produces general rains over the whole of the country over which it blows, but sometimes only local *orages*, or storms of rain. This can easily be accounted for when it is considered that the contour of the Alps admits of one current of air passing up a valley to be in its cause and in its effects quite independent of a current passing up a neighbouring valley, though they have had a common origin,—and that a difference in the cooling of the currents of air may occasion a precipitation of rain in one valley, while the neighbouring valleys, being warmer, are enjoying a cloudless sky."

When the late Emperor Napoleon came to power he took steps to give effect to the observations and reasonings of MM. Fabre and Surell, which the pre-occupation of public men with political changes had previously prevented.

In 1860 the work of *reboisement* was begun. To the report given by the Director-General of the Administration of Forests, of what had been done in 1867-1868, are appended a number of monographs on works executed in different departments, embracing the departments of the Isère, the High Alps, the Low Alps, Drôme, Gard, Hérault, Aude, and the High Pyrenees, all telling of success.

Amongst others, of which details are given of what had been done, and of what results had followed, is mentioned the case of the torrent of Saint Marthé, on the right bank of the Durance. Of this M. Costa de Bastelica, in a work already cited, remarks :—"This torrent supplies amongst many others a remarkable example of what can be done. In 1841, when M. Surell wrote his valuable work, this torrent had a sad celebrity for its violence. It swept away every bridge thrown across its course. On every occasion of a storm of rain the inhabitants of the banks of the river were thrown into disquietude, fearing to see it burst their dykes, and spread over the plain.

"The works undertaken with a view to secure its extinction were only begun in 1864, and in 1869, when M. Cézanne, before the publication of his work, did me the honour to allow me to show to him and explain our works, he noted the fact that the work of extinction was so complete that a simple foot-bridge placed only 50 centimètres, or 20 inches, above the torrent, had become a work that bade defiance to the greatest floods which now occur. This foot-bridge still stands, and there have been no want of violent storms of rain: in the interval there has been no change in the meteoric conditions. The effect of the extinction of the torrentiality was then attained and certain, and this so much so that the syndicate, organised by the proprietors interested, having no longer anything to do, dissolved itself."

In accordance with this fact are facts innumerable illustrative of the efficiency of vegetation in extinguishing torrents and preventing the formation of torrential floods, by which disastrous inundations are occasioned. Of these, as has been stated, details have been given in a separate volume,* and with these details copious information in regard to legislative measures and practical operations by which the results in question were obtained, together with *résumés* of the works which have now been cited, and notices of others which have been published on the subject.

In the conclusion of the volume there are remarks on the preventability by *reboisement* and *gazonnement* of such sudden and disastrous inundations as that which in 1875 proved so destructive to Toulouse and the valley of the Garonne.

A similar inundation of the Loire occurred in 1846. In a valuable work by M. Vallés, published in 1875, entitled "*Etude sur les inondations leur causes et leurs effets,*" the author denies the efficacy of *reboisement* as a means of preventing inundations. But M. A. F. Hericourt, in writing of this work in the *Annales Forestieres* for December 1857, in an article entitled *Les inondations et le livre de M. Vallés,* combats his views; and he thus maintains his position that the *reboisement* of a portion of the upper basin of the Loire would have prevented the inundation of 1846:—"Accepting," says he, "the data of M. Vallès, who has analysed with much care the various phenomena

* Reboisement in France; or, Records of the Replanting of the Alps, the Cevennes, and the Pyrenees with trees, herbage, and bush, with a view to arresting and preventing the destructive consequences and effects of Torrents. London: H. S. King & Co. 1876.

which characterised the flood of October 1846, in the upper basin of the Loire, I will admit with him that if we could have held back 175,000,000 cubic metres of water, the inundation which proved so sad a calamity to France would not have proved so painful an event. The upper basin of the Loire, as far as Roanne, comprises an area of 640,000 hectares (158,080,000 acres), of which at least a third, say 213,000 hectares (52,693,000 acres), might be profitably re-forested. The inundation was caused by a rain which lasted sixty hours, and poured upon the soil a sheet of water 153 millimètres (about 6 inches) in depth. This portion of the basin of the Loire, therefore, received 979,200,000 cubic metres of water. On the hypothesis of M. Vallès, 244,800,000 cubic metres were absorbed. There accordingly remained for superficial flow, 734,400,000 cubic metres.

"But let us suppose that, in 1846, the 213,000 hectares above-mentioned to have been covered with massive woods, and then let us calculate what would have happened. These 213,000 metres would have received, as their share, 290,000,000 cubic metres. The absorbent qualities of the soil are increased 40 per cent. by reforesting, and this operation would have withdrawn 130,116,000 cubic metres from the superficial flow, which would have reduced the amount upon the re-timbered portions to 195,174,000 cubic metres. But this liquid mass would have been hindered in its course down the valley, as we have above explained, by the passive resistances of every kind which the forest presents, and a half, at least, would not have arrived until after the other half, which had fallen in other portions of the basin, had passed off. We may therefore conclude that the superficial flow would not have exceeded 500,000,000 cubic metres, and that the calamities occasioned by the inundation of 1846 would have been completely prevented by reforesting."

As rain is the precipitation from the air of a quantity of moisture which it can no longer retain, so rivers are composed of the draining off of a quantity of the rainfall which the ground upon which it has fallen can no longer retain; and—while the flow and escape of the rainfall is arrested by much of it being absorbed and retained by the decaying debris of leaves and twigs lying on the surface of the ground in a forest, and by the humus in the soil, and by being carried to a great depth along the channels of the roots—a secondary effect of this is to regulate, and, in doing so, to some extent to equalise over a considerable time the continuous flow and delivery of the streams and rivers by which it is drained.

In not a few of the statements which are given in preceding chapters in regard to the effects of the destruction of forests, mention is made of what had previously been perennial streams being often dry, while at other times the water-course was filled from bank to bank with a rushing torrent. There might be as much water delivered by these in the course of the year as ever there was—though this might be questionable, and the observations cited by Herr Wex, and given above, show that in some of the principal rivers of Europe a greatly increased irregularity of flow has been accompanied by a diminished annual delivery—but the flow was irregular, and the correction of this is a consequence of the absorption referred to. Among the consequences of this may be reckoned the following :—

1. The devastating and destructive effects of floods are mitigated, if not altogether prevented. 2. The prolonged retention of the rainfall in an inland situation increases both the moisture of the atmosphere and of the soil, by prolonging the periods of evaporation and infiltration. 3. From both of these effects will follow other consequences tending to perpetuate the results so obtained. 4. Not only will the promotion of vegetation, desirable as an end, be accomplished, but one of the meteorological effects of vegetation, the increased or maintained humidity of the atmosphere, will be secured.

CHAPTER VI.

On the Correspondence between the Distribution of the Rainfall and of Forests.

As the student of Anatomy takes up now a muscle, now a nerve, now an artery, and now a vein, and traces it by careful dissection from all integuments and other structures with which it may be united, giving to it for the time his undivided attention, and leaving for subsequent consideration the connections and relations in which each stands to each and each stand to all, so would I pass from the consideration of one subject to the consideration of another, treating each as for the time the one subject with which we have to do, and leaving for subsequent consideration the various facts evolved in their combined connections and relations.

It has been alleged that the distribution of forests corresponds to some extent with the distribution of the rainfall. And this raises the questions, Which is cause and which is effect? or are they both consequences of a common cause? and in either case to what extent may they be legitimately regarded as cause and effect?

In Scottish courts of justice it is customary for the public prosecutor to lead evidence and then to state his case as founded on this, while in English courts he states his case and then leads evidence to establish it. I do not admit that I have got a case to establish; but I shall state what my belief is, adduce observations in illustration of different particulars, and then state what I consider to have been proved.

It appears to me that observations made show in many cases a general correspondence between the distribution of the two—that in many cases the distribution of the rainfall has been determined in a great measure by the geographical position and by the contour of the country, and that this distribution of the rainfall may have determined the distribution of the forests—but that the forests once established may have exercised an important influence in further modifying the distribution of the rainfall in time and in space.

SECT. I.—*On the Measure of Correspondence between the Distribution of the Rainfall and of Forests.*

I have said it appears to me that observations made show in many cases a general correspondence in the distribution of the rainfall and of forests. It may occur to many on the mention of this that while there are found forests covering extensive plains, their special habitat appears to be the mountain side—and that the rainfall in the vicinity of a mountain range is in general greater than it is on the horizontal area of an extensive plain.

But the correspondence is more marked than this alone would intimate. It happens to be the case that, in some cases, the observations have been given to the world by observers having decided views in regard to the connection of cause and effect, and in illustration of their views; but at this stage they are adduced only as illustrative of the measure of correspondence which has been observed.

The first observations I adduce are some brought before the Meeting of the British Association for the Promotion of Science, held at Brighton in 1867, by Dr Brandis, Superintendant-General of Forests in India, in a paper On the Geographical Distribution of Forests in India. Dr Brandis considering India as divided, by observation of the rainfall, into arid, dry, and wet districts, stated that in the west corner of India was what might be called the arid tract, extending from the coast of Cutch and from Scinde in the south to the Salt range in the north, and from the hills of Beloochistan in the west to the Aravalli range in the east. The average rainfall in this district was less than fifteen inches. Throughout this arid part of India the spontaneous arborescent vegetation was extremely scanty, although a thin sprinkling of low thorny scrub on the hills offered ample and interesting employment to the botanist. In this region the work of the forester was limited to those tracts which stretched along the Indus and its principal tributaries, watered by the annual overflow of the river during summer, or which could be otherwise irrigated. Thus in Scinde there were on both sides of the Indus river 352,000 acres of Government forest maintained solely by the overflow of the river and by percolation. The result of the deflection of a river from its course was that the forest near the old bed frequently perished.

Outside this arid tract there were two belts, with an annual rainfall of between fifteen and thirty inches, which might be called the dry zones of India. The spontaneous arborescent vegetation was scanty, save in the moist lands along the great rivers, but it was better than in the arid tract. In the southern dry zone, comprising part of the Deccan, was the country of the sandal wood, a small tree which did not grow gregariously, and did not form continuous forests. Here, too, were the ancient irrigation works, tanks, and gigantic stone dams across rivers ; and where water was thus supplied, fields and gardens were most luxuriant.

"Beyond these dry zones, and in the rest of India generally, the rainfall exceeded 30 inches; but even in these moister parts of the country the conditions for forest vegetation were not everywhere as favourable in India as in Europe. Really thriving forests were only found where the fall exceeded 45 inches, and luxuriant vegetation was limited to those belts which had a much higher rainfall. Within the moist regions, with a rainfall exceeding 60 inches (in one place rising to 250 inches) and in Eastern India, there was a great variety of good forest. Of the *Deodar* forests of the North-West Himalaya a small portion only fell into this belt, the greater part lying in land where the rainfall was less than 60 inches. Between the dry and moist regions was a vast tract of country with an annual rainfall of more than 30, but less than 60 inches, comprising the greater portion of the upper Gangetic plain, the whole of Central India, and the western side of the peninsula. In this part of India the main obstacle to a luxuriant forest growth was not so much an insufficient supply of moisture, as its unequal distribution over the seasons of the year. Of the moist zones, there were two in which the annual rain exceeded 75 inches, the smaller one along the western coast of the peninsula, and the more extensive one on the outer Himalaya ranges, the hills of Bengal, and the coasts of Burmah.

"On the western coast the rainfall was moderate as far down as Surat, 47 inches, and Bombay had 72 inches; but Janna, only a few miles inland, had 102. Further down the coast the rainfall was heavier. Rutnaghem had 115, and Canara had 123 inches. Approaching the southern extremity of the peninsula, the rainfall gradually diminished to 28 inches at Cape Comorin. In this narrow moist belt were found some of the finest forests in India. The teak forests of North Canara, protected by the difficult nature of the country, the teak and blackwood forests of Wynaad and the Anamallays and the forests of Travancore were reputable forests, which might stand comparison with the oak and beech forests of the Spessart, and the oak forests of Central France. The teak plantations of Nellumboor, in Malabar, which were commenced in 1844, and now covered upwards of 2,400 acres, were a splendid instance of luxuriant forest growth on a good soil, in a foreign climate, and under good management. The moist region of the Himalaya and the eastern part of India had a much larger extent. The Kangra valley, in the Punjab, had a rainfall of 100 inches, and from here the moist narrow belt, but widening gradually, ran in a south-westerly direction as far as Sikkim. Near Simla, the width of this belt, with a rainfall of 75 inches, was not more than 30 miles. Near Darjeeling, it extended into and comprised the whole of Assam, Eastern Bengal, as far as Dacca and British Burmah. A second belt of between 60 and 75 miles, ran outside the foot of the Himalaya, comprising the estuary of the Ganges and part of Orissa. Within these moist regions of northern and eastern India, were a great variety of good forests. Only a small portion of the deodar forests of the north-west Himalaya fell within this belt, the greater part lying inland, where the rainfall was less than sixty inches. The india-rubber forests of Assam and Cachar were within the range of the heavy rainfall as well as the ironwood forests of Arracan and the teak forests of British Burmah.

"Between the dry and moist belts there lay, as has been intimated above, a vast tract of country with an annual rainfall varying from thirty to sixty inches. In this part of India the main obstacle to a luxuriant forest growth was not so much an insufficient supply of moisture as its unequal distributions over the seasons of the year. In the greater portion there was a long dry season and a short rainy season. During the dry season the leaves and grass get excessively dry and inflammable, and the smallest spark was then sufficient to create a conflagration, which did not stop until it had reached the limits of the forest. These jungle-fires destroyed millions of seedlings, and those which escaped were scarred and had in them the germs of early decay. The jungle-fires were sufficient to explain the remarkable fact that, in a large proportion of the forests of Southern and Central India, and in some of those of the north, the mature trees were unsound or hollow."

I could scarcely desire a better illustration of what I mean by a general correspondence between the distribution of rainfall and of forests, leaving out of view all that may be said bearing upon the question of cause and effect, than is afforded by this statement.

A view similar to that advanced in regard to the geographical distribution of forests in India is advanced in regard to the distribution of forests in America, by Mr Charles Maclaren, in an article on America in the "Encyclopædia Britannica."

In this the writer says,—"We are induced to think that in all countries having a summer heat exceeding 70°, the presence or absence of natural woods, and their greater or less luxuriance, may be taken as a measure of the amount of humidity and of the fertility of the soil. Short and heavy rains in a warm country will produce grass, which, having its roots near the surface, springs up in a few days, and withers when the moisture is exhausted; but transitory rains, however heavy, will not nourish trees, because after the surface is saturated with water the rest runs off, and the moisture lodged in the soil neither sinks deep enough nor is in sufficient quantity to furnish the giants of the forest with the necessary sustenance. It may be assumed that twenty inches of rain falling moderately, or at intervals, will leave a greater permanent supply in the soil than forty inches falling, as it sometimes does in the torrid zone, in as many hours. It is only necessary to qualify this conclusion by stating that something depends on the subsoil. If that is gravel or a rock full of fissures, the water imbedded will soon drain off; if it is clay or a compact rock, the water will remain in the soil. It must be remembered also that both heat and moisture diminish as we ascend in the atmosphere, while evaporation increases; and hence that trees will not grow on very high ground, though its position in reference to the sea and the prevailing winds should be favourable in other respects."

Assuming as unquestionable that the trade winds are the agents which transport the moisture exhaled from its surface to the interior of great continents, where it is precipitated as rain, or dew, or snow; and that mountains, by obstructing aerial currents and presenting great inequalities of temperature, cause precipitation, this writer says, —"Let us consider then what will be the effect of a mural ridge like the Andes in the situation which it occupies. In the region within the 30th parallel the moisture swept up by the trade wind from the Atlantic will be precipitated, part upon the mountains of Brazil, which are but low, and so distributed as to extend far into the interior; the portion which remains will be borne westward, and, losing a little as it proceeds, will be arrested by the Andes, and fall down in showers on their summits. The aerial current will now be deprived of all the humidity which it can part with, and arrive in a state of complete exsiccation at Peru, where no rain will consequently fall. That even a much lower ridge than the Andes may intercept the whole moisture of the atmosphere is proved by a well-known phenomenon in India, when the Ghauts, a chain only 3000 or 4000 feet high, divide summer from winter, as it is called: that is, they have copious rains on their windward side, while on the other the weather remains clear and dry; and the rains regularly change from the west side to the east with the monsoons.

"In the region beyond the 30th parallel this effect will be reversed. The Andes will in this case serve as a screen to intercept the moisture brought by the prevailing west winds from the Pacific Ocean; rains will be copious on their summits, and in Chili on the their western declivities, but none will fall on the plains to the eastward, except occasionally when the winds blow from the Atlantic."

And he adds,—"The views on the subject of climate we have been unfolding will enable us to throw some light on an interesting point, the distribution of forests."

There is appended a small map of America, in which by long hatched lines are shown the positions of the chains of mountains; white spaces represent lands on which little or no wood grows; shading represent the regions of forests, dense forests being represented by double shading, and thinner ones by open lines; while arrows indicate the direction of prevailing winds. And in explanation it is stated,—"In speaking of the *region of forests*, we neither restrict the term to those districts where the natural woods present an unbroken continuity, nor extend it to every place where a few trees grow in open plains. It is not easy to give a definition that will be always appropriate; but in using the expression we wish to be understood as applying it to ground where the natural woods cover more than one-fourth of the surface." And there is given the following statement in regard to the distribution of the forests,—"In North America, to the west of the Rocky mountains, is thus represented a woody region, extending from lat. 35° to about 58°, of unknown breadth, densely wooded from the coast, more thinly wooded towards the mountain range; to the east of the mountains, an extensive region stretching E.NE. to the ocean, partly a bare desert, partly covered with grass and clothed with trees. On the east coast and more to the south is the Allegany range, with dense forests on the east and the south and thin on the west, the forest region thus indicated being bounded by a curved line passing from the mouth of the St. Lawrence, in lat. 50°, through Lake Huron to St. Luis in Mexico; and an arrow points out the direction of the wind turned from its course, ascending the valley of the Mississippi, and nourishing the western parts of these forests. To the south of lat. 30° the equatorial winds blowing from the east prevail; and from 35° southward from the forest lands of the Rocky Mountains, is the table land of Mexico, graduating in the north-west into the dry plains of Sonora and California, all bare or nearly bare of wood. From this region, down through the Isthmus of Panama, there are dense forests. These dense forests fork and stretch to some extent along the western coast of South America to Amotape, whence stretches a long strip of dry bare sand; on the west side of the Andes, which constitute Lower Peru and the north part of Chili, a little to the north of the equator, about midway from both coasts, is the Llanos, (a bare plain of caraccas, nearly fenced round with mountains); passing this to eastward, the dense forests follow the coast line, stretching far into the interior, somewhat diminished in density, and forming the great region of forest which constitute the basin of the Amazon and occupies all the rest of Brazil.

"Near the equator the moisture is so excessive that after 150 or 200 inches of rain have fallen on the east coast there is still sufficient humidity in the atmosphere to afford copious showers to all the country up to the Andes. Here, therefore, the woods reach from side to side of the continent. But as we recede from the equator the humidity diminishes rapidly, and though the continent becomes narrower towards the south the supply of rain falls off in a still greater proportion, and the forests extend over a much smaller space. At the foot of the Andes the forests extend to 16° or 18° south lat.; on the east coast, to 25°, probably 30°. Thence, on the east coast are the Pampas, or open lands of Buenos Ayres, extending, on the east side of the Andes, from the latitudes mentioned to Cape Horn.

"But on the western side of the Andes, extending through the same latitude, are the forests of Chili, where the prevailing winds which are from the west, coming loaded with the moisture of the Pacific Ocean, produce copious rains to nourish the herbage and forests. This applies chiefly to the country south of the 35° parallel. From that to Coquimbo, lat. 30°, the wood is scanty."

In this, as in the account given by Dr Brandis of the Geographical distribution of forests in India, we find, apart from the facts embodied in the statement, an illustration of a general correspondence between the distribution of the rainfall and of forests.

Independent testimony on the distribution of the rainfall in

America is supplied by the Smithsonian Institution, unencumbered by any theory. The arrangements made by this Institution for collecting, collating, reducing, and utilizing meteorological observations are on the most ample scale.

Towards the close of 1873 I received from Professor Henry a series of rainfall tables, comprising all the observations that have been made in regard to the rainfall in the United States since the settlement of Europeans in the country, and an intimation that they had commenced a new epoch, and had subsequently to the publication of these tables distributed several hundred rain-gauges in addition to those previously used, and to those which had been been provided by the Government in connection with the signal source; and three rain charts are given showing, from the material collected in the general table of results, the geographical distribution of rain over the area of the United States, with the average amount fallen during the year, and during the seasons of summer and winter. The first chart exhibits the results from 750 stations, and the others the result obtained from nearly the same number.

In regard to the general character of the distributions of rain on the average throughout the year, it is stated,—"The most striking features of the phenomenon of rain, as delineated on the chart, are the apparent precision and continuity in the law of its distribution, and the great variation or range in its amount. Thus the curve, passing over places where the annual fall amounts to 40 inches, can be followed from New Brunswick, on the Bay of Fundy, to Texas; the isohyetal line of 36 inches, similarly, runs without interruption from the St. Lawrence River to the mouth of the Rio Grande. The regularity of the curves is sufficiently distinct to mark out everywhere the progression in the deposition of the aqueous vapour. The annual amount varies from four inches in the Yuma and Gila Deserts, at the head of the Gulf of California, to 80 inches and more on the Pacific Coast in Washington Territory; on the Gulf Coast 64 inches appears to be the maximum amount, and 48 on the Atlantic Coast.

"The principal supply of rain over the United States comes from the Gulf of Mexico; its diffused vapour can be traced from the eastern slope of the Rocky Mountains to the Great Lakes; while the supply of vapour from the Atlantic Ocean is distinctly traceable over that area lying north and east of Virginia. All States and Territories west of the Rocky Mountains receive their supply of rain from the condensed vapours of the Pacific Ocean.

"There are distinct localities of entry of *maximum* rain from each of these basins of supply; the vapours from the Pacific are deposited within a remarkably well-defined coast region between latitude 41° and our boundary at the Straits of Juan de Fuca; the rain pours down with great intensity on the coast between the mouth of Columba River and Cape Flattery. It is surprising how little rain falls on the Pacific coast between San Diego and Cape Mendocino, and how quickly the atmosphere becomes drained of its vapour as we leave the coast and proceed inland in latitudes north of 41°. The coast range of mountains here act powerfully as condensers by forcing the air up their western slopes.

"The densest part of the Gulf vapour is thrown over the delta of the Mississippi River, and as far east as longitude 86° its *axis of diffusion* can be traced distinctly to the west end of the Lake Erie: it is inclined towards the northeast for two reasons—the effect of the earth's rotation on a flow from the south, and the influence generally of the prevailing westerly winds. A second sweep over the country occurs in southern Florida, most likely due to the immediate proximity of the Gulf Stream; and there is a third, as yet undefined, influx, passing through Georgia and South Carolina.

"The condensation of vapor from the Atlantic is most apparent a *short distance inland* at the following localities: Along the coast of Maine near Eastport and near Portland, in central Connecticut, western Massachusetts, and extending to southern Vermont, and near the entrance of Chesapeake Bay. Upon the whole, hills and mountain ranges appear to have a comparatively small directive influence upon the distribution of the rain. Florida, which may be considered as almost perfectly flat, exhibits well-defined bounding lines of rain distribution. River courses also seem to influence the amount of rain, as along the Rio Grande. At the mouth of the Hudson River, the curves become suddenly contracted; and some similar feature can perhaps be traced out on the Mississippi delta near New Orleans. Beyond furnishing by their evaporation a supply to the general fund of moisture, the Great Lakes do not appear to exercise any direct influence; on the yearly average the rains along their borders are not increased. There is even a remarkably small amount of rain-fall in northern New York, close to Lake Ontario. The effect of equalizing the temperature produced by all large bodies of water has no doubt a direct influence upon the distribution of rain; the greater and more sudden the variations in temperature, the greater, comparatively, the rain-fall.

"The laws of the distribution of the rain-fall, as far as they depend upon the *changes* of temperature and direction of wind, can be studied to better advantage by means of the two charts showing the distribution in summer and in winter, than by that for the year, since the latter necessarily brings out the resultant phenomena, and should consequently be of greater complexity than either of those for the extreme seasons. With a few exceptions, presently to be noticed, the distribution of rain in the extreme seasons is not very dissimilar from that of the year as a whole."

It is stated in the report that the tables show that mountains and hills have apparently a comparative trifling divertive influence on the distributions of rain. For this conclusion some of my readers may not have been prepared. To what extent, if any, the distribution of forests may correspond with the distribution of rain is not referred to; but in a work on the aspects presented by forests in different parts of the world, by M. F. S. Marny, we have notices of the forests in the United States, of which we may avail ourselves to see how far these independent records—the one of the rainfall, and the other of the forests—correspond.

After a graphic description of the forests of South America, M. Marny says:—"On re-ascending into upper Mexico and reaching California, arborescent vegetation resumes, with regard to kinds, the character of our temperate climates, but it still preserves its gigantic character which belongs to the trees of the New World. In Oregon, the pines that fill the forests spread along the sea shore seem to be the kings of all the pines in the universe. Their diameter is often 5 mètres, their height surpasses sometimes 100, and their cones are 15 inches long. The pine *lambertina* gives to the coast of California an imposing but melancholy aspect. The lines of pines run along the shore as far as Russian America, where they are associated with oaks and birches. Their less lofty species prevail in the forests of New Hanover, of New Georgia, where they adorn, with sycamores and maples, the slopes which incline towards the ocean."

Along the coast, from lat. 50° to 41°, we have according to the rain-chart a rainfall of from 60 to 40 inches, diminishing as we proceed inland to 52, 44, 32, 30; and in the longitudes of Nevada, extending thence to Minnesota, Nebraska, and Kansas, 16 and 20, with no mention of forests, but in the State last-named it rises to 20, 24, and 28.

M. Marny proceeds:—"Crossing the Appalachian and the Rocky

Mountains, we encounter new lines of forest-trees. One of the first is traced by the bald cypress, which seems to be surrounded by natural boundaries. These are protuberances formed upon the roots of this conifera, and they often rise to a mètre in height: which barriers defend the trunk against the attacks of large animals. These cypresses compose gigantic thickets, which cover the swamps of the lower Mississippi, of the Arkansas, of the Red River, and of Florida, and extend as far as the mouth of the Ohio. It was under the vast shade of one of these trees that Cortez and all his army found a refuge in Mexico. Their wide stems, of conical form, are crowned with a multitude of horizontal branches, which are entangled with each other, and confounded with those of the neighbouring cypresses. These vaults of foliage, which are frequently superimposed, give to the forests of this cypress an aspect quite peculiar. The short leaves of a sombre green, represent on drawing near a kind of crape, which impresses on these shades a funereal appearance. And under these gloomy domes, which are here and there enlightened by a few openings made by the winds, or due to the age of the branches, all the scourges of man, whether animate or inanimate, seem to have given each other the rendezvous. Death soars over these shady solitudes, which incessantly evoke the idea of it. Fevers, alligators, serpents, mosquitoes contend with each other for the woodman who goes with his axe to strike their trunks—the growth of ages. But no danger arrests the avidity of man, nothing terrifies the enterprising descendant of the Anglo-Saxon race. The *lumberers* venture through these pestilential swamps, and precipitate into the waters of the Mississippi the trunks they have uprooted.

"The Mississippi, that ancient father of waters, is indeed the great agent of destruction to these forests of North America; its waters, especially at the period of inundation, are continually charged with enormous masses of wood, with gigantic rafts which encumber its bed, and are self-constructed with more solidity than any raft made by the hand of man. These trains of trees are especially remarkable upon the Atachafalaya, one of the arms of the Mississippi. They are equally met with upon the Red River. One of the affluents of this river, the Nashita, is interrupted for a space of seventeen leagues by an almost uninterrupted succession of these rafts. M. de Humboldt has made known the same fact in the Orinoco, whose bed is unceasingly encumbered by a mass of trunks, which seem as if driven into the mud.

"These swampy forests, by the destructive action of humidity, finish by transforming themselves into vast bogs, which present the appearance of great inundated plains, whose surface might be covered with trees brought along by the waters. These immense stagnant pools, these seas of mud, still furnish a soil sufficiently firm for a species of cypress, and of broom which grow there; they offer the only ground of support for the foot of the animals that wander in these aquatic solitudes,—bears, wild cats, wolves. The most celebrated of these swamps is the Great Dismal, which Mr Lyell has described in his interesting journey in the United States, and which extends between the towns of Norfolk, Virginia, and Weldon, North Carolina."

In the Lower Mississippi we have, according to the rain-charts, a rainfall of 56, 60, and 64 inches per annum; in Arkansas, a rainfall of 42, 44, and 50; in Norfolk, Virginia, 44; in North Carolina, 44, 48, and 52.

M. Marny continues,—"Upon the lower levels of the Alleghany Mountains, the rhododendron and the kalmia display their elegant flowers. From stage to stage the vegetation is modified; and to forests of oak succeed the resinous pines, with which are associated magnolias, poplars, and different species of *nyssa*.

"The forests of the Alleghanies belong to one of four forest zones which embrace North America; they extend over the south-west coast as far as to the south of the bay of Chesapeake. They chiefly contain pines, firs, cedars, and cypresses."

In this district we have a rainfall of 36, 40, and 44 inches.

"The second zone, which corresponds with the region of magnolias, catalpas, tulip-trees, stretches over the Floridas and Louisiana; it is characterised in several parts by forests of cedars, known under the name of cedar-swamps. In Louisiana the rather stunted stems of the wax-myrtle are found among the rhododendrons.

"In Florida and Carolina are forests called *pine-barrens* composed of gigantic pines, reaching a height of more than 50 métres, and rivalling those which clothe the opposite coast of the American continent. These *pine-barrens* comprise a broad band several hundred miles in length. Behind these forests of coniferæ, which form the second forest line, one encounters on disembarking upon these shores —the first being composed of graceful palms—come other forests not less dense, but composed of a thousand kinds of wood. 'There,' writes M. F. de Castelnau, 'the magnolia exhibits with profusion its leaves like immense spatulas, while the air is embalmed by its beautiful and enormous flowers so dazzlingly white. It is intermingled with a hundred species of sassafras, catalpas, laurels, cedars, gum-trees, in the midst of which the magnificent evergreen-oak distinguishes itself. Everywhere the cornel-tree dazzles the eyes by its silvery splendour; the azalea is lavish of its corolla, like an elegant butterfly; and the sumach displays with pride the magnificent splendour of its scarlet bouquets. All these various trees are closely matted together by lianes without number—veritable alliances with these brides of nature.' "

In Florida we have a rain-fall of 60, 52, 48, 44, 40, and 36 inches, and in South Carolina the same.

"The third forest zone invests the hills and low mountains of the Carolinas, of Pennsylvania, and comprehends the slopes of the Alleghanies which we have just described. The oak, the birch, the mulberry, the sycamore, the maple, occupy these woods. The willow-leaved oak, the elm, and the chestnut, principally form forests in Pennsylvania and in New Jersey; in the environs of Habochene venerable forests run parallel to the coast. The two parts of this state form a striking contrast to the rest; whilst a vigorous vegetation adorns the northern divisions, those that lie to the south offer only an arid sandy soil, which has its own species and its especial forests. The upper Ohio flows under a bower of tulip-trees and planes, whose elegant foliage is reflected in its waters.

"But it is in the state of Indiana, above all in the environs of New Harmony, upon the banks of the Wabach, that the forests of North America show themselves in all their magnificence. They present, among the forests of the New world, a distinct character, and one of their peculiarities is the want of evergreen plants, with the exception of the mistletoe, a species of bignonia, Dutch rushes, which are a kind of equisetum, and the *Miegia microsperma*. When the woods are stripped of their foliage, the eye is attracted only by the equisetum just named which reaches a height of eight or ten feet In these collections of trees the traveller is struck by the gigantic planes, ramifying themselves into a certain number of hollow trunks, which serve him as a shelter in time of need. To these planes are united maples of proportions almost as great, several oaks, and notably that which bears the name *Mossy over-cup oak*, whose enormous acorns are strewn over the ground, and which grow in close ranks. A multitude of climbing-plants embrace the trunks of the large kinds, the quinate-leaved ivy, the poison ivy, the bignonia, which attach themselves to the trunks like a thick net-work formed of aërial roots, to which are attached at right angles the branches that bear the leaves. Among these mighty trees there are lofty thickets of 15, 20, and 30 feet in height, composed of the papaw-tree, the spice-wood or fever-bush, and the red-bud tree. Below these smaller kind of trees the ground is still covered with shrubs, and in the openings grow the *Rhus typhina* and the *Rhus glabra*, Magnificent catalpas appear at every step in a wild state; but the botanist seeks in vain for trees with aciculate leaves, the pine, the cypress, or for the rhododendrons, the azaleas, the magnolias, the chestnuts, which are met with in other parts of America.

" These woods are rapidly thinning. Legions of backwoodsmen take up their abode in them; and they are speedily cleared. Already wood is becoming singularly dear at New Harmony; and the hickory, which gives out so powerful a heat, has been cut down with a profusion and ignorance usual with the first colonists of forest countries."

In Indiana we have a rainfall of 44, and 40.

" The fourth zone loses the physiognomy of the subtropical vegetation, to resume that of the vegetation of our northern countries. It comprehends the greater part of New York, New England, Vermont, New Brunswick, Canada, the region of the lakes; to this region Newfoundland belongs.

" In the state of New York, forest vegetation is of a heavy and dense character; which is owing to the predominance of certain kinds of hemlock, spruce, fir. The black-spruce constitutes the characteristic tree of this cold region; it forms a third of the forests in all the districts comprised between 44° and 53° north latitude.

" A great part of Long Island is covered with forests, of which one-half is formed, according to Dr Timothy Dwight, of yellow-pines.

" The borders of Lake Huron are covered with gigantic forests of planes, between the close ranks of which are seen groups of tamarask or of American larch, of pendulous larch, that frail tree which seems to be an arborescent reed. All the vegetation of the borders of this lake is of a more decidedly grand character than that of the other lakes. The forests of Lake Erie are enriched with the sassafras-laurel, the magnolia, the *Cornus Florida*, whose branches, adorned in autumn with bunches of scarlet, agreeably diversify the sombre verdure of the rest of the forest. The vegetation of Lake Ontario resembles that of Lower Canada; yet we find there some characteristic species—Canada poplars, the robinia, the lime, the resinous pine, and the red pine.

Upon the borders of Lake Champlain, the sugar-maple, the balsam-fir, the Virginian poplar, are equally remarkable.

"In the environs of the Falls of Niagara the tulip-tree, the red cedar, and the Canadian yew grow in great abundance; whilst near to Kingston, which is only seven miles from the cataracts, an immense forest, composed of horse-chestnut trees, has taken possession of the soil to the exclusion of every other kind.

"Around Bloomfield, not far from Lake Canandagua, magnificent forests of oak furnish the colonists with a valuable wood, and embellish the slopes of the hills.

Throughout the district specified we have a rain-fall of 44, 40, 36, 32, and on one very limited spot so little as 28.

"When we advance into Canada, forest vegetation gradually dwindles, and at length becomes quite stunted. We no longer meet with any thing but little firs, dwarf birches, and lank poplars. This is observed to the north of Quebec, and of the parallel of the Isle of Manitoulin."

Within the line indicated we have a rainfall of from 32 to 44, the latter being the rainfall at St. Johns, New Brunswick; falling to 40 and 36 as we come nearer to the St. Laurence.

Thus does it appear that every observation made in North America seems to tend to show a general accordance between the distribution of the rainfall and of forests.

Something similar may be observed in the distribution of forests in South Africa. In the Colony of the Cape of Good Hope all the existing forests are found on mountain slopes following the convex curve of the sea coast from the mouth of the Orange River on the west to Port Natal on the east. The trees are comparatively few in number on the Cedar-Bergen range, in Clanwilliam, but so numerous were they formerly as to have suggested the name given to the mountains; they are more numerous on the Table Mountain range near Capetown; they appear in greatest abundance in the districts of the Knysna and George; but they abound also in Kaffraria and in the Trans-Kei territory. This curve encloses an extensive inland district almost destitute of trees, bounded on the north by a district crossing the continent beyond the colonies, in which trees are more numerous, connecting the forest lands of the east with forests on the west coast further to the north.

Co-extensive with these forests, there is what may be called comparatively a copious humidity of soil and climate; while in the districts in which there are none, the soil and the climate are comparatively dry. There have been described by Livingstone three distinct meteorological zones in South Africa: the eastern, comprehending Zulu-land, Natal, Independent and British Kaffraria; the central, comprising a portion of the elevated Central Basin of the continent, and divided from the eastern by the Drakenberg, Malutis, and other ranges; and the western, including the Káláhári Proper, the wastes of Namaqualand, and the wilds of Bushmanland—the latter, situated to the south of the Orange River.

The first of these is comparatively well watered, and there we find extensive districts covered with ever-green succulent arborescent herbs, and most of the extensive forests. In the second we find comparatively little water, and forests disappearing. The third is arid and sterile and barren in the extreme.

I have had occasion to cite the statement that "the prevalent winds of most of the country thus divided are from the northeast. Heavily laden with vapour from the Indian Ocean, the clouds, under the influence of these easterly currents, are driven over the Zulu territory, Natal, and Kaffirland, watering those lands luxuriantly; but when the moisture-bearing nimbi arrive at the peaks of the mountain ranges, not only have they parted with a large proportion of their water, but they are then on the edge of the more arid central basin, and begin to meet with the influences of the heated and naked plains, under the radiation from the surface of which, and in an increasing degree as the Bechuana tribes are past and the Káláhári is reached, the clouds rise higher above the earth, the moisture evaporates in a thinner vapour, and as a consequence fewer showers fall upon the hot thirsty soil beneath.

"The further we journey from the Drakensberg eastwards, the greater becomes the diminution of water.

"Leaving the mountains, the Lesuto or Basuto land, as it is called, is without doubt the best watered portion of the central meteorological district, mainly, it is presumed, on account its being intersected by the Malutis range. Towards this important section of country, from November to April, the northeast winds blow from the shores of Mozambique and the delta of the Zambesi immense masses of cloud, which sweep heavily over the earth, darkening the sky, and preceded in their course by dreadful peals of thunder. On reaching the high land, the aërial lake is shut in by the huge table-headed mountains; as a consequence, a rapid condensation takes place, and then a veritable deluge ensues. In a few moments cataracts rush from the mountain heights, the smallest and most thread-like rivulets are transformed into torrents, and the rivers overflowing their banks cover the plains: this sometimes lasts for days together *(Casalis)*. It is from the accumulation of these waters that the Lekoa, the Caledon, and many other tributaries of the great Orange River, which with slow and majestic course flows to the westward across the vast plains of the centre of South Africa, take their rise. As the mountains, however, merge into the plains, and these again into the Káláhári, we are reminded by the gradual diminishing rivers of the continual aridity of the soil, till we reach Great Namaqualand, where the occurrences of periodically filled water-courses again testifies to the descent of rain.

"In this latter district, however, as well as in the desert, rain falls only from thunder-clouds. These rise from the northeast, and are always hailed with delight by the inhabitants of those parched and burning regions; but they are partial in the distribution of their precious treasure, the storms frequently passing over with tremendous violence, striking both European and native with awe at their terrific grandeur, while not a particle of rain descends to cool and fructify the barren waste."

Thus do we find in Asia, in America, and in Africa alike, a general accordance between the distribution of the rainfall and of trees.

SECT. II.—*On the Distribution of the Rainfall dependent on Geographical Position, being determined by the contour of a country.*

Of two existing phenomena it is sometimes difficult to determine what is the order of sequence in which they have appeared—which is cause and which is effect—or whether both be not consequences of the same cause; and this we may experience in view of the correspondence between the distribution of the rainfall and that of forests.

Whatever may be the effect of a copious rainfall on a mountain side in promoting a growth of forest trees—and whatever may be the effect of a forest there, in producing and maintaining an abundant rainfall—it is the case that the configuration of a country, irrespective of forests, exercises a considerable influence on the territorial distribution of the rainfall.

The effect which may be produced by altitude alone on the distribution of the rainfall receives an interesting illustration from observations collected and published by M. Belgrand* in regard to a wind-wave which passed over Europe towards the end of September, 1866.

This wave originated in America, on a line which extends from Buenos-Ayres to the North Pole; it traversed the Atlantic, and reached England on the 20th September, and France, Belgium, and Holland on the 21st. On the 22nd, it reigned at the same time over Nancy, and over Paris. On the 23rd, it raged over the sources of the Seine, and of the Loire, and extended to the Garonne. On the 24th, it passed over Lyons; its fury broke upon the St Bernard, from the 24th to the 26th; and from the 23rd to the 24th, upon the Simplon.

On all the elevated places it poured out a quantity of rain equal to about a fifth of the average annual rainfall. On the contrary the low-lying plains were almost everywhere spared; England and Normandy did not receive a twentieth of the annual rainfall. Shielded by the mountainous backbone of France, which stretches obliquely from the Vosges to the Pyrenees, and as a watershed divides the water between the ocean and the Mediterranean, Carcassonne, Montpelier, Grenoble, Lyons, Bourg, and Bezançon did not receive any extraordinary rainfall; it did not rain at all at Strasburg, at Dresden, at Munich, at Breslau—nor did it in Austria or in Italy. In Switzerland, and even in Savoy the rain was not great, while Mont Blanc, the Simplon, and the St Bernard received only 17 per cent. of the annual rainfall.

There is much that is interesting in the study of the atmospheric wave, sweeping along 1700 feet above the level of the sea, with a stretch of wing, extending some 1200 miles and more, skimming the high lying plateaux of France, and by a flight of 200 leagues a day dashing itself against the summits of the Alps; but it is to the distribution of the rainfall occasioned by it with which alone we have to do here.

At the meeting of the British Association for the advancement of science, held this year (1876) in Glasgow, Sir William Thomson made a communication in regard to the production of the phenomenon known as a "mackerel sky," which suggests an illustration of the phenomenon under consideration.

Schoolboys amuse themselves sometimes with skimming flat stones

* Belgrand: Annales des Ponts et Chausees. Sept. 1866.

along the surface of smooth water. The same phenomenon is produced upon a greater scale when a cannon ball, aimed at a floating target, strikes the water and rebounds into the air again and again ere it disappears. I have often, at the Cape of Good Hope, seen indications of the southeast wind advancing in waves, raising dust where it seemed to descend and strike the ground, but leaving undisturbed alternate stripes over which it seemed to bound or *rebound* at a higher level. Thus may it be with all currents, whether of water or of air, descending and striking upon other matter, solid, liquid, or gaseous, at an acute angle of inclination—as is indicated by the undulations or waves raised by the breath on a cup of tea, by the wind on a pond or placid stream, and by a storm upon the sea. And, according to the supposition of Sir William Thomson, a current of air striking upon a lower current, advancing in the same direction but with less velocity, or advancing in another direction, or upon a stratum of air in a state of quiescence,may rebound as does the skimming stone or the rebounding cannon ball on striking the water. And if the temperature of this current of air were near to that of the dew-point, or point of saturation, when it rebounded to a higher elevation, the temperature being thereby reduced, a condensation of moisture would ensue; but when the rebounding force was exhausted, and it again descended to a lower level, it would acquire a higher temperature, and the condensed vapour would be again dissolved in the air, producing the phenomenon of alternating stripes of cloud and of sky.

It is to this difference in the power of air to sustain vapour in solution at the different temperatures through which it passes at different elevations that I refer as illustrative of the rainfall occasioned by the wind-wave which has been spoken of. I have had occasion to refer to an illustration of the same kind afforded by the passage of the southeast wind over Table Mountain, producing dense clouds and even drizzling rain on the mountain top, but the clouds disappearing as the current pouring over the front of the mountain reached a lower level but a higher temperature; so is it with the wind-wave deluging the mountains with rain but passing over the lower-lying plains without any such effect.

Such wind waves, varying in their sweep and in their dimensions, but essentially the same, are not of unfrequent occurrence. Most of those, of which the phenomena have been studied, have swept along the surface of the earth and the ocean, and even they may have produced or yielded a greater rainfall on mountains than on plains; as in passing over mountain elevations the temperature of the air would experience a great reduction, and a precipitation of the moisture they contained would follow.

And it may be the case that the presence or the absence of forests on the mountain summits might affect within a limited range the degree to which the temperature of the wave in passing over the ridge would be reduced. So would a fire in a hunter's cabin! So would the huntsman's breath, and even the huntsman's presence, and every discharge of the huntsman's rifle! But in the presence of such meteorological phenomena as are under consideration all of these are as nothing.

And as is the case in such occasional disturbances, so may it be, and most probably it is, with the regular current of the atmosphere passing over a mountain range in its course to the equator from the pole, or striking upon a mountain top in its return to the arctic or antarctic zone. The great change of temperature occurring in the case cited made manifest in such a way as to arrest attention the consequence of such a change in so far as it affected the rainfall; but any reduction of temperature below the dew-point would, in proportion to its extent, produce corresponding effects. Such a reduction of temperature frequently follows the passage of an atmospheric current over a mountain range; and to the altitude of the mountain, so completely as almost to warrant the use of the term exclusively, is the greater rainfall on the mountain attributable.

I have hesitated about using the term exclusively, not on account of the influence which the circumstance of the mountain summit being clothed or being bare of forests might have in somewhat, but probably to an imperceptible degree, modifying the result; but I have done so on account of the influence on the rainfall exercised by the contour of the mountain range.

This subject, the influence on the rainfall exercised by the superficial configuration of a country, has engaged the attention of M. Cézanne. From his sequel to *Etude sur les torrents des Hautes-Alpes*, I translate the following statement:—

"When a rain-producing wind strikes against an eminence which forces it to rise in the atmosphere, a double effect is produced: the ascent of the air itself tends to a reduction of temperature, and consequent condensation of vapour; but besides this, the atmospheric current turned from its course is subjected to friction against the cooled surface of the earth, and the rain is, as one may say, mechanically pressed out of the clouds. For these reasons, it rains more on the headlands than on the exposed slopes; but in the deep *fiords* of Norway, a pluvial rain, sharply arrested by a wall of rock, deposits immediately a maximum of rain.

"There falls annually at Bergen, 2 mètres (80 inches) of rain; at Bourdeaux, only 719 millimètres (29 inches); at Nantes, 1 mètre (40 inches); at Cherbourg, 830 millimètres (33 inches).

"On the coast-land of the Mediterranean, the rain-producing wind blows from the east, or the south-east, in a vertical direction to the wall of the Cévennes, upon which descend violent showers. There falls annually at Marseilles, 512 millimètres (20½ inches); at Toulon, 505 (20 inches); at Nismes, 640 (26 inches); at Montpelier, 770 (31 inches); at Viviers, at the foot of the mountains, 900 (36 inches); at Joyeuse, at the bottom of a valley, 1·300 millimètres (52 inches).

"The region of the Jura gives as characteristic of the rainfall the following figures: Lyons, 776 millimètres; Maçon, 876; Bourg, 1^{m} 172; Syam, in the gorge, 1^{m} 630.

"Some writers have erred in thinking that they may conclude, from such and similar facts, that the quantity of the rainfall in a place increases with the altitude of the place. Formulated thus, the law is not correct; and the phenomenon cannot be explained satisfactorily. The phenomenon is mechanical as well as physical, and is more intelligible when formulated thus: *The pluvial rainfall is greater in proportion as the atmospheric current arrested by an obstacle is compelled to rise more rapidly.* It is not then the altitude of a place which is of most importance, it is the *incidence* with which the rain-yielding wind strikes the slope which opposes it; but the law regulating this incidence it is not easy to determine.

"From what has been stated it comes to pass that in order satistorily to compare two rain-gauges it is necessary to take into account their absolute elevation, and along with this the slope and configuration of the mountain sides which support them. The following table, in which are brought together several localities situated in the gorges of the Jura, show that the altitude is not the dominating element—for the maximum of rainfall is far from corresponding with the maximum of elevation:—*

* *L'Eveillé: Recherches sur les inondation (annales de la Société d'agriculture de Lyon,* 1858).

Locality.	Altitude. *Mètres.*	Rainfall. *Millimètres.*
Pierrechatel, ...	161	1260
Varambon, ...	233	1111·8
Saint-Rambert, ...	310	1592
Syam, ...	365	1741
Saint-Claude, ...	444	1457·7
Pontarlier, ...	840	970
Fort-de-Joux, ...	1001	1176·7
Saint-Cerques, ...	1045	1560

"At the convent of the great Saint Bernard (altitude, 2620 mètres, = 8733 feet) there is collected annually 1500 millimètres (60 inches) of water. If the most elevated pluviomètre in Europe be at the same time one of those giving the high measurements, the cause of this is perhaps less its altitude than its topographical position. The instrument is placed in a narrow embrasure, dominated by glaciers, in which the winds, come from what direction they may, must pass on violently, and be rapidly cooled.

"The obstacle once passed, the rain diminishes—the current descends and becomes heated again; desirous of repairing its loss, it drinks up the clouds with avidity, and dries up the mountain slope on the opposite side."

Giving then a graphic account of the appearance presented by a sea of clouds rising up a mountain side and pouring over into the valley beyond, when this is contemplated from a surmounting height, which has been already quoted (ante p. 157), he goes on to say,—
"That the superficial aspect of a country has an important influence on the phenomena of the rain may be illustrated by many well-known cases.

"On the two sides of the Scandinavian Alps, the west wind and the east wind give inversely fine weather and rain, the one to Sweden and the other to Norway.

"When it rains at Narbonne the sun shines at Montauban.

"The rain comes from the west in Switzerland, and from the east in Lombardy. It is in consequence of its being sheltered from the south and southeast winds, which drench the basin of the Rhone, that the valley of the Durance presents that exceptionally dry climate which M. Surell points out to be favourable to the development of torrents.* It rains upon an average, at Marseilles, 57 days in the year; at Arles, 45 days; at Aix, 40; but in the region of the Durance it rains only 38 days in the year.†

* Surrel, chap. xxi.

† Arago: *Melanges*, p. 430.

"Under the tropics, where prevail the trade-winds blowing from the east, the lands which incline towards the east are inundated with torrential rains: thus is it on the coast of Mozambique, and in the basin of the Amazon. On the contrary, it almost never rains on the western slope of the Andes. It is said that thunder has not been heard at Lima three times in as many centuries.*

"In the Indian peninsula the eastern coast, or that of Coromandel, is watered by the North-east Monsoon; and the west coast, or that of Malabar, by the South-west Monsoon.†

"When, after having climbed the slope of a mountain, the atmospheric current, greatly relieved of its load, comes upon a platean, it freely expands; but its lowest layer, being in contact with the earth, is alone reduced to a lower temperature. From which it comes to pass that, from the same wind, a plateau, though more elevated, receives less rain than the ascending slope, but receives more than does the descending slope beyond.

"The summit of the elevation which separates the Ocean from the Mediterranean supplies the following table :—‡

Region.	Altitude—Mètres.	Rainfall—Millimètres.
West Slope (Toulouse), ...	148·50	632·7
Summit (Castelnaudary), ...	170·00	630·0
East Slope (Carcassonne), ...	113·00	757·3

"From this table it may be seen that the slopes receive a little more rain than do the summits, and if it be borne in mind that the summit gets rain—now from the east wind, now from the west wind,—while Carcassonne, for example, does not receive it except by the east wind, it is beyond a doubt that the summit receives less rain from the same wind than is received by the two slopes which are ascended by the pluvial current.

"On a very interesting hyétographic chart, prepared by M. Delesse, *Ingenieur en chef des mines*,‖ it is seen that the plateaux of La Beauce and of La Brie, subject to the influence of the west wind alone, present a very manifest minimum. There falls at Chartres 540 millimètres, at Meaux 400 millimètres of rain annually.

"La Burgogne forms, as is known, a basin which stretches itself

* *Revieu: Theorie de la pluiè (Annuaire de la Société météorologique de France*, (1866) tome XIV.)

† *Lamairesse (annales des pont et Chaussées*, October 1869).

‡ *Raulin: Observations Pluviomètriques.*

‖ *Delesse: Distribution de la Pluie en France (Bulletin de la Société de geographie Aon*, 1868.)

from North to South, between the walls of the Forez and of the Jura. This basin is crossed by the west wind, which distributes its rain in such a way as to give clear testimony to the influence of mountain elevations. *

Regions.		Mean of observations. Altitude—Metres.	Rainfall—Millimetres.	Places of Observation.
Slope of the Forez passed over by the pluvial wind descending, ...	...	440	704·3	3 stations.
Bottom of Valley.	Right bank of the Saone, ...	252	695·7	5 „
	Left bank of the Saone, ...	234	730·1	6 „
Adjacent region at the base of the Jura passed over by the pluvial wind re-ascending, ...	...	301	1087·8	5 „
Gorges of the Jura where the pluvial current is compressed, ...	...	549	1358·0	8 „

"From this table it is seen that the pluvial wind produces very different effects indeed according as it descends an incline, or re-mounts an acclivity. When it is descending it gives quantities of rain almost equal at the very different altitudes of 440 and 252. While, when it re-ascends, it suffices to pass on the opposite bank, from the level of 234 to the height of 301, for the quantity of rainfall to increase 50 per cent. During the descent there is precipitated less rain at the level of 252, than is precipitated in the re-ascent at the lower level of 234; there falls twice as much rain on the re-ascending acclivity, at the level of 549 mètres, than falls on the descending incline by which it came, at the level of 440 mètres, although the difference between the two altitudes scarcely exceeds 100 mètres."

From what has been advanced it may be seen that in rainfall determined by geographical position, the distribution of this is greatly modified by the contour of the country. But this is not done only in the way which has been referred to. M. Cézanne goes on to say:—"The elevation of the ground acts in yet another way on the distribution of the rain: altitude modifies the proportion of rain falling in the different seasons of the year; in this way elevation above the level of the sea has the same influence as distance from the coast. During summer the maximum of rain falls in places of considerable elevation or distance from the sea, but during winter in

* L'Eveille: *Recherches, &c.*

low-lying lands or places near the coast. And when one observes the distribution of the rainfall over the ramifications of the same valley, the phenomena become still more interesting. The basin of the Seine is particularly suited for this study, since it is regular in form, largely open to pluvial winds, and more especially since M. Belgrand, who has explored it in its every part, has made us acquainted with his scientific investigations.*

"Near the sea, at the lighthouse of Fatonville, there falls annually 799 millimètres of rain. From this point to the valley of the Oise the plateau maintains perceptibly its level; in consequence of this the quantity of the rainfall diminishes in proportion as the pluvial current advances from the sea. The average sinks to 580 millimètres in the valley D'Oise, and to 575·6 millimètres at Paris; but it re-increases from that point as the land itself rises: it amounts to 656 millimètres at Hirson; towards the Ardennes, at the altitude of 196 mètres; and to 1570 millimètres at the Settons, on the height of the Morvan, where the altitude is 596 mètres.

"It is remarked that it rains more in valleys than on elevated plains, because the atmospheric current follows by preference the deep depressions which cut up the plateaux, in the same way as on the flat bottom of a valley levelled by an inundation, the current by its tumultuous waves still marks out distinctly the line of the old *thalweg*.

"But M. Belgrand, however, has established as a fact that the pluvial current does not go up indifferently every valley; it passes bye the valley D'Oise, and ascends by preference the valley of the Seine, and by that of the Yonne, which in going up from Montereau is a direct continuatiou of the first.

"Even at Paris the hill of Montmartre divides this current, which bifurcates as does a river around a pier of a bridge; the pluvial wind passes by preference behind the hill, and La Villette receives more rain than does Paris. Thus each valley receives more rain in proportion as it is set towards the atmospheric current which brings the rain."

Other observations not less interesting are adduced by M. Cézanne, illustrative of an influence on the distribution of the rainfall being exercised by the contour of a country.

In illustration of the same thing, M. Raulin, *Professeur à la*

* Belgrand: *Regime de la pluie dans le basin de la Seine* (*annales des Ponts et Chausées.* 1865).

Faculté de Bourdeaux, has given the following note as a contribution to the researches of M. Cézanne :—

"In 1868 and in 1869 I established as a fact that in Northern and Central Europe, and in Siberia, on to Kamschatka, there had been a predominance of rain during three months of summer, the more marked as we advanced farther to the east, while in the region of the Mediterranean there had been a sparsity of rain during the same season.

"It is interesting to investigate what is in France the pluvial *régime* of the lofty chain which separates the two great orographic or mountain-bound basins of northern and of southern Europe; and this I shall now attempt to do by means more especially of observations made by the *Service des Ponts et Chaussées,* which the *Ingenieurs en Chef* of the Alpine Departments have had the kindness to communicate to me.

"It might naturally be supposed, *a priori,* the northern *régime* having summer rains so copious and predominant on one hand in all the plains of Switzerland, and on to Lyons; and on the other hand in the Lombardo-Venetian plain of the Adriatic, on to that of Milan,—that this *régime* would be continued in the equally cold high mountains of the western branches of the Alps, which stretch from Mont Blanc in the south to Nice and Draguigan; but it is not so.

"In the high southern summits at the Great St Bernard, even there the Mediterranean *régime* is deplored, and it is matter of complaint that the rains of summer are scarcely two-thirds of those of spring, which exceed somewhat those of autumn; and this poverty of atmospheric moisture in summer goes on progressingly increasing in proportion as advancing from that northern station one approaches to the Mediterranean.

"In the High Alps, at Briançon, the rains of spring prevail still more, being more than double those of the summer; on the other stations of the department, Gap and Serres, and also at Die on the Drome, the rains of autumn reach on an average double the measure of those of summer.

"In the Lower Alps, at Barcelonnette, Digne, Castellane and Manosque, the difference between the quantities of the rainfall in summer and in autumn is still greater: it is the same on the plateaux from Var to Régusse.

"At Valences, at Yiviers, at Orange, at Avignon, the spring rains still predominate, but they are greatly exceeded by those of autumn.

"On the coast from Marseilles to Toulon, Hyèns and Gênes, the rains of spring are frequently less than those of winter, the quantity of which is greatly exceeded by that of the autumn rains.

"The Mediterranean *régime*, thus characterised, clears the Appennines and extends itself into the southern portion of the plain, from the Po to Parma and to Guastalla; but already at Bologne, and in the northern part at Padua and Milan, and in Piedmont at Turin and Yvrée, the northern *régime* is again found characterised there as at Geneva by a constant augmentation of the quantity of rain in winter and in autumn.

"On the circumference of the western branch of the Alps, the pluvial region presents a great difference, such as has already been referred to. On the plain of Switzerland, and on its prolongation to the south-west, from Zurich to the confluence of the Rhone and the Isère, it is the northern *régime* which most prevails, with a preponderance of summer rain at Zurich, exceeded by that of autumn rains at Geneva, at Chambérg, at Lyons, and even at Annonay and Tournon (Ardèche). But it is seen suddenly to change and to pass completely into the Mediterranean *régime* in the valley of the Rhone, from the point at which it passes the confluence of the Isère."

There is given a tabulated statement of observations made on the coast of the Mediterranean throughout the year from 1851 to 1866; on the basin of the Rhone from 1853 to 1860; and on the basin of the Durance from 1856 to 1866; with the names and the altitudes of the stations at which they were made, which gives evidence of the facts stated. The stations included in the table, with the respective altitudes are the following:—On the sea-border of the Mediterranean, Marseilles, Toulon, Hyères, Gênes and Régusse; in the basin of the Rhone, altitude 40 mètres, Valence 113, Lyons 295, Chambérg 305, Geneva 387, Die 413, and Great St. Bernard 2491; in the basin of the Durance, Manosque, altitude 370 mètres, Digne 639, Serres 662, Gap 740, Castelane 786, Embrun 870, Barcelonne 1173, and Briançon 1305.

And M. Raulin goes on to say:—"As regards the quantity of rain which, upon an average, annually falls on the ground in the Western Alps, there are great differences between different stations. That of the Great St. Bernard, the most elevated, receives the greatest quantity of water.

"In the High Alps, and in the Lower Alps, the quantity much less considerable goes on, in general, increasing in proportion as the stations are less elevated, as is also the case from Briançon to Die (Drôme) and from Barcelonnette to Régusse (Var).

Altitude in Metres.				Rainfall in Millimetres.	
	2491	Gt. St Bernard,	...	1239·1	
	1305	Briançon,	...	684·6	
	1173	Barcelonette,	...	439·7	
	870	Embrun,	...	603·6	
763	740	Gap,	...	796·9	835·1
	786	Castellane,	...	873-4	
650	662	Serres,	...	706·4	706
	639	Digne,	...	705·5	
	575	Regusse,	...	993·3	
332	413	Die,	...	732·9	682·5
	370	Manosque,	...	632·0	

"Thus whilst in the Pyrenees the rainfall goes on increasing with the altitude, it is rather (with the exception of the Great St. Bernard) the reverse which is the case in the French Alps, which are moreover much less rainy.

"The quantities of water which fall in the circumference of the Alpine region to a similar extent show great diversities: almost the same at Zurich and Geneva; they increase at Chambérg, to diminish at Lyons, Annonay and Tournon. Descending the Isère they are greatest from Valence to Orauge; and diminish greatly at Avignon. On the sea board they are remarkably great from Marseilles to Gênes. In Piedmont they are as great at Turin as in the valley of the Rhone; in descending the Isère; at Yvrée they reach a figure much higher than at the Great St. Bernard."

To this statement by M. Raulin there is appended a valuable note of considerable length on the extent of what has yet to be learned in connection with the theory of rain. The observations which have been cited are advanced in proof of its not being the altitude of localities irrespective of the contour of the country which determines the quantity of rain falling there; and they have been adduced here solely in illustration of the fact that the contour of a country has much to do with the distribution of the rainfall.

There are countries in which rain rarely or never falls. In the Great Sahara of Africa, says Sir John Herschel, rain is unknown; as also in Arabia and part of Persia, in the great desert of Geb; in the table land of Thibet, &c.; while at Coimbra, on the coast of Portugal, there falls 118·8 inches of rain per annum; at Mahabalchwar, near Bombay, there falls upwards of 254 inches; at Uttray-Mallay, there falls upwards of 267 inches; and at Cherra-Ponjee, 592 inches.

Such a distribution of the rainfall is evidently attributable primarily to geographical situation, and thus may it be with the rainfall generally. But the observations of M. Cézanne and of M. Raulin seem to show that irrespective of forests the distribution of rainfall dependent on geographical position may be determined by the contour of a country. And when, in view of this, we look to the correspondence between the distribution of the rainfall which has been adverted to, we see no necessity for concluding that it has been the existence of the forests which has determined the corresponding distribution of the rainfall in the places cited, as that seems to exercise a much more powerful influence than this can.

SECT. III.—*On the Distribution of Forests Affected by the Distribution of the Rainfall.*

The general accordance between the distribution of forests and the distribution of the rainfall on the earth's surface, detailed in the first section of this chapter, naturally suggests, as has been stated, the enquiry, Can they be consequences of some common cause? or is this general accordance only an incidental coincidence? or are they connected together as being one of them the effect of the other as the cause or the occasion of its appearance? And if so which of them, the distribution of the rainfall or the distribution of the forests, which is the cause and which is the effect? To what extent is the one the cause or occasion of the appearance of the other? and may not that which may appear to be the effect have a reflex influence upon that which appears to be the cause or occasion of the other?

Such is the question raised, and I have adduced evidence to show that the distribution of the rainfall dependent on geographical position may be determined in a great measure by the contour of a country, the elevation and the configurations of its mountains, its valleys and its plains, irrespective of whether it be clothed with woods or altogether devoid of these; and in a preceding section I have stated my opinion to be that the distribution of the rainfall may primarily have determined the distribution of the forests, but that the forests once established may have exercised an important influence on the distribution of the rainfall.

It is stated by Mr Marsh: "There is good reason to believe that the surface of the habitable earth, in all the climates and regions which have been the abodes of dense and civilized populations, was, with few exceptions, already covered with a forest growth when it first became the home of man. This we infer from the extensive vegetable remains—trunks, branches, roots, fruits, seeds, and leaves of trees—so often found in conjunction with works of primitive art, in the boggy soil of districts where no forests appear to have existed within the eras through which written annals reach; from ancient historical records, which prove that large provinces, where the earth has long been wholly bare of trees, were clothed with vast and almost unbroken woods when first made known to Greek and Roman civilization; and from the state of much of North and of South America, as well as of many islands, when they were discovered and colonized by the European race.

"Whenever a tract of country, once inhabited and cultivated by man, is abandoned by him and by domestic animals, and surrendered to the undisturbed influences of spontaneous nature, its soil sooner or later clothes itself with herbaceous and arborescent plants, and, at no long interval, with a dense forest growth. Indeed, upon surfaces of a certain stability and not absolutely precipitous inclination, the special conditions required for the spontaneous propagation of trees may all be negatively expressed and reduced to these three: exemption from defect or excess of moisture, from perpetual frost, and from the depredations of man and browsing quadrupeds. Where these requisites are secured, the hardest rock is as certain to be overgrown with wood as the most fertile plain, though, for obvious reasons, the process is slower in the former than in the latter case. Lichens and mosses first prepare the way for a more highly organized vegetation. They retain the moisture of rains and dews, and bring it to act, in combination with the gases evolved by their organic processes, in decomposing the surface of the rocks they cover; they arrest and confine the dust which the wind scatters over them, and their final decay adds new material to the soil already half formed beneath and upon them. A very thin stratum of mould is sufficient for the germination of seeds of the hardy evergreens and birches, the roots of which are often found in immediate contact with the rock, supplying their trees with nourishment from a soil deepened and enriched by the decomposition of their own foliage, or sending out long rootlets into the surrounding earth in search of juices to feed them.

"The eruptive matter of volcanoes, forbidding as is its aspect, does not refuse nutriment to the woods. The refractory lava of Etna, it is true, remains long barren, and that of the great eruption of 1669 is still almost wholly devoid of vegetation. But the cactus is making inroads even here, while the volcanic sand and molten rock thrown out by Vesuvius soon become productive. Before the great eruption of 1631 even the interior of the crater was covered with vegetation. George Sandys, who visited Vesuvius in 1611, after it had reposed for several centuries, found the throat of the volcano at the bottom of the crater 'almost choked with broken rocks and *trees* that had falne therein.' 'Next to this,' he continues, 'the matter thrown up is ruddy, light, and soft: more removed, blacke and ponderous: the uttermost brow, that declineth like the seates in a theater, flourishing with trees and excellent pasturage. The midst of the hill is shaded with chesnut trees, and others bearing sundry fruits.'"

And Mr Marsh adds in a foot-note :—"Even the volcanic dust of Etna remains very long unproductive. Near Nicolosi is a great extent of coarse black sand, thrown out in 1669, which, for almost two centuries, lay entirely bare, and can be made to grow plants only by artificial mixtures and much labour.

"The increase in the price of wines, in consequence of the diminution of the product from the grape disease, however, has brought even these ashes under cultivation. 'I found,' says Waltershausen, referring to the years 1861–62, 'plains of volcanic sand and half-subdued lava streams, which twenty years ago lay utterly waste, now covered with fine vineyards. The ashfield of ten square miles above Nicolosi, created by the eruption of 1669, which was entirely barren in 1835, is now planted with vines almost to the summits of Monte Rosso, at a height of three thousand feet.'—*Ueber den Sicilianischen Ackerbau*, p. 19."

I accept as probable the statements which have been cited in regard to the tendency of trees and arborescent shrubs, in common with other vegetables, to diffuse themselves extensively, and in the struggle for life to retain possession of the soil; but there are conditions essential to their success in doing so, and one of these is an adequate supply of water, not in excess, and varying with varying requirements. An excess of water may prevent vegetation,—it may prevent germination, prevent vigorous growth, prevent the formation of flowers and the maturation of fruit; and a deficiency of water at any corresponding critical period may have the same effects. There are general laws in accordance with which is governed the distribution of all vegetables, and the consideration of some of these laws may make this manifest.

We may study the phenomena in the growth of mould as well as in the growth of a forest, and find some advantage in doing so.

If a little decaying cheese, a decaying orange, and a decaying pear be exposed to the air they may be found after a time covered with mould; and microscopic examination will show the three moulds to be different each from the others. How may this be accounted for? Observation fails us; we are thrown upon reason. Nobly have several students of natural history endeavoured to extort from Nature an answer to the question—How do germs first originate? and Nature, ever truthful, has truthfully replied to her questioners, but the reply has always shown that the question was not so expressed as to elicit by an explicit answer to it the information which was desired. It is thus that I look at the experiments which have been made in connection with what has conventionally but unscientifically been called spontaneous generation. And whilst awaiting patiently, and with deep interest, the devising and application of a testing experiment—which shall finally close all controversy—I take up the question I have stated: How has the mould been produced, and that in three different forms?

There are three solutions of the problem which at once offer themselves; and these are not necessarily antagonistic to each other: it may be the case that each and all of them may be correct. It may have been the case, for aught we know to the contrary, that by chemical action, or this in some one or other of its correlated forms, the decomposed organic matters which were the subjects of experiment have been resolved into the germs of these moulds; it may, for aught we know to the contrary, have been the case that there were germs of mould floating in the atmosphere, which alighted on the decaying cheese, orange, and pear, and there germinated, the different forms they took being determined by differences in the conditions in which they were placed on these different substances; or it may have been the case, for aught we know to the contrary, that germs of all the three species of mould, and many germs of other genera of organic structures were floating in the atmosphere, but of these only those which found in the decaying masses an appropriate soil and condition of growth germinated there, and grew and brought forth fruit.

These several suppositions are not necessarily antagonistic; but the last is the only one in entire harmony,—or, if that form of expression be deemed too sweeping, the one most in accordance,—with what has been observed in regard to the diffusion of more highly organised vegetable forms.

It is of these I have to speak, and I employ what has been said not as an argument but as an illustration.

To allay suspicions and fears which may arise in some minds, but which I consider groundless and unnecessary, I may state that the underlying question does not relate to the existence of what may be called a personal Creator, though that question may legitimately be engrafted upon it; but it relates solely to the mode of creation—the wonderful workings of the Creator in clothing the earth with diversified forms of vegetation; and further, that it takes not up the question of evolution and development, which has disturbed many of the Christians of our day—as did the discovery of the earth's motion, by Galileo, disturb many of the Christians of his day,—but it takes up only the question of the distribution of existing species of plants, in whatsoever way these have been produced.

We do not find the pear mould growing on the cheese, nor the cheese mould on the orange, nor the orange mould on either. Each is confined to it own *habitat.* Neither do we anywhere find all kinds of plants growing intermixed on the same bank. In different places we may find many different kinds of plants growing intermixed, but the plants so intermixed in their growth are different in different places.

There are some plants which are widely distributed. With others it is otherwise, they are confined each to some one locality. Of the former, we have examples in the silver weed *(Potentilla anserina)*, in the goosegrass or cleavers *(Galium aperine)*, in the square-stalked willow herb *(Epilobium tetragonum)*, in the water starwart *(Calitrichê verna)*, and in the daisy (*Bellis perennis*); of the latter, we have examples in the Scottish primrose *(Primula Scottica)*, which is found only in the north of Scotland and the Orkneys, in the Pride of Table Mountain *(Disa grandiflora)*, which is found only on the mountain at the Cape of Good Hope, whose name it bears, and in the Kerguelens-land cabbage *(Pringlea antiscorbutica)*, which is found growing on an island most remote from any continent, and which, besides this esculent, yields only seventeen other flowering plants.

Again there are some plants which you never find excepting near the sea; others which you never find excepting on marshy ground; others which you never find but in Alpine regions. There are some plants which are never found growing wild excepting in the tropics, and others which cannot be reared there *even by artificial culture.* There appear to be, at least, three determining conditions of the distribution of plants: heat, moisture, and soil. I say, at least three, for I think there are others, such as atmospheric pressnre, &c.; and the modifications of these three, and the combinations of these supply an indefinite variety of conditions only some of which will secure the germination, fructification, and continued reproduction of any one or more kinds of plants.

Seeds are dispersed widely by the wind and rivers and ocean currents, by man and bird and beast; but in order to germination there is required for each, within a definite range, heat and moisture and shade; in order to growth there is required, it may be, some other measure not less definite of moisture and heat and sunshine, and along with these a soil containing certain constituents for each, in a definite state of disintegration, and in definite states of combination; in order to the flowering, and again in order to the fruiting, and yet again in order to the conservation of the seed in the soil, on until the period of germination, there are required a succession of definite varying measures of heat and sunshine and moisture: the range of each may be more or less considerable, but still it is limited by extremes beyond which it cannot pass without fatal effects to the reproduction of the plant.

If the seed have decayed before reaching the spot where it finally rests, if there it be eaten by bird or beast, or if the germ be destroyed or be consumed by some insect, it will never germinate. If throughout the various stages of growth and reproduction which I have referred to, and the intermediate stages connecting these, there be at any time too much moisture, or too little, too much heat or too little, too much sunshine—for the effect of this is not confined to the production of heat alone—or too little, the plant—be it herb, or grass, or bush, or tree—will not be reproduced; and be it noted the definite measure of heat and moisture and sunshine are not the same throughout but vary in a definite order of progression; and should these fail at any subsequent period, at any point of the progression, this will be fatal to the continued reproduction of the plant, be it grass, or herb, or bush, or tree.

Did occasion serve I could produce illustrative cases in point.

And it begins to appear that if, when the seed of a tree was borne to any spot by the winds, or by the waves of the sea, or by the current of a stream, or by bird or by beast, there was on that spot either excess or deficiency of moisture the seed would not germinate. Other pre-requisites there are, but with these others these. To many seeds the stagnant pool and the arid sand would be equally fatal, but the rainfall evaporating and draining off by infiltration and *ruissellement* all in excess of what the soil could retain by its hydroscopicity and capillary attraction, would supply the very amount of humidity required. But fresh supplies varying in quantity with the requisites of the seedling, the sapling and the tree, and with the requisites of the tree at the period of flowering, of the setting of the fruit, of the maturing of the fruit, and of the casting of the seed, are needed. These the parched land could not supply, neither could the snow covering the mountain summit, nor the marsh in the valley below, though the rain falling on the mountain side, with its excess drained off before it could damage, and its supply from time to time renewed, might to some extent determine the primary distribution of forests clothing the mountain side; and while other kinds of trees perished there, they might find the conditions of their growth in the moister land below, kept moist by the rainfall, and the drainage of the rainfall, from a higher level, or on the banks of streamlets and rivers fed by this rainfall and dependent thereon for their continuous flow.

We need not to take up, in connection with this subject, the question, Whence come the seeds? But there is another question, nearly akin to this, which suggests itself, and which finds in connection with the subject under consideration a ready answer: Might not other seeds besides those producing the forests also find their way thither? They might and so might seeds of trees; find their way to plains where grow only herbs and grass; and where now grow the trees there may grass and herbage, as well as moss and fern have formerly flourished; and on the arid plains seedling trees may have appeared again and again but only to perish in all the leaves of their spring. And to the rainfall may be attributed the limitation as well as the determination of the distribution of each.

It has been intimated by a writer, quoted in the preceding section, that much depends on the distribution of rain in time as well as in space.

From what has been advanced we may infer that of the seeds of grasses, of herbs, and of trees alike, falling anywhere, like the mould germs alighting on the cheese, the orange, and the pear, those only which found there all the appropriate conditions of germination, growth and reproduction would there flourish and be reproduced, and any failure of the requisite conditions, occurring at any time, would prove fatal to them. An appropriate supply of moisture is one of those conditions. Under artificial culture we may see a plant damp off, turnips braird but never come to maturity, and a seeding tree perish from drought: thus may seedling trees have perished on the plain, a consequence of the distribution of the rainfall, and in the account which has been given of the geographical distribution of forests in India, mention is made of forests near the bed of a river frequently perishing, through that river changing its course; all of these are occurrences indirectly connected with the distribution of the rainfall. But while the trees perished, the herbage and the grass flourished; and it is the converse of this which we see in the growth of the forest, where, it may be, lichen and moss, and fern and sedge, and grass and herbage, had successively, alone or conjointly, held for a time exclusive possession of the field.

In further elucidation of this subject it may be mentioned that by many it is held that, apart from all that has been alleged in regard to evolution and development, there is a natural succession of plants following each other in the occupation of the same ground, the homologue of the natural succession of animals which have inhabited the world, specified in Genesis as water animals and wingéd fowls, cattle and creeping thing, and beast of the field and man,—and a struggle for the possession of it between plants and possession by immigrants: the homologue of man's replenishing the earth and colonising with immigrant families lands previously peopled by other races And both in connection with the natural succession and with the succession by immigration the distribution of rainfall has its function.

It is frequently alleged that the order of natural succession is something like this: the germ of a lichen, falling upon a rock or stone, it may be, being moistened by rain, or dew, or a little water lying there, germinated, produced other germs, and died. Some generations did, it may be, the same, produced other germs, and died; subsequently, it may be ages later, the germ of a moss, or of some other more highy organised vegetable structure, fell there, and found in the remains of decayed lichens a soil and the conditions favourable to its germination and growth and reproduction, and more favourable to its continued reproduction than to that of the lichen, and ultimately it obtained and maintained exclusive possession, it may have been for ages, until some other germ or seed of some vegetable holding a still higher position in the gradation of organic structures—a fern, it may have been, a grass, a daisy, or some other herb, or all of these in succession fell there, until at length on the accumulating soil there appeared in succession, or in contemporaneous growth, a mass of mixed and tangled vegetation, requiring only to be subdued by man to make the soil composed of mineral constituents and decomposed organic matter bring forth "fruits of increase" and "herbs meet for them by whom it is dressed."

I do not like the expression " struggle for possession " being applied to vegetation; I prefer making use of the corresponding expression, " survival of the fittest;" bnt the expression " struggle for possession " has come into more general use.

In illustration of what has been likened to a struggle for possession between immigrants and earlier settlers, let me refer to what may sometimes be seen, in our own day, on a flowery bank of one of our hedge-rows, or by the side of a country walk. Let it be supposed that the case is one in which the flowers consist mainly of dog violets and of pansies in equal proportion. Any other plants would equally serve for illustration; these are selected of design. If such a bank were revisited, after some years of absence, it might be found as flowery as ever; but the flowers would not be all of the same kinds, in the same proportion, as before. Amongst other changes, it may be that either the pansies or dog-violets would have disappeared, and the species remaining would be more numerous than either were. By transmutation or development? Oh, no! not at all; but thus: the soil exposure, heat, and moisture could scarcely fail to be more adapted to the requirements of the one than to those of the other: in an infinitely minute degree it might be, but still the difference was there; and even if the quantity of seed cast by each plant should have been precisely equal, this infinitely minute difference of adaptation would suffice to bring about the change.

I shall magnify the effect to make it more apparent. If there were a hundred plants of each when first observed, in the year following there might be 105 of the one and only 95 of the other; in the year after there would be the progeny of 105 plants of the one and the progeny of 95 of the other less favourably situated species, and this might present us, not with 110 of the one and 90 of the other, but perhaps 112 of the one and 88 of the other; and the disproportion in years following would go on increasing in a corresponding accelerating ratio. And indications of something like this having occurred in forests have been observed: a forest of mixed trees giving place to one of uniform production. And thus may the successions have occurred, while the seeds of trees which had not germinated lay dormant, awaiting their time to germinate whenever, in the changes accompanying progressive desiccation, the dominating trees should succumb, and they be able with greater success to take their place.

From a work by Vaupell we learn that the earlier forests of Denmark were composed of birches, oaks, firs, aspens, willows, hazel and maple, the first three being the leading species, but these have now been succeeded by the beech, which at present is the tree which greatly predominates. It is a tree more inclined to be exclusive than any other broad-leaved tree, but it is being encroached upon again by the fir. And is there not a cause? There is; and Vaupell seems to consider that man is unconsciously—and to his own disadvantage—helping forward the encroachment of the Goths and Vandals on the nobler races at present in possession. And the views advanced by them may subserve our present aim.

In regard to the removal of fallen leaves he remarks:—"The removal of the leaves is injurious to the forest, not only because it retards the growth of trees, but still more because it disqualifies the soil for the production of particular species. When the beech languishes and the development of its leaves is less vigorous, and its crown less spreading, it becomes unable to resist the encroachments of the fir. The latter tree thrives in an inferior soil, and being no longer stifled by the thick foliage of the beech, it spreads gradually through the wood, while the beech retreats before it and finally perishes." And in connection with this he adverts to the fact that "The leaves belong to the soil. Without them it cannot preserve its fertility, and cannot furnish nutriment to the beech. The trees languish, produce seed incapable of germination, and the spontaneous self-sowing, which is an indispensable element in the best systems of sylviculture, fails altogether in the bared and impoverished soil."

Thus may the succession of firs to beeches, if it should ultimately occur, be satisfactorily accounted for. And in a corresponding way may some of the previous successions of different kinds of trees be accounted for: I say not in the same way but in some corresponding way; and in some corresponding way may much of the grass and herbage which previously covered the forest ground have given way to the forest trees, not because the conditions were absolutely unfavourable to them, but because being also favourable to the growth of trees, and perhaps comparatively more so, or otherwise simply in virtue of their more sturdy constitution, these having gained a footing maintained it, and the others were overpowered. Now one of the conditions determining this was a particular distribution of the rainfall both as to time and space, which was essential to the growth of the trees which then existed, and but for whch the grass and herbage would have been left in undisturbed possession.

Such is in part the effect of the distribution of the rainfall on the distribution of forests.

SECT. IV.—*On the Local Effects of Forests on the Distribution of the Rainfall within the Forest District.*

While the primary distribution of forests appears to have been determined by the general distribution of the rainfall, forests appear to influence the subordinate distribution of the rainfall, both in time and space, over the forest district; and irrespective of this, though connected therewith, they exercise an important influence on the disposal or distribution of the rainfall within the district in which they exist.

The most manifest of the effects of forests on the rainfall is that which they exercise upon the distribution of it after it has fallen. Of the water which falls as rain a portion is evaporated, a portion is absorbed by the ground, and a portion immediately flows back again toward the sea; each of these is the complement of the others, and their proportions vary under varying conditions; previous to the growth of forests the rush was impetuous; subsequent to the growth of forests it is restrained. What was then allowed to run to waste, like the extravagant expenditure of the prodigal, is now husbanded, as is the income of the typical *pater-familias.*

Cézanne, speaking of the whole series of phenomena brought under review by him in treating of this effect of forests in connection with geological changes, says in a passage I have cited in a volume on "Reboisement in France":—

"There may be given in a few words a *résumé* of the whole series of these phenomena.

"The mountains are the result of a series of upheavals following one upon another in the same region. A final agitation gave to the different chains of these the existing elevation; it elevated the summit and opened up deep fissures or divisions, which have become the valleys of the present time. From the time this occurred the waters began to fashion the *thalwegs*, following the line which best suited them; wearing down outlets and filling up basins. It is necessary to admit, or to assume, that the depth or thickness of the alluvial deposits in the bottom of certain valleys—for instance, those of the Isère in the Graisivaudan, or of the Rhine in Alsace,—is to be reckoned by hundreds, and perhaps by thousands, of mètres or yards; for even yet certain lakes existing in depressions of the Alps have their bottom below the level of the sea.

"After a long series of ages the mountains assumed the leading features which they now exhibit, when, the climate changing, great glaciers carried on actively the work of erosion; these have planed away escarpments, and fashioned into something like horizontal lines the rocky belts of the valleys.

"*Débâcles*, or inundations, from the escape of the waters of pent-up lakes, and deluges resulting from the tremendous rains of summers on the extensive fields of ice, have carried away and deposited in the principal valleys in certain favourable places, but more especially at the *débouchés* of lateral gorges, the masses of lœss which have formed cones in the higher plains, and in which the water-courses have subsequently dug out the secondary valleys.

"At a later period, after the melting away of those glaciers, the torrents seized upon the bared mountains; and without restraint they have dug out their basins, and have again taken up the materials disintegrated by the glaciers, and deposited these in the gigantic cones which give to certain regions a physiognomy peculiarly their own.

"But after a time the forests, spreading by degrees, stifled the waters under a mantle of verdure; the torrents became extinct,—an era of peace and of comparative quiet supervened in the mountains; then the tribes of men, who during the glacial period rambled over the low-lying plains, in company with the reindeer, the aurochs, and the bears, began to spread themselves in the high-lying valleys. The most ancient settlements were made at the gorges of the torrents, towards the summit of the cone; in point of fact, there are to be found in the mountain valleys very few of these gorges in which we do not meet either with an existing village or with an ancient ruin.

"In this location, which was then one favourable to their pursuits, the primary inhabitants could profit by the exceptional fertility of the cone of deposits; they had nothing to fear from the principal river, which flowed through the lower-lying lands, nor from the torrent, which was then extinct; they commanded the plain, and found themselves at the gate of the mountains; the adjacent gorge supplied them with water, the forest supplied them with wood, the rock supplied them with stone, and their flocks spread themselves over the verdant ridges around them.

"Little by little, a reckless use of the forests and of the pasturage disturbed the equilibrium of the natural forces; and now the old sore is re-opened, and anew, by man's deed, the mountains are inoculated with the leprosy of the torrents. The evil has gone on increasing during prolonged ages of disorder and recklessness; the position of the cultivated grounds, and of the villages established at the *débouchés* of the torrents, has now become critical in the extreme; and unless we go back, as we have done, to the olden times, we are unable to account for men having taken up their dwelling in the spots, of all others, which at this day appear to be those which are more immediately threatened.

"But at last an era of reparation begins; and, thanks to the eminent men who have in bygone years given their mind to the work, the next generation may hope to see the final decline of the modern renewed Torrential Era."

Views similar to the views thus advanced by Cézanne are advanced by Costa de Bastelica, with this difference that he considers even the mounds of detritus attributed to glaciers have been also the products of torrents, which have become extinct under the effects of the forests.

In illustration of how the forests may have operated, in those prehistoric times, in arresting the flow of the rainfall, I adduce the following, the type of many others which I have brought forward in the volume referred to. It is from a paper which appeared in *Revue des Eaux et Forêts*, for April 1866.

"The State possesses, in the department of Vancluse (says the Forest Conservator, Labuissière), a forest of more than 3000 hectares, situated on a portion of the mountain Luberon nearest to the valley of the Durance. This region is very much cut up, and traversed in all directions by very narrow and deeply embanked ravines in the midst of masses, more or less dense, of Aleppo pines and green oaks.

"These ravines are almost the only outlets for the transport of woods, in consequence of the difficulties which would be encountered and the expense which would be incurred in making more practicable ones on the rapid declivities, strewn with enormous masses of rock. There exists one so situated, called the Ravine de Saint-Phalez. The direction is from north to south, in the midst of a mass of Aleppo pines in a state of growth more or less compact.

"Its length, and for four kilomètres, or from the road from Cavaillon to Pertuis, to the domain of Saint-Phalez, of an area of about 50 hectares, forms the *bassin de réception* of the torrent.

"This land is well cultivated; there are no declivities too steep for cultivation; it comprises vineyards, meadows, and arable land; the soil is argillaceons

"The ravine of Saint-Phalez receives many affluents, the most important of which is that of the Combe d'Yeuse, which joins it near the summit, where are some hundred mètres of the cultivated grounds of which I have spoken.

"The Ravine de la Combe-d'Yeuse is of much less considerable length than that of Saint-Phalez; it is scarcely two kilometres. It is strongly embanked, surmounted by steep declines, covered with green oaks of eight or ten years growth and with Aleppo pines of different ages. Its *bassin de réception*, of about 250 hectares (or 113 acres), comprises the whole slope, precipitately inclined, with a general southwest aspect; it is closed at the top by a deep bed of rock cut into peaks of the most imposing aspect.

"The geological formation is absolutely the same, as are all the other conditions, at all the points which I have examined. In no part is to be seen either spring or appearance of humidity; no water is seen excepting at the time of storms or great rains, and this water soon passes away, with the differences which will afterwards be mentioned. At all other times these ravines are of a desolating aridity.

"In the night of the 2d or 3d of September, 1864, there fell a rather abundant rain over all this portion of the mountain. In the morning the argillaceous grounds of Saint-Phalez were saturated, of which evidence was found by anyone attempting to cross them. The ravine of Saint-Phalez, the receptacle of the surplus water, had flowed but slightly; that of the Combe-d'Yeuse remained dry.

"The day of the 4th September was very warm; a water-spout borne along by a southwest wind struck on the Luberon. Its passage did not last more than forty minutes; but scarcely had it come when the torrent of Saint Phalez became awful. Its maximum delivery was about two cubic mètres. It did not flow more than fifty minutes, but with an average delivery of half a cubic mètre; it had then passed in all 15,000 cubic mètres of water; its height had been $0{\cdot}04^{m}$. Each square metre had received 40 litres, and the 50 hectares of Saiut-Phalez 20,000 cubic metres. The ground had only retained 5000, which is sufficiently explained by their argillaceous character and their state of saturation the night before. But while the torrent of Saint-Phalez flowed, filled from bank to bank, seizing and carrying off rocks which had been employed to form a road which was believed to be safe against all contingencies, that of the Combe-d'Yeuse and all those traversing wooded lands remained dry, or gave only an insignificant quantity of water.

"On the slope opposite to that of which I have been speaking, in the valley of the Peyne, a carriage-road newly formed did not experience the least injury throughout the whole of the portion of it passing through tne forest of the domain; but at its issue, on the lands of the Libaude and of the Roquette, it had been, so to say, destroyed. A cart loaded with faggots was upset and smashed by the waters, which flowed from all the cultivated slopes, and tore along, with the noise of thunder, at the bottom of the ravine.

"My good fortune secured to me another subject of study on the same ground.

"On the 25th October following I went to the sale of the fellings of the Tarascon, where there fell an abundant rain. The next day (the 26th) the weather was clouded. I set off for the Luberon in the hope of arriving there at the same time as would a storm of rain which I saw approaching. I arrived first; the ravine of Saint-Phalez was still moist, from the passage in small quantity of the waters of the night before; they had served, as appeared, to saturate the lands of the domain, as had previously happened on the 7th [3rd ?] September.

"I had scarcely gone over two kilomètres in the ravine when the water began to rush with great violence; ten minutes later it precipitated itself in its ordinary *canal d'ecoulement*, completing the work of destruction begun in the month of September. The lands of Saint-Phalez had then absorbed but little or none of the water that day.

"The storm was not of long duration—an hour at most. The time was unfavourable for collecting on the ground exact measurements, but I reckon that the torrent delivered, at its maximum, somewhat less water, perhaps, than on the 4th of September. The flood, however, was more frightful; it swept away rocks with so much the greater ease that nothing had been repaired since the first storm, which had left the stones dug out, and without bond of cohesion among themselves.

"To gain the forester's house, which was on the slope of the left bank, it was necessary to make a long circuit—to go round the domain of Saint-Phalez, and to cross the grounds belonging to it, in which one sank to the depth of 0·30 mètres, or twelve inches. Before arriving at my home I had still before me the ravine of the Combe-d'Yeuse, and I feared I should be stopped there by a new obstacle. I was agreeably surprised to find it dry. An hour after the storm the ravine of Saint-Phalez had ceased to flow.

"It rained throughout the whole of the 28th without there being anything to remark similar to what had happened on the preceding days. The only effect of this was that, on the evening of the 30th, near the forester's house, and at 200 or 300 mètres from the ravine of Saint-Phalez, there was seen coming down, in that of Yeuse, a small fillet of clear water; its volume increased perceptibly during three days, to diminish in like manner during the two which followed; its passage broke down a little of the foot-path which goes along the valley, but caused only a damage easily repaired. This foot-path did not present the same solidity of structure as that of the Combe de Saint-Phalez, built on enormous blocks of rock which had stood for several years, and which had allowed of passage with a waggon some days before its destruction by the storm in September. If the Combe-d'Yeuse had yielded as much water as that of Phalez, and if these two masses of water had come at the same time, the damage caused in the plain would have been considerable, and the Durance, which received these waters, would have been so much the larger.

"Thus we have two torrents very near and under the same conditions—except that the basin drained by the one comprises 50 hectares of cultivated lands, that of the other 250 hectares of woodlands. The first receives, and allows to flow away, the waters of the greater part of a storm in a few hours at most, causing thereby considerable damage; the second, which had received a greater quantity of rain, stores it—keeps it for two days—evidently retaining a portion of it, and takes three or four days to yield up the surplus, which it does in the form of a limpid and inoffensive stream."

A question in connection with this subject, which excites much general interest, is—Do woods and forests increase the quantity of the rainfall? We have had testimony to the affect that in certain conditions they increase the quantity of the local rainfall; there is no evidence that in consequence of this there is a diminished rainfall elsewhere, and if there be not it follows as a consequence that they do increase the rainfall, though it should be found that they do so only by causing the same material to fall again and again in the form of rain; but the increase, whether tested by local observations carefully conducted as were those of Mathieu, and of which have been cited, [ante p. 64] or by more general observations carefully collected as were those discussed by Mr Draper, [ante p. 100] appears to be very trifling; and when there are brought under consideration such features of physical geography as are referred to by Cézanne and by Costa de Bastelica, and attributed to torrents occasioned by the rainfall previous to the *régime* of forests in the locality, it may well be doubted whether the amount of rainfall all the world over has not been diminished rather than increased since was issued the fiat: Let the earth bring forth grass upon the earth—the herb yielding seed, and the fruit tree yielding fruit after its kind whose seed is in itself.

I have quoted the statements of Herr Wex in regard to the local effects of forests on the rainfall, given in his treatise on the "Diminution of Water in Streams and Rivers, with the increase at the same time of occasional inundations in low-lying agricultural districts."

The Commission appointed by the Academy of Science at Vienna, appointed to consider that treatise and to report, reported in regard to the effect of forests on the rainfall as follows:—"The influence of forests on the quantity of the rainfall is a subject which has engaged the attention of many naturalists. From many different points of view has this influence been discussed, the discussion being founded partly on theoretical considerations, partly on the altered climatal conditions of country in which forests have been destroyed.

"In connection with theoretical considerations it has been extensively maintained that forests arrest the floating clouds, as do mountain ranges opposed to a current of clouds, and like these occasion a condensation of moisture; and further that by the relatively lower temperature prevailing in a forest than in the open country, thus occasion a precipitation of that moisture in the form of rain; and in reference to this point more especially has Dr Berger in Frankfort devoted attention to the difference in favour of rainfall in the temperature and condition of moisture in the forest, in comparison with these in the open country.

"It is on the whole probable that some such influence is produced by forests; but perhaps on the one hand the importance of this influence has been over-estimated; and on the other hand there is a lack of direct and decisive proof as to the effect; as the pluviometrical observations made for this purpose in stations within and outside the forests extend over too short periods, and to some extent have been made in conditions or circumstances which do not admit of strict comparison, such as the difference in condition at different elevations, inclinations, and exposures in different directions, &c.

"From the great importance, in the interest of agriculture, of the alleged diminution in the rainfall, the Scottish Meteorological Society decided, in 1859, at the request of their president, the Marquis of Tweeddale, to offer a prize for an essay on the question, Whether any change had occurred in the quantity of rainfall in the west of Europe.

The successful essayist, Mr F. H. Jamieson, found in the observations of the rainfall over extended periods, to which he had access, no reason to conclude that there had been any progressive diminution in the rainfall; local oscillations alone were apparent, and the causes of these it would be difficult to determine.

"This essay gave occasion for the institution of other similar investigations; and also for the establishment, through the British Association for the Advancement of Science, of a number of stations for the observation of the rainfall in different parts of Great Britain and Ireland. And a committee was appointed by the Association to give attention to the subject.

"Mr G. J. Symons, in London, undertook the inspection of the stations and the collating of the observations reported.

"Observations made at several stations in England and Scotland, of which Mr Symons was enabled to avail himself in the investigation, extended back to 1726.*

"Thanks to the observatory at Paris, we have still earlier observations, carrying us back to the year 1688.†

"According to observations made in England and in France there is no evidence of a diminution in the annual rainfall; but on averages of ten years there are seen differences in the quantity of the rainfall, the causes of which have not yet been determined.

* He gives in the Report of the British Association for 1866, by means of registers received from seventeen stations, the following data in regard to the rainfall in England in proportional measurements :—

Period.	*Proportional measurement.*		*Period.*	*Proportional measurement.*	
1726–1735	94·6	86·7	1806–1815	94·6	99·3
1736–1745	78·7		1816–1825	103·9	
1746–1755	78·6	83·5	1826–1835	101·3	100·8
1756–1765	88·2		1836–1845	100·2	
1766–1775	103·6	98·4	1846–1855	100·6	98·5
1776–1785	93·2		1856–1865	26·3	
1786–1795	96·6	93·2			
1796–1805	89·7				

† In the *Annuaire météorologique de l'Observatoire physique central pour* 1873, Marié Davy gives the following calculation of the annual rainfall at Paris :—

Period.	*Average in millimètres.*	*Period.*	*Average mm.*
1688–1700	517	1791–1798	413
1701–1710	481	1804–1810	518
1711–1720	465	1811–1820	496
1721–1730	378	1821–1830	514
1731–1740	411	1831–1840	507
1741–1750	420	1841–1850	529
1773–1780	540	1851–1860	520
1781–1790	507	1861–1870	493

"It would be rash to conclude, from the fact that no permanent change in the direction spoken of has been proved to have occurred in the west of Europe, that no alteration of the kind has taken place in the interior of the continent; and there are certain pluviometrical records made at continental stations which do not indeed go so far back, but which also, so far as they go, are not unfavourable to the supposition of some such diminution having occurred.*

"Blodget arrived at a similar conclusion from an examination of pluviometrical observations in North America; although the destruction of forests had been carried out there to such an extent that a change in the rainfall might have been expected.

"In reference to the older observations of the rainfall we must observe that their value is very much diminished by the circumstance that the observations were not made every day, but sometimes at long intervals; besides which, the rain-gauges were often placed in unsuitable localities, as on roofs and on towers, &c. Both of these circumstances would produce an effect in the same direction, giving returns of less than the actual rainfall at the time at which they were made.–

"In view of all the facts of the case, although the actual measurements of the rainfall, extending back for 200 years, cannot be adduced as evidence of any progressive diminution in the quantity of the rainfall, it would not be right to attach no weight to the facts brought forward by the author, more especially from Milne Home's paper in the Journal of the Scottish Meteorological Society, (vol. III. p. 35) from Becquerel, (*Atlas météorologique de l'Observatoire de Paris, pour* 1867) and from a great many other sources, which tend to prove a deterioration in climate to have taken place in consequence of the extensive destruction of forests.

"The Commission agrees with him in considering *that it is probable, forests have an influence on the quantity of the rainfall, and especially on the distribution of the rainfall over the year, although the direct observations in our possession do not as yet seem sufficient to determine the extent of that influence.*"

I am quite aware that there are facts recorded which appear to

* In the Imperial *Central-Anstalt für meteorologie* have the obervations in about 120 stations in Europe and North America, been examined on this point.

*On the effect of altitude on the returns of the rain-gauge there are numerous statements. In Möllendorfs works (p. 102) it is shown that at different stations the lower rain-gauge received from 13 to 60 per cent. more rain than on a higher place one did.

point to a different conclusion from that which is thus announced. But I have to say in reference to this, that it was implied in or covered by the instructions given to the Commission to consider this matter and to report; and further, that I find no difficulty in accounting for any of the apparently conflicting facts referred to, without compromising the conclusion arrived at by the Commission, and I know of numerous facts in accordance with that conclusion.

M. E. Renou, in a paper entitled *Thèorie de la pluie*, which appeared in the *Annuaire de la Société Météorologique de France* (t. xiv. p. 89, 1866), writes :—"When it is seen that the rain depends as its condition on great atmospheric movements, and is only modified by the principal accidents of soil, mountains, and seas, what influence can the cultivation by man, and more especially the forests, have upon this phenomenon? A generally-existing opinion attributes to them an important influence on the distribution of the moisture precipitated from the atmosphere; but this opinion, which is purely theoretic, has absolutely no foundation: there never has been cited in support of it a single indisputable observation, and if in certain lands, as Algeria, it rains more on forests than on the lands devoid of these, in attributing to them an influence on the rain this is only to confound the effect with the cause. The rainfall follows in a striking manner the *relief* of the soil, and forests appear nowhere spontaneously excepting where there is a sufficiency of rain. This observation is applicable to the analogous cases cited by M. Boussingault in America. It is precisely at the line of contact of the bare regions and the wooded regions near the limits of the natural growth of woods that this can be remarked; these forests do not generally receive sufficient rain for them to grow everywhere, and they are found only there where the position and arrangement of the mountains permit the soil to receive the greatest quantity of water.

"Charts representing courses followed by storms of rain and storms of hail do not indicate the least deviation from their course in the vicinity of forests. The celebrated hail-storm of the 13th June 1788 has long ago shown this to be the case; it followed a line almost straight, absolutely independent of what was seen on the soil beneath it.

"The opinion in regard to the influence of forests on rain is just like all prejudices: it has been repeated for a considerable length of time without having the least proof. In my opinion, man has not the least influence on natural phenonena. Formerly, it was sought to connect meteorological phenomena with dominant local influences;

but, in proportion as the study of them extended, the magnitude, grandeur, and general character of atmospheric phenomena came to be recognised."

In citing these views of M. Renou I am citing what has been cited in France with approval; and there is much in them with which I agree, but this so combined with much with which I do not agree that I am almost glad to have the opportunity to state wherein we differ.

I have given evidence of my belief that the primary distribution of forests is attributable to the previous geographical distribution of the rainfall; but I consider that this is not incompatible with their exercising an influence on the subordinate subsequent distribution of the rainfall within the district in which they have grown: in other words, that while the primary distribution of forests appears to have been determined by the rainfall, once established, they may, and they do, exercise a manifold influence on the rainfall. Sinbad's adventures with the Old Man of the sea, and Æsop's fable of the horse being saddled and bridled by man, have made us acquainted—many of us while yet young, acquainted—with the principle that consequences may flow from an action which were not anticipated when that action was performed. The Spaniards have a proverb to the effect that Whoever gets a wife gets a master. The Scotch have another version of the same proverb which is not less pat: their version of it is—Whoever gets a man gets a master. And in many lands it is seen that a family often produces on both of the parents a very marked change of habit. So is it here, the mountains once clothed with forests, all is changed. And it is to what takes place in this altered condition that the report cited refers.

M. Renou seems to attach importance to storms of rain and storms of hail advancing in a direct line, deviating from this in passing near by a forest. On this subject M. Cézanne writes:—"On charts which have been published by the Academy M. Becquerel has represented the course of certain [thunder] storms. Some people have thought that they could conclude from these charts that storms avoid forests. But it should be remarked that these charts having been prepared from testimony supplied by populations and Assurance Companies, the abundance of documents establishing the devastations caused by the hail is not necessarily in exact relative proportion of the frequency and violence of these storms: it depends more especially on the density of the populations and the richness of the crops. If the wooded regions do not supply documents towards establishing the statistics of storms, it is because in the forests there are neither notable devastations committed by them nor inhabitants to report them.

"The department of the Gironde furnishes a striking case in support of this explanation. According to the storm chart of this department (*Atlas meteorologique*, 1868) the hail would seem to fall by preference on the banks of the Garonne, or in the rich canton which extends between that river and the Dordogne, but particularly on the inhabited places; and, on the contrary, that the desert *landes* were entirely spared by the hail.

"But it is well known that the *landes* are traversed by violent storms; but the shepherds of the *landes* do not send bulletins to the Observatory!"

So much in regard to storm-charts such as are cited by M. Renou. In regard to the kind of storms referred to by him, they are such as were not likely to deviate from the cause in consequence of any such difference on the surface of the earth as a forest might present.

Of the hailstorm cited by M. Renou, Sir John Herschel writes:—"In the hail-storm of July 13th, 1788, which passed across France from south to north, two such tracks were marked, of 175 and 200 leagues in length respectively, parallel to each other, the one four leagues broad, the other two, and separated by a track five leagues in breadth, in which only rain fell. A similar character is very common, though not to such an extent. Such linear hail-storms are always attended with violent wind, sudden depression of the barometer, indicating a great commotion in the air, and probable mingling of saturated masses of very different temperature.

And in writing on the Hydrology of South Africa, I had occasion to state: "According to views advanced by Espy, a distinguished American meteorologist, the two parallel lines along which the hail-storm advanced in the case mentioned by Sir John Herschel can be satisfactorily accounted for. According to one of the laws regulating storms, many of these advance, as does a wheel, rotating and progressing horizontally—as a wheel does vertically in advancing along a road—as is made visible in a small advancing whirlwind of dust, or leaves, or straw, or chaff. The cyclone, a whirlwind of such extent as to create a storm, is fed with air as it advances; this, raised to a great height, expands, cools, precipitates the moisture it contained, and throws this off in a frozen state—as does a twirled wet mop throw off drops of water,—and by gravitation it falls. As the rotating whirlwind advances, the motion of the air forming the forefront will cross the breadth of the circle from left to right, or from right to left, as the case may be; the air forming the rear will cross the breadth of the circle in the opposite direction, and scatter the hailstones or rain over the whole breadth traversed in two showers, minutes, hours, or days apart; but at the sides the wind blows in but one direction on the right of the circle, and in one direction, the opposite of this, on the other, and along the lines followed by these the hail or rain falls continuously in greater abundance."

M. Cézanne writes in reference to what he had stated relative to the fall of rain being determined in a great measure by the contour of a country, and which I have already quoted:—

"It may be said—if the rain acted as if it had caprices and the protuburances of the soil caused a change in the pluvial current—will a mass of forests which raises itself on the plain remain without any influence? Stating the question thus, it must be admitted as unquestionable that forests may exercise an influence on the rainfall. It may so happen, for example, that a forest of trees coming to bar up a valley of little depth may interrupt the pluvial current, and notably diminish the quantity of water collected in a pluviometer which would be placed behind it. The town of Erfurt, for example, sheltered against the west wind by the Thuringian forest, receives less rain than do adjacent regions.* It is not necessary to speak of a high forest of timber trees; a simple wall, suitably disposed, suffices. It is well known that the face of such a wall, exposed to the pluvial wind, receives more rain than does the sheltered side,—what is kept on the one side falling there leaving so much the less to fall on the other; and observations show that it is enough to raise up buildings or other erections in the neighbourhood of a pluviométer to produce a change in its receipts."

But the hail-storm cited by Renou was not a fall of rain produced by a pluvial wind blowing along the surface. The hail was produced at an elevation far above the loftiest forest, where the forest could not produce such a deviation as he states did not occur.

And with regard to his belief that it is beyond the power of man to exercise the least influence over physical phenomena, the expression given of it would require some qualification in order to exempt at least such physical phenomena as are mentioned by M. Cézanne in the statement by him which I have just cited, and who holds the same opinions as does M. Renou on the point to which I understand him to refer.

* Kaemitz.

So far as my own observations have gone it is in accordance with what has now been advanced. My observations have been made incidentally and not of purpose, and they are general rather than precise. They have been made, one class of them in Scotland, the other in Africa, or countries which are in very different climatal conditions, and for this it may be considered by some that some allowance should be made; but such as they are they are these : While the genial shower or the drizzling mist appears to be a characteristic of woodland rain, deluges of rain like thunder plumps are the forms which I have found most characteristic of rain in the arid regions of South Africa ; frequent showers and constant damp in spring and autumn and winter alike are characteristic of woodlands in Britain with which I am familiar, a cloudless sky, and a persistent drought broken only by an occasional deluge, brief in its duration and local in its range, are the characteristics of the other. In the one we have the rainfall distributed over eight or ten months of the year, with occasional showers in the course of the intervening summer ; in the other a drought continued for months, or it may be for years, and a rainfall of two days or three, or of some hours, or it may be of half an hour at most. In the one we may have the rainfall distributed over the whole of the area of a hundred or a thousand square miles, falling not over the whole simultaneously or continuously, but so distributed in time as well as in space that no part suffers lack ; in the other we may have a deluge of rain over twenty square miles at one time within an area of a thousand, and a deluge over other twenty square miles at another time, weeks or months, or it may be years thereafter.

The geographical distribution of rain may be attributable to geographical position and contour of the country. Such deluges of rain as have now been referred to may be attributable in some cases to eddies in one or other of the aerial currents flowing continuously between the equator and the poles; in other cases to the passage of a minor cyclone or whirlwind above the place ; but the frequent drizzling genial showers prevailing in a wooded country may be considered a form given to the rainfall in some measure by an influence of the woods; and the absence of these in arid woodless regions, in which the mean annual rainfall is the same and the conditions similar, may be considered in a corresponding manner attributable to the absence of forests.

CONCLUSION.

We are told in the book of Proverbs: "He that is first in his own cause seemeth just; but his neighbour cometh and searcheth him." I have stated in preceding chapters, with such precision as I could attain unto, what I consider to be the effect of forests on the humidity of the soil and character of the districts in which they exist; but I am aware that a compilation might be prepared of observations made by men of science which might seem to support a widely-different conclusion. I have given attentive consideration to all such to which I have had access, and prepared a statement on their apparent bearing on what I have advanced; but I refrain from inserting this, not because I consider them unimportant, for I consider them equally valid and equally important with many—I may say with any—which I had advanced. I refrain from inserting this first, and mainly, because I am unwilling to add to the expense and the bulk of the volume; 2ndly, and the reason weighs with me almost as much as the first, I wish to present the subject to my readers in as simple a form as I can, and without complications which I do not consider necessary for my purpose; and I know of nothing which has been advanced as observations made, or conclusions deduced by reasoning, or phenomena observed, which are incompatible with what I have advanced.

From what has been advanced it appears to be established as a fact that there are cases in which an extensive destruction of forests has been followed by a marked desiccation of soil and aridity of climate, and some cases in which the replanting of trees has been followed by a more or less complete restoration of humidity,—or the planting of trees where there were none has been followed by a degree of humidity greatly in excess of what had previously been observed; that there are cases in which the rainfall within forests, or in their immediate vicinity, has been perceptibly greater than in the open country beyond; but that there are also cases in which it is alleged that the desiccation of some lands once clothed with forests and fertile, now treeless and barren and dry, may be attributable in part, if not in whole, to other causes besides the destruction of the forests, and cases in which the extensive destruction of forests does not appear to have extensively affected the quantity of the rainfall over a wide expanse of country.

These facts may, by a little latitude in the use of language, be characterised as antagonistic or conflicting; but they may nevertheless be accepted as facts, and that with the admission that if facts they must be perfectly compatible with each other, and not only compatible but consistent with each other in the actually existing system of things, and necessary to be known in order to a correct conception of this system as a whole.

As it is with these apparently conflicting facts which I have cited so does it appear to me to be with those apparently conflicting facts, connected with details, which I have refrained from bringing forward here: they do not appear to me to invalidate in any way those which have been founded on in the conclusions I have advanced.

When I was a boy I was told of one of my townsmen, that, being on trial before one of the magistrates for the theft of a hen, when a witness testified that he had seen him take it, he broke forth with a vehement appeal "Your honour! I can bring forward twenty men who did not see me." And to such testimony might be likened testimonies to facts which are not in question cited as sufficient to invalidate explicit testimony to other facts observed. I am prepared to admit unhesitatingly all that can reasonably be said in regard to my acceptance as facts of what I have accepted as such; the conclusions I have drawn from them I commend to the consideration of my readers; and I leave to their judgment to determine to what extent these should influence deliberations on the adoption of practical measures to avert the evil and to secure the good which appear to be at our command.

The effects of forests in retarding the flow of the rainfall after its precipitation has been established, I consider, beyond all question; and not less so their effect in maintaining a general humidity of atmosphere and of soil.