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Carbon in Drylands: Desertification, Climate Change and Carbon Finance

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Technical Note: Carbon in drylands - Desertification, climate change and carbon finance

Introduction

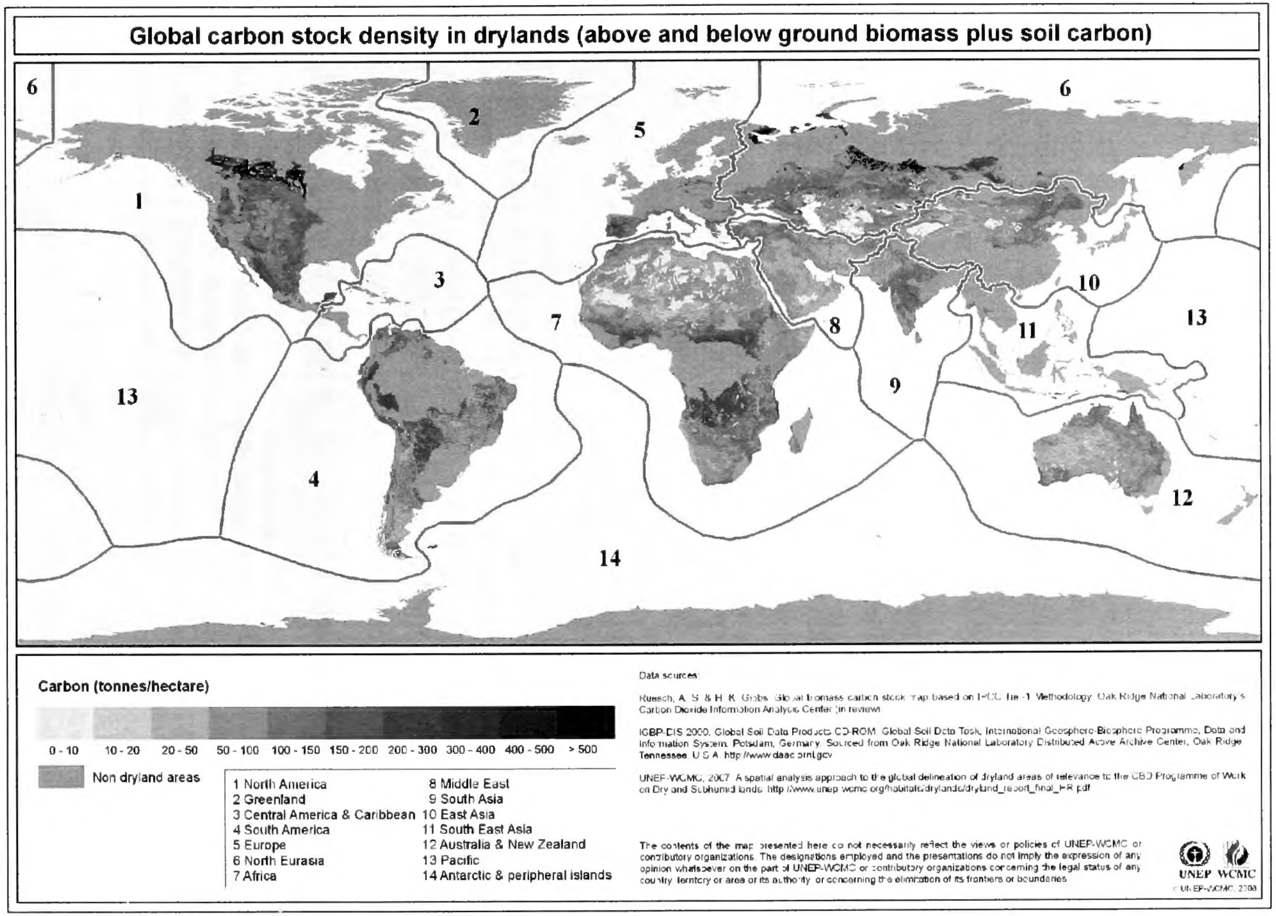
Drylands cover about 40% of the Earth's land surface, excluding Antarctica and Greenland, and are home to more than two billion people (WRI 2002). They are susceptible to desertification, land degradation and drought (DLDD) and their populations, agriculture and ecosystems are vulnerable to climate change and variability. The United Nations Convention to Combat Desertification (UNCCD), one of the three 'Rio' conventions born out of the 1992 United Nations Conference on Environment and Development (UNCED), aims to address these issues and emphasises action to promote sustainable development at the community level.

The other Rio conventions are the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD). The areas of interest of the three Conventions are closely linked and each has accepted the need to work in concert. One area of joint interest is that of the uptake of carbon dioxide from the atmosphere by plants and its storage in ecosystems. It is perhaps the only practicable way of removing carbon dioxide from the atmosphere in the short term and therefore one of the few options for addressing its existing carbon load, as distinct to slowing future loading by reducing current and future emissions. Most attention so far has focussed on carbon sequestration by tropical forests. More recently, some have argued for a more holistic approach to terrestrial carbon (The Terrestrial Carbon Group, 2008). This paper reviews the potential for carbon sequestration in dryland ecosystems, which includes forests, but also covers other habitats, such as grasslands, and, importantly, soils. It also considers ways in which carbon storage in drylands affects land degradation issues.

Carbon storage in drylands

Plants take up carbon dioxide from the atmosphere and incorporate it into plant biomass through photosynthesis. Some of this carbon is emitted back to the atmosphere but what is left—the live and the dead plant parts, above and below ground —make up an organic carbon reservoir. Some of the dead plant matter is incorporated into the soil in humus, thereby enhancing the soil organic carbon pool.

Plant biomass per unit area of drylands is low (about 6 kilograms per square meter) compared with many terrestrial ecosystems (about 10–18 kilograms). But the large surface area of drylands gives dryland carbon sequestration a global significance. In particular, total dryland soil organic carbon reserves comprise 27% of the global soil organic carbon reserves (MA 2005). The soil properties, such as the chemical composition of soil organic matter and the matrix in which it is held, determine the different capacities of the land to act as a store for carbon that has direct implications for capturing greenhouse gases (FAO 2004). The fact that many of the dryland soils have been degraded means that they are currently far from saturated with carbon and their potential to sequester carbon may be very high (Farage et al. 2003).


Global carbon stock density in drylands (above and below ground biomass plus soil carbon)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Carbon (tonnes/hectare)
0 - 10
10 - 20
20 - 50
50 - 100
100 - 150
150 - 200
200 - 300
300 - 400
400 - 500
> 500
Non dryland areas
1 North America
2 Greenland
3 Central America & Caribbean
4 South America
5 Europe
6 North Eurasia
7 Africa
8 Middle East
9 South Asia
10 East Asia
11 South East Asia
12 Australia & New Zealand
13 Pacific
14 Antarctic & peripheral islands
Data sources:
Ruesch, A. S. & H. K. Gibbs. Global biomass carbon stock map based on IPCC Tier-1 Methodology. Oak Ridge National Laboratory's Carbon Dioxide Information Analysis Center (in review)
IGBP-DIS 2000. Global Soil Data Products CD-ROM. Global Soil Data Task, International Geosphere-Biosphere Programme, Data and Information System, Potsdam, Germany. Sourced from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A. http://www.daac.ornl.gov
UNEP-WCMC, 2007. A spatial analysis approach to the global delineation of dryland areas of relevance to the CBD Programme of Work on Dry and Subhumid lands. http://www.unep-wcmc.org/habitats/drylands/dryland_report_final_FR.pdf
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The map above shows how the density of carbon stored, that is, the mass of carbon per hectare, varies throughout drylands. The carbon densities are derived from two global datasets: the carbon stock in biomass is from a map based on IPCC Tier-1 Methodology using global land cover data. (Ruesch & Gibbs, in review); soil carbon is from Global Soil Data Products CD-ROM. (IGBP-DIS 2000). The delineation of drylands is from UNEP-WCMC's map of areas of relevance to the CBD's programme of work on dry and sub-humid lands (UNEP-WCMC 2007). The UNCCD defines drylands according to an aridity index: the ratio of mean annual precipitation to mean annual potential evapotranspiration. The CBD definition of 'drylands' used within its Programme of Work on Dry and Subhumid Lands (UNEP/CBD/SBSTTA/5/9) differs from the UNCCD definition described above in two ways:

i. It includes hyperarid zones (CCD does not) (UNEP/CBD/SBSTTA/5/9), which represent approximately 6.6 percent of the Earth's land surface.

ii. Major vegetation types are used to define dryland areas in addition to those defined according to the aridity index (UNEP/CBD/SBSTTA/5/9).

Table 1 gives a breakdown of the carbon stored in each region in drylands. Figures for the total carbon stock in each region are from Campbell *et al.* (2008) and are derived from the same data as the dryland figures. Estimates of carbon stored in each region are sensitive to changes in land cover type. Therefore for detailed regional or national purposes, it will be necessary to refine global land cover data with more detailed local data. Nevertheless, this global overview shows that dryland carbon storage accounts for more than one third of the global stock. In some regions, such as the Middle East and Africa, a very high proportion of carbon is in drylands, so any sequestration measures there would need to address dryland ecosystems. Even in regions such as Africa and South Asia, where moist forests contain a lot of carbon, dryland carbon storage is still significant.

Table 1. Comparison of total and drylands carbon stocks in regions of the world

Map number	Region	Total carbon stock per region (Gt)	Carbon stock in drylands(Gt)	Share of regional carbon stock held in drylands (%)
1	North America	388	121	31
2	Greenland	5	0	0
3	Central America & Caribbean	16	1	7
4	South America	341	115	34
5	Europe	100	18	18
6	North Eurasia	404	96	24
7	Africa	356	211	59
8	Middle East	44	41	94
9	South Asia	54	26	49
10	East Asia	124	41	33
11	South East Asia	132	3	2
12	Australia/New Zealand	85	68	80
13	Pacific	3	0	0
Total		**2053**	**743**	**36**

Land degradation and carbon emissions

According to the Millennium Ecosystem Assessment, "some 10–20% of the world's drylands suffer from one or more forms of land degradation. Despite the global concern aroused by desertification, the available data on the extent of land degradation in drylands (also called desertification) are extremely limited. In the early 1990s, the Global Assessment of Soil Degradation, based on expert opinion, estimated that 20% of drylands (excluding hyper-arid areas) were affected by soil degradation. A study based on regional data sets (including hyper-arid drylands) derived from literature reviews, erosion models, field assessments and remote sensing found much lower levels of land degradation in drylands. Coverage was not complete, but the main areas of degradation were estimated to cover 10% of global drylands." The MA estimated that the true level of degradation lay somewhere between the 10% and 20% figures. (MA 2005). The Land Degradation Assessment in Drylands (LADA) project, funded by the Global Environmental Facility (GEF) and carried out by the Food and Agriculture Organization of the United Nations (FAO) is drawing together information about degradation and developing ways of assessing the extent of land degradation and its impacts.

Land use change and degradation are important sources of greenhouse gases globally, responsible for about 20% of emissions (IPCC, 2007). Land degradation leads to increased carbon emissions both through loss of biomass when vegetation is destroyed and through increased soil erosion. Erosion leads to emissions in two ways: by reducing primary productivity, thereby reducing soils' potential to store carbon and through direct losses of stored organic matter. Although not all carbon in eroded soil is returned to the atmosphere immediately, the net effect of erosion is likely to be increased carbon emissions (MA, 2005).

There have been a number of estimates of the rate of carbon emissions due to land degradation in drylands at different scales. At the global scale, Lal (2001) estimated that dryland ecosystems contribute 0.23 – 0.29 Gt of carbon a year to the atmosphere, which is about 4% of global emissions from all sources combined (MA 2005). In China, degradation of grassland, particularly on the Qinghai-Tibetan Plateau, has led to the loss of 3.56 Gt soil organic carbon over the last 20 years. It is estimated that the soils of China overall now act as a net carbon source, with a loss of 2.86 Gt in the same period (Xie et al., 2007). It is therefore vital from a climate perspective that this region is managed to enhance carbon sequestration (Xu et al., 2004) and further study is clearly required in this area (ESPA China 2008).

Grace et al. (2006) reviewed carbon fluxes in tropical savannas. They found that carbon sequestration rates in these ecosystems may average 0.14 tonnes carbon per hectare per year or 0.39 tonnes carbon per hectare per year. They concluded that "if savannas were to be protected from fire and grazing, most of them would accumulate substantial carbon and the sink would be larger. Savannas are under anthropogenic pressure, but this has been much less publicized than deforestation in the rain forest biome. The rate of loss is not well established, but may exceed 1% per year, approximately twice as fast as that of rain forests. Globally, this is likely to constitute a flux to the atmosphere that is at least as large as that arising from deforestation of the rain forest."

As well as contributing to greenhouse gas emissions, drylands are themselves vulnerable to the effects of climate change and the impacts of climate change in these areas may lead in turn to further carbon emissions. Any further failure of plant growth due to increased temperatures would further reduce carbon inputs to the soil, accelerating its degradation. Smith et al point out that 'even partial loss of vegetation integrity could make soils more vulnerable to degradation through other agents such as grazing and cultivation.' (Smith et al 2008)

Climate change mitigation through addressing DLDD

Addressing land degradation in dryland ecosystems presents two complementary ways of mitigating climate change. First, by slowing or halting degradation, associated emissions can be similarly reduced. Second, and arguably of greater significance, changes in land management practices can lead to greater carbon sequestration, that is, to removing carbon from the atmosphere. In general, the carbon storage potential of dryland ecosystems is lower than for moist tropical systems, but the large area of drylands means that overall they have significant scope for sequestration.

Managing drylands for carbon sequestration

Since carbon losses from drylands are associated with loss of vegetation cover and soil erosion, management interventions that slow or reverse these processes can simultaneously achieve carbon sequestration. There is a wide range of strategies to increase the stock of carbon in the soil. Examples include enhancing soil quality, erosion control, afforestation and woodland regeneration, no-till farming, cover crops, nutrient management, manuring and sludge application, optimal livestock densities, water conservation and harvesting, efficient irrigation, land-use change (crops to grass/trees), set-aside, agroforestry, and the use of legumes (FAO 2004, Lal 2004, Smith 2008).

There is a growing interest in assessing the carbon sequestration potential of such strategies quantitatively. Using a modelling approach, Farage et al (2007) found the most effective practices for increasing soil carbon storage were those that maximised the input of organic matter, particularly farmyard manure (up to 0.09 tonnes C per hectare per year), maintaining trees (up to 0.15 tonnes C per hectare per year) and adopting zero tillage (up to 0.04 tonnes C per hectare per year (Farage et al 2007).

Tiessen et al. (1998) reviewed data on carbon and biomass budgets under different land use in tropical savannas and some dry forests in West Africa and North-Eastern Brazil. They found that improvements in the carbon sequestration in these semi arid regions depended on an increase in crop production under suitable rotations, improved fallow and animal husbandry, and a limitation on biomass burning. Use of fertilizer was required for improved productivities but socioeconomic constraints largely prevented such improvements, resulting in a very limited scope for changes in soil carbon management.

Increasing carbon stocks in the soil increases soil fertility, workability, water holding capacity, and reduces erosion risk and can thus reduce the vulnerability of managed soils to future global warming (Smith, 2008). However, hidden costs also need to be considered, such as the addition of mineral or organic fertilizer (especially nitrogen and phosphorus) and water, which would need significant capital investment (MA 2005).

Estimates of dryland carbon sequestration potential

Several studies have attempted to assess the potential for carbon sequestration in drylands. Considering all drylands ecosystems, Lal (2001) estimated that they had the potential to sequester up to 0.4–0.6 Gt of carbon a year if eroded and degraded dryland soils were restored and their further degradation were stopped. In addition, he suggested that various active ecosystem management techniques, such as reclamation of saline soils, could increase carbon sequestration by 0.5–1.3 Gt of carbon a year. Squires et al (1995) estimated similar figures. Keller and Goldstein (1998) reached the slightly higher figure of 0.8 Gt of carbon per year using estimates of areas of land suitable for restoration in woodlands, grasslands, and deserts, combined with estimates of the rate at which restoration can proceed.

Other studies have examined specific ecosystems in particular locations. For example, Glenday (2008) measured forest carbon densities of 58 to 94 tonnes C/ha in the dry Arabuko-Sokoke Forest in Kenya and concluded that improved management of wood harvesting and rehabilitation forest could substantially increase terrestrial carbon sequestration. Farage et al. (2007) used soil organic matter models to explore the effects of modifying agricultural practices to increase soil carbon stocks in dryland farming systems in Nigeria, Sudan and Argentina. Modelling showed that it would be possible to change current farming systems to convert these soils from carbon sources to net sinks without increasing farmers' energy demand. The models indicated that annual rates of carbon sequestration of 0.08-0.17 tonnes per ha per year averaged over the next 50 years could be obtained.

Despite these studies, significant gaps in knowledge remain. Better information is needed on the impact of land use changes and desertification on carbon sequestration and the cost-benefit ratio of soil improvement and carbon sequestration practices for small landholders and subsistence farmers in dryland ecosystems (MA 2005).

Linking drylands development and carbon markets

There are two markets for carbon sequestration: a) the compliance market governed by the United Nations Framework Convention on Climate Change (UNFCCC) through its Kyoto Protocol and b) the voluntary market. The role of the natural biosphere in climate change mitigation is recognised in the UNFCCC through Land Use Land Use Change and Forestry (LULUCF).

Annex I Parties, under Article 3.3 of the Kyoto Protocol, can use *"direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in carbon stocks,"* to meet emissions reductions targets. In addition, they can elect Forest Management, Grassland Management, Cropland Management, and Revegetation for inclusion in the accounting process. There are calls by some to include all lands and associated processes in the LULUCF, rather than the narrow activities specified above.

The rules for LULUCF were only set after emission reduction targets had been agreed. This has been viewed as a limitation, as in effect land use activities 'offset' emissions in other sectors, rather than acting as an integral part of the mitigation portfolio. Issues still remain over the permanence of sequestration activities as management changes or natural disturbances can quickly release any carbon accumulated.

The opportunities for Non Annex 1 countries to participate in such activities is also limited, and restricted to the Clean Development Mechanism (CDM); where Annex I countries can gain carbon credits through activities in developing countries. CDM activities are restricted to Afforestation, Reforestation and Deforestation activities, and can make up only 1% of the emissions reduction portfolio for Annex I countries.

As yet few forestry-based carbon sequestration activities have been funded through the CDM, partly because of concerns about additionality, permanence and leakage. Voluntary markets have developed their own regulations and protocols, and are the only outlet for reduced deforestation programmes at the moment.

However, the UNFCCC is considering introducing a financial mechanism to reduce emissions from deforestation and forest degradation (REDD) in developing countries. There is still a great deal of uncertainty about the form of the mechanism, not least how it will be funded. One option is to do so though a specific fund, another is a market-based mechanism that would allow developing countries to sell carbon credits on the basis of successful reductions in emissions from deforestation and forest degradation. A market-based mechanism is expected to generate a much greater supply of funds; one estimate, based on a relatively low carbon price of U.S. $10 per ton and an estimate of individual countries' ability to slow deforestation, suggests a potential market of U.S. $1.2 billion a year (Niles et al., 2002).

The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD Programme) is a collaboration between FAO, UNDP and UNEP. It is aimed at "tipping the economic balance in favour of sustainable management of forests so that their formidable economic, environmental and social goods and services benefit countries, communities and forest users while also contributing to important reductions in greenhouse gas emissions". Its immediate goal is to assess whether carefully structured payment structures and capacity support can create the incentives to ensure actual, lasting, achievable, reliable and measurable emission reductions while maintaining and improving the other ecosystem services forests provide. The UN-REDD programme has nine initial pilots, two of which – Tanzania and Zambia – are dryland woodland countries.

The potential scale of funding available through a market-based REDD has drawn attention to both its potential for achieving other benefits simultaneously and the risk of displacing degradation into areas that may have low carbon storage potential, but that are valuable in other ways (Miles and Kapos 2008). There are technical and statistical challenges of measuring changes in above and belowground carbon stocks over large areas in drylands with the required accuracy, and further research is required to demonstrate the feasibility of large area measurement schemes. The pros and cons of carbon accounting at different scales (e.g. individual land user, watershed, national level) and the associated transaction costs in administering such schemes also still need to be evaluated.

REDD is applicable to forested ecosystems only, but other carbon markets may include projects based in other ecosystems, depending on their carbon sequestration potential. Regardless of the market, the price of carbon strongly influences whether interventions to manage land degradation and carbon sequestration simultaneously are cost effective. At present, the price of soil organic carbon, for example, is low, at about $1 per tonne, so only low-cost interventions are likely to be cost effective for land managers. For example, Smith (2008) concluded that there was technically the potential to increase soil organic carbon stocks by about 1–1.3 Gt per year. However, he found that if carbon prices were less than US$20 per tonne it would only be economically feasible to increase soil carbon stocks by up to 0.4 Gt carbon per year. At higher carbon prices, costlier interventions may generate sufficient revenue through carbon credits to be worth undertaking.

The important questions for drylands, then, are first to identify areas, forest or otherwise, where the carbon storage potential is great enough to attract carbon finance based on that alone and second to consider whether REDD and other mechanisms could prioritise schemes that also delivered co-benefits such as watershed or erosion protection.

The studies referred to in this technical note indicate that, although carbon density (tonnes of carbon stored per hectare) of drylands is low, the total amount stored can be large as the areas involved are large. As such, interventions that increase the amount of carbon stored in drylands, particularly those that are relatively low cost, may be attractive to carbon markets. Tropical dry forests can store significant amounts of carbon (ECCM 2007) so REDD may be a suitable finance mechanism for anti-degradation measures in these ecosystems, particularly in dryland nations that do not have carbon-rich moist forest. However, it would be helpful to have more information on the characteristics of dryland forest and their carbon storage potential, as well as greater clarity of the form that REDD mechanism will take, to estimate the likely scale finance available for UNCCD-relevant forests.

It is clear that dryland carbon sequestration, particularly in soils, can provide other ecosystem and social benefits such as as the rebuilding of the biophysical foundations of a sustainable natural environment – biodiversity, forests, livestock, soils, water, natural ecosystems - thus increasing productivity, improving water quality, and restoring degraded soils and ecosystems. In its 2004 report on carbon sequestration in dryland soils, the FAO concluded that "actions for soil improvement through carbon sequestration are a win - win situation where increases in agronomic productivity may help mitigate global warming, at least in the coming decades, until other alternative energy sources are developed" (FAO 2004).

Conclusions

Sustainable land management practices that address desertification, land degradation and drought (DLDD) in drylands can also have significant carbon sequestration potential, particularly where they increase the organic carbon content of soils. As Lal (2004) pointed out, the carbon sink capacity of tropical dryland soils is high in part because they have already lost a lot of carbon. Restoring that carbon offers long-term sequestration and can improve crop yields and increase ecosystems' resilience to future climate variability. Indeed, the UNCCD's 10 year strategic plan (10YSP) recognises the links between DLDD and climate change. One indicator of the plan's strategic objective 3 "to generate global benefits through effective implementation of the UNCCD" is to achieve an "increase in carbon stocks (soil and plant biomass) in affected areas" (indicator S-6).

However, weak institutions, limited infrastructure and resource-poor agricultural systems often limit the capacity to address soil carbon and DLDD. Carbon markets offer a possible way of financing measures to do so in some areas. However, for significant carbon finance to be channelled to dryland ecosystems, it may be necessary that market mechanisms allow prioritisation or a premium for schemes that offer other benefits. Both forest and non-forest ecosystems have carbon sequestration potential, but the price of carbon traded in the voluntary market is often too low to influence land management practices at present. The 10YSP has already set a strategic objective (Strategic objective 4) of mobilising resources to support implementation of the Convention through building effective partnerships between national and international actors. Work that encourages national and international carbon markets to consider co-benefits in terms of ecosystem serves as well as carbon is in line with this objective.

Given that soil carbon sequestration has much to offer climate change mitigation, land and livelihood protection and resilience to climate change, but that actions to enhance it may be hampered by lack of finance, lack of data and perhaps capacity to implement changes, it is all the more important that policies and institutions addressing these issues should work co-operatively, as set out in 10YSP.

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