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COMPUTER-ASSISTED PLANNING SYSTEMS FOR INDIVIDUAL FARMS

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COMPUTER-ASSISTED PLANNING SYSTEMS FOR INDIVIDUAL FARMS

Proceedings of a seminar held by the
Department of Agricultural Economics,
University of Illinois, Spring Semester, 1969

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Preface

Computer systems have increased in number and in capabilities at a rate undreamed of two decades ago. This increase is accelerating now and is expected to accelerate in the foreseeable future. The increase in speed and capacity of computers reflects a growing awareness among widening classes of users of the efficiencies gained from computer applications. But efficiency alone does not properly describe either the motivation to use computers or the effects of their use. New tasks become feasible, and the effects extend far beyond costs, including shifts in the loci of decision making and changes in the management of information.

Accounts of such changes are available outside agriculture and are noted in references cited in the following papers. Because of the organizational complexity of decision making in agriculture, the rate of change in utilizing computers in agriculture has been slower. Also, the farm sector of agriculture is dominated by firms that are ill-equipped to internalize the costs and returns from the use of computers, both because of the small size of the farm firm and the high fixed costs of computer technology. Finally farms are so varied in planning needs as to complicate the development of a system that is general in terms of data or method.

Considerable progress has been made in designing computer programs to meet the needs of processing data from farm records. A number of interesting research and development activities are continuing in this important area, and some of them are referred to in several of the following papers. More extensive accounts can be found elsewhere.

Less has been accomplished in the development of computer *planning* systems for farms. The research and development activity in planning is more recent than in farm records, and the most appropriate methods may not yet be identified. One specific system described in the following papers is a whole-farm planning system, activated by a matrix generator and interpreted with a report-writer. It differs from systems built around the use of matrices developed specifically and manually on a case-by-case basis, and from matrices developed for "typical" farms.

It is likely that several planning methods will be developed, each with a role to play in a commercially viable planning system. Who will be most likely to furnish such a planning service? Several candidates are visible: professional farm managers, financial intermediaries, firms related to farms in factor or product markets, and perhaps others, including new software agencies yet to be developed. It may be that the planning services offered farmers will be produced by a combination of such agencies. One purpose of these papers is to review the advantages and disadvantages of the various likely suppliers.

The role appropriate for land-grant universities in research and development, as related to computer-assisted planning methods for individual farms, is explored, keeping in mind their advantages and disadvantages as suppliers. This role can be evaluated on two grounds. First, programs for graduate students can be enriched by research and development projects conducted with the students' help. Because the costs of large segments of the graduate program are fixed anyway, it may be cheaper for such research and development to be done in universities than in commercial firms. Moreover, the students are provided with valuable experience in the design of practical computing systems. Secondly, there may be substantial arguments to support the use of public resources to develop technologies with such far-reaching implications. There seems little doubt that real success in the area would generate important elements of control in decision making. In any event, analogous arguments support research that develops new crop varieties, feeding systems, etc.

However strong the arguments may be for research and development in computing technology, there remain questions about the extent of the activities engaged in. One may defend university-centered research and development that generates operational systems but deny institutional extension of the activity to the production of services on a commercial basis. Yet between these extremes is a subtle area for experimentation with systems, trying them in pilot studies and using farmers in demonstration panels. All degrees of such activities can be found in other programs conducted by units of land-grant universities.

The following papers were first presented in a series of seminars at the University of Illinois at Urbana-Champaign in the spring semester of 1969. Substantial changes have since occurred in computer facilities and computing technology. This is characteristic of the field and presents a significant source of organizational problems. Yet the basic issues addressed during the seminars remain unresolved. The nature of the issues, and the response of participants at the seminars, have encouraged the Program Committee to make these papers available to a wider audience.

Seminar Program Committee
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Delmar Wilken

Marketable Management Services: Research and Development

C. B. Baker[1]

Our concern is with the agricultural system. It is a complex system. Its components include the farm sector, the farm-supply sector, and the sector of firms that buy, process, and sell farm products. It also includes financial intermediaries that channel funds into the farm sector, either directly or via farm-related firms, and research and educational agencies that channel managerial services into the farm sector, directly or indirectly.

While our concern is with the whole agricultural system, the focus of our concern is the farm firm. More specifically, we are interested in the alternatives for meeting managerial requirements of the farm firm and how the alternatives are affected by the evolution of computer-assisted planning methods. All components of the agricultural sector are potential sources of managerial services for the farmer. This holds true both as the components now exist and as they may exist after reorganizations likely to result from changes in comparative advantages arising from complementarities affected by cost economies in computerizing managerial services.

Our concern is founded upon questions raised by decision makers in all components of the agricultural system about the role appropriate to their firms or agencies. The social consequences are profound. Available evidence, for example, is not persuasive that large farms always use resources more efficiently than small farms (*1*).[2] Yet large farms arise from aggressive use of financial means if the growth-conscious operators are at least competitive in efficiency. Will this process be influenced by changes in the access of farmers to managerial services? If so, will the changes accelerate or decelerate the trend toward bigness? In all these issues the role of the land-grant university must be reexamined. What role is appropriate in the university's research, education, and public service activities? How will its research and educational functions be affected? What responsibilities does it have in the evolution of information-processing systems?

We address ourselves first to problems of combining men and machines in the acquisition and use of information for managerial tasks. The process has extended further and faster in nonagricultural sectors

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[1] I have benefited from comments on an earlier version of this paper from Professors Fliegel, Swanson, and Hinton, as well as from several participants in the seminar program.

[2] Numbers in parentheses refer to references at the end of the paper.

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than in agricultural sectors — especially the farm component of the agricultural sector. We shall look at nonagricultural experiences for examples of problems that might be anticipated. However, ready inferences from these experiences are hampered by differences that are apparent between the farm firm and its nonagricultural counterpart and by the extreme heterogeneity in each sector. Our comparisons must therefore be broad. To increase validity, however, we will confine our view in both instances to firms that are commercially oriented and are full participants in the economic dynamics of their sector. An exception will be briefly noted in the case of the agricultural sector.

Management and Systemation

Outside agriculture, most managerial tasks are accomplished within large firms whose managerial resources are found largely within the firms. These managerial tasks are common to all firms and can be identified as (a) perceiving problems, (b) formulating objectives, (c) assembling information, (d) making choices, (e) executing decisions, and (f) bearing consequences of decisions. It is common to group (a) and (b) under the heading of "planning," (c) and (d) under "decision making," and (e) and (f) under "administering." The system in which managerial tasks are performed is partially closed inasmuch as observations of the results of administration are fed back as informational flows to be incorporated in subsequent planning and decision making.

Similarly, the firm, whatever and wherever it may be, must have enough of two managerial necessities: managerial skills and decision-relevant data. The managerial skills are those of observation, or data-acquisition, and logic, or data-use. (Eisgruber (*2*) makes a distinction between "data" and "information.") Both skills are closely associated with the storage and retrieval of data to meet informational requirements on the one hand, and the processing of data on the other. Both requirements are related to all the managerial tasks to which we have already referred.

It is essential to grasp the interrelation of tasks and requirements. Changes in computer technology are reducing the costs of storing, retrieving, and processing data. In turn, decision behavior is being modeled with increasing degrees of realism. Hence the costs of performing different managerial tasks are being reduced. But the reductions differ among tasks, with important implications that remain to be analyzed.

Already we have referred to "system." By this we mean a collection of components assembled to produce an output, consuming inputs in the form of physical resources and informational requirements. A system may be simple or complex. In terms of economic phenomena, a system may be macro — for example, a national economy, a market, or a sector such as agriculture; or it may be micro, such as a firm or a household; or it may be sub-micro, such as a crop system, a livestock system, a machine system, a soils complex, a soil-plant relationship, etc. The agricultural system already alluded to is a complex network both within and among firms associated with producing food and fiber. It consumes physical resources and informational flows at all levels of the network. Decisions too are highly interrelated, though the interrelationships are not always explicitly recognized.

For complex systems, it may be useful to differentiate among planning, decision making, and administration, though all are closely related. The objective of planning is to so organize a system that its responses to stimuli will be consistent with managerial objectives. Available literature provides little firm evidence on planning behavior, and especially little on planning criteria. Simon *(3)* provides a plausible hypothesis in the notion of "satisficing"; according to this, the search for alternatives that would modify the firm's organization is triggered by the perception that aspiration levels are not being realized. An objective in building or modifying a firm organization is a system that responds to environment changes in a manner consistent with objectives to be met in decision making and administrative functions.

The objective of decision making is to minimize the cost of making choices that maximize plan objectives consistent with managerial and organizational constraints. The objective of administration is to minimize the cost of executing decisions while controlling the system's operation and feeding back information for subsequent planning. The system is open, however, to informational flows from outside the firm in the form of unrecorded as well as recorded data. The system is partially, perhaps largely, an open one, in the case of the farm firm.

The term "systemation" is sometimes used to characterize the current phase of organizational evolution: labor specialization has led to mechanization, followed in turn by automation, the phase just preceding systemation. Systemation is distinguished from automation by globalness of scope as well as by organizational and management functions, rather than by operational functions alone. Automation, as commonly conceived, describes a mechanical system for accomplishing a specific task. In sophisticated cases, a feedback loop is included through which a measure of control can be exercised. A thermostat is an early and common example of automation with feedback. More elaborate examples are commonplace in agriculture and elsewhere.

Systemation includes assembling and processing information and learning activity. In short, managerial decision making, with learning as a phase thereof, becomes an integral part of the system's organization. In large nonagricultural firms, systemation has evolved into elaborate man-machine combinations, with hierarchies of "management" and associated staff being shuffled and reshuffled in the evolution. Clerks are replaced or supplemented by keypunch operators, lower management personnel by computer programmers and computer engineers, and middle management by systems analysts. Even the higher management echelons now are influenced as informational flows and decision loci are modified with the ever-changing hardware and software that arise from research and development in computer companies and universities.

In 1955, there were but 10 or 15 computers in the U.S., valued at about $30 million. By 1965, there were 31,000, with a combined value of about $7.8 billion. In 1966, it was estimated that by 1970 the number of computers would more than double the 1965 count and the value nearly triple (*4*). Current estimates for 2000 A.D. are as high as $200 billion.

Management in the Agricultural System

The development of computer use in agriculture has so far been much more restrained than in other businesses. The reasons are not hard to find. Most farm firms are still organized as proprietorships, with profound consequences for the supply of both capital and management. Capital from sale of equity is denied the proprietor firm. Management tends to be centered in the individual proprietor to a higher degree than is common in corporate business organizations. Exceptions in management can be found, of course, in either direction; we note only broad tendencies. The main problem is found in the prevalence of small farms in place of large firms and in an array of managerial resources that extends beyond the farm firm, as compared with the concentration of managerial resources within the nonfarm firm. Only recently has it been conceived that "management" for farms comes in separable components and that the components can be developed, bought, and sold. This would have been hopelessly visionary twenty years ago. Today's developments bring such prospects to agriculture and promise startling changes in its internal structure and in its relations with other sectors.

Limited access of farmers to capital markets generates several features of modern farms that are relevant to the seminar program. One of these is land tenancy. Land constitutes a huge proportion of the assets on large commercial farms. A substantial proportion is owned by nonoperators and leased by farm operators. This makes considerable financial sense, given the state of financial markets and production opportunities available to farm operators. Such an arrangement, however, introduces an interesting problem that is certain to gain importance in the years ahead. The professional farm manager constitutes one source of managerial talent that can be brought into the farm business. His approach ordinarily is through the landowner. Another source is the market firm, whether factor market or product market. The immediate contact of the market firm is with the operator, who often is the tenant. Indeed, the operator may be a tenant of land parcels owned by several landowners. When later we compare the position of alternative sources of managerial services we will need to recall this peculiarity of the farm firm.

Mrs. Penrose (*5*) ascribes growth of the corporate firm to an agressive search for alternatives that will absorb accumulations of excess managerial capacity. The accumulation can occur by managerial development from within the firm or from purchase of talent outside the firm to add to an existent managerial team. The same phenomenon is possible in the case of a proprietor firm although its expression may differ dramatically. Learning may generate excess managerial capacity in the farm operator himself. But the operator can also acquire *access to* supplemental managerial services, chiefly from farm-related firms and educational agencies. Such firms and agencies possess particular important attributes that condition the cost at which the services can be made available and may also condition the quality of the services. But more of this later, both in this presentation and in subsequent papers in the seminar program.

With respect to nonfarm experience and results, Whistler (*6*) has noted that ". . . in those firms where the accounting/finance department has always had computer control, it is almost always the case that the major part of computer time is spent on accounting applications. In firms where any other department *now has* or *has had* control, the major part of computer time tends to be spent on other activities (inventory management, production scheduling, marketing, purchasing)."

Implications of this observation for agriculture are most interesting. In passing, we note that it is not common in farming to find records or accounting systems with anything like the sophistication common to large nonfarm firms. Nor are farms obviously managed with reference to recorded data in a manner comparable with that of nonfarm firms. In the latter, accountants often gravitate to top management positions with profound consequences for the organization of managerial decision making. Whether anything comparable in agriculture is likely is still a moot question. Might it be worthwhile to consider the consequences in terms of dynamic aspects of agriculture?

In any event, the organizational stresses generated by the introduction of machines into decision making are likely to be different and more diffuse in agriculture than in nonagricultural firms. Numerous "interface" problems met in nonagricultural applications will occur in agriculture as well. They will occur wherever men and machines meet in the information flows and information-processing system. But outside agriculture, many of the interfaces occur within a single firm's organization. Consequences are reflected in intrafirm shifts in decision responsibilities and control mechanisms. In agriculture, the same interface problems are certain to be met. But in addition there are usually interfirm relations to manage as well, including interfirm shifts in the location of decision-making activities.

Important questions therefore relate to the likely positions of farm-related firms and agencies in the supply of services for a computer-assisted managerial organization. Alternatives are readily seen to be farm supply firms, firms in farm product markets, financial intermediaries accessible to farms (directly or indirectly), and farm-related professional personnel, including professional farm managers, accountants, land-grant universities, or perhaps even new organizations developed in response to organizational requirements to which no current source is well oriented. The implications for research and educational agencies in agriculture are profound, as are the implications for structural characteristics of agriculture.

Comparative Advantages of Alternative Sources of Computer-Assisted Decision Making

Firms that sell to or buy from farmers have obvious complementarities between their merchandising activities and any advisory service they might make available to farmers. Indeed, the salesman or buying agent has historically played the role of informal advisor. Increased precision in production properties of inputs has emphasized the advisory role and made it more demanding in the cases of machines, equipment, fertilizer, feeds, and other agricultural chemicals. Recent attempts to formalize the role somewhat have introduced computer-assisted methods as a basis for managerial assistance. A familiar example is that of International Mining and Minerals Corporation, which utilized inputs of climatological, soil, and fertilizer data to construct a model for minimizing the costs of producing a given corn yield.

The more formal roles have so far been confined to services closely associated with the input(s) sold by the factor supply firm. However, the University of Illinois was engaged several years ago by one supply firm to at least investigate the whole-farm consequences of a partial advisory service that would take into account only crops and crop production alternatives. With the prospective development of "supermarket" farm supply outlets, the potential planning range obviously is expanded for the farm-related business that complements merchandising activities of the firm.

Buying agents have played a less important role in farm-level managerial decision making, except in the cases of specialty crops and other enterprises with output contracted for by firms that closely specify production and marketing conditions. Such enterprises are so far relatively unimportant in Illinois agriculture. Whether they will remain so is still an open question. Should cattle, swine, poultry, egg, or other enterprises become heavily subject to contract production, marketing, or finance, one might anticipate that the contracting firms would take considerable interest in managerial decision making at the farm firm level. Indeed, the strength or lack of complementarity between contract procurement and managerial services may be an important influence on contract production. This is another reason our seminar topic is of importance.

Financial intermediaries are strong contenders for direct or indirect participation in managerial functions. They possess two important advantages. First, they come closer to sharing the farm operator's farm-wide interest than do firms in a particular input or product market. Second, on the cost side, financial intermediaries may have an advantage over nearly any other contender. To support a line of credit, or even to conduct the financial affairs associated with a successful farm of commercial size, the farmer already originates a significant stream of information that flows through the financial intermediary. The flow could readily be augmented if profitable use for supplemental information can be demonstrated. Already, many banks and other financial intermediaries are equipped with or have access to computers required for development of computer-assisted managerial services.

However, before we concede the game to financial intermediaries, one must recognize some limitations. While the scope of concern between financial intermediary and farmer comes close to coinciding, the depth of concern is far from the same. The financial intermediary has an interest in the outcome of decisions only after the farmer has absorbed much of the impact of an unfavorable (or favorable) outcome relative to expectation, in the form of lowered (or increased) levels of income and equity. Commercial loans are subject to criteria intended to protect the lender against all but catastrophic failure in expectations. Given that returns to the lender are fixed, and not related functionally to the profitability of farmer actions, one can hardly expect the lender to be as deeply or as immediately concerned with details of planning and managerial decision making as is the farmer. All this is to suggest that the information that flows from borrower to lender is more adequate to support *loan* decisions than it is to support *managerial* decisions. For the latter, the information would have to be considerably enriched. While the financial intermediaries are in a position to compete advantageously, the certainty of their so doing is by no means assured.

One intriguing possibility is the development of a repository of information that could be obtained by subscription by others who have a comparative advantage in processing information in a computer assisted planning service. Thus the farm supply firm, a professional farm manager, or someone else might "buy" the data, perhaps as output from the financial intermediary repository. The data would be provided in a form readily adapted to the needs of the planner. Further elaborations are out of place here, but the possibilities are obvious and most interesting.

We already have referred to professional personnel in general and to professional farm managers in particular. The current orientation of most professional farm managers is toward the landowner. As has already been noted, this may tend to keep the professional farm managers from developing computer-assisted managerial services that are essentially designed for the farm operator. However, the professional farm manager need not always be oriented to the owner. He might supply useful managerial services to large operators if the costs of the services were reduced enough to make them profitable. Certainly the farm manager and the farmer would have a common scope of interest, since the manager's return depends upon the whole farm. One is led to the possibility of several professional farm managers supporting a facility for data storage, retrieval, and processing. Or perhaps a farm manager could more cheaply subscribe to a data repository such as a bank and hire still another agency to process the data.

In other countries with large farms, especially commonwealth countries, commercial accountants are used more widely than is common in the United States. Where this exists, a natural alternative is the evolution of computer-assisted managerial services via electronic data processing of records data. It is possible that tax consultants in the United States may eventually develop in this direction, complementing the services already offered on the basis of information furnished by the farmer to complete income tax returns. Again, combinations may be possible among the tax consultant-turned-accountant, the professional farm manager, and perhaps the financial intermediary.

The Role of the Land-Grant University

It remains to comment on the appropriate role of the university in developing and using computer-assisted managerial services. My comments today must be considered tentative and subject to change, perhaps even radical change. My hope is that the proceedings of the seminar program may provide the basis for evaluating my ideas and revising them to represent a more defensible posture. However, it seems reasonable to look at the university in the same way we have looked at other potential suppliers of managerial services. What are the comparative advantages and disadvantages of the university in this role?

The fundamental roles of the university are research and education. In its research role, the university is inevitably a repository for data. As we are now organized, the data flow inward from numerous sources, including the university itself. But we must recognize the peculiar focus for the inward flow. It is intended chiefly to enrich the educational programs of the university. The diversity of audience for the educational programs forms much of the basis for the controversy as to what constitutes an appropriate role for the university. There are problems too in agreeing on what constitutes "education."

A primary audience is students. Research and development activities are natural complements of an educational program designed to produce competent research investigators. Such students, moreover, need access not only to appropriate flows of data but also to research experience in the design of models to meet the needs of research problems and in the quest for supplementary data needed to make the models operational. In short, complementarities exist in the university in the form of methodological developments that can be associated with graduate programs for potential research personnel.

But other audiences also exist. In land-grant universities, extension services offer educational programs for farmers as well as others.[3] Historically, land-grant extension services have been organized to serve broad educational purposes, rather than individual farm consulting programs. It has been presumed that farmers can draw help in managerial decision making from such broad programs, communicated in groups or by mass media. Beyond this, it has been felt that farmers could and should pay for consulting services, as others do.[4]

The role I suggest is confined to that of research and development, in which the university equips students to be functional and to develop methods appropriate to the needs of innovators. In such an approach, the development of a matrix-generator or a report-generator (as will be discussed in following papers) can be viewed as research and development output. Such output would be available for innovation much as would be a new idea in farm machinery or buildings, a new tillage practice, a new herbicide, etc.

Others might argue that the university should be more active in operational aspects of computer-assisted managerial services. Indeed, we have assumed such a role in the case of record-keeping. I do not intend to support or criticize the decision made in the case of farm records; it may be relevant, however, to point out some differences that may imply a defensible difference in the role of the university. Data from the farm records support all kinds of research efforts. The university's activity perhaps can usefully be defended on the basis of costs of providing comparable data by alternative means. The development of data-*using* methods, however, may not provide a similar defense, or at least the defense seems to be less substantial.

There is an intimate connection between any planning and managerial service, computer-assisted or otherwise, and a record-keeping system. One might look at the questions farmers must resolve in planning and managerial decision making as a basis for determining the character of farm record systems. Records currently kept by most farmers are oriented nearly exclusively to income tax returns. Whether right or wrong, most farmers have not been convinced that it is worth their while to modify and complicate their record-keeping efforts to support more fundamental requirements of decision making. If computer-assisted methods can make results of more realistic models

[3] We leave aside the nonfarm audiences also served by land-grant universities, not because they are unimportant, but because they are only marginally relevant to this discussion.

[4] Eisgruber (*2*) suggests that an "'agricultural information system' . . . must become commercially viable after a reasonable period of development," if the system is essential to success in farm management in contrast to research or educational objectives.

accessible to farmers, a radical change may follow in demands of farmers for record-keeping services. A properly organized research and development program may thus become a substantial complement to the university's record-keeping activities.

This seminar series is organized to recognize problems and alternatives of supplementing managerial services for commercial farmers who recognize a payoff that more than offsets the costs of obtaining the services. It may be worth raising another point, however, with respect to the public service role of the land-grant university. Do we have a social responsibility to subcommercial farms? In the past this role has been confined largely to public policy advice and to education efforts confined mostly to counseling such farmers either to vacate the farm sector in quest of superior economic alternatives or to find the means, managerial and capital, to advance into the commercial category.

It has been assumed that, when the marginal value product of urban labor exceeds that of rural labor, the "excess" labor should be moved from rural to urban areas. Crises in urban areas, substantially related to the influx of rural migrants ill-adapted to urban life, have raised reservations to this assumption. It is entirely possible that a policy of "labor storage"[5] in rural areas may be seriously considered in the future. If so, there may well be associated with such a policy a program of qualitative improvement in managerial skills for those on subcommercial farms. The land-grant university could and perhaps should assume a significant role in such a program. The most obvious role would be an operational one, providing computer-assisted planning and managerial services to subcommercial farms.

Much remains to be said and analyzed. I will have served my purpose if my remarks have stimulated you to follow the more interesting sessions to come.

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[5] I owe the origin of this term and a part of the idea to Professor F. C. Fliegel, who has expressed the further concern that the crisis manufactured in the United States by rural-urban migration threatens to be magnified manyfold in less developed countries as technological innovations in agriculture trigger the migration of rural people to the city.

Research and Development in Planning Methods for Individual Farms

John T. Scott, Jr.[1]

EARLY FARM-MANAGEMENT PLANNING

The development of farm-management planning has been going on for many years. Early farm-management research workers often came primarily from disciplines such as agronomy, biology, and engineering and often had only minor training in economics, business, and accounting. Consequently, research in farm management in general, and development of planning methods in particular, were influenced by the engineering and single-enterprise approach. Physical input and output coefficients were emphasized for many years, without suitably integrating the enterprises involved or investigating the effects of their interrelationships on the farm as a whole (*1*).

At this early stage, there was little development of underlying theory and little use of received theory — either from the rapidly-developing sister discipline of economics or from psychology and the behavioral and managerial sciences. There were few theories, concepts, or prediction models. Many early farm-management workers had a good intuitive sense of the right thing to do, but this came largely from experience and observation, rather than from the study and development of any specific systematic farm-management planning method or tool.

A single measure of success for individual farmers was difficult to establish, a problem still at issue in farm-management research. As was soon noted, particularly during the late 1920's and 1930's, the outward signs of success — the latest in new machinery and large inflexible complexes of buildings — were not lasting measures of success. Without a measure of management ability, it was even more difficult to find and measure "causal" variables, that is, variables that could be controlled or changed to bring about desired results.

The further development of farm management centered largely on the development of physical criteria for success: highest yields per acre, greatest number of pigs weaned per litter, most pounds of butterfat per cow, and many others. Such measures are still important yardsticks in their context, but they fail to emphasize the importance of the interaction of various products or inputs and their effect on the whole farm business.

[1] Thanks go to Professor C. B. Baker for suggesting possible items to include in this paper.

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At that time then, emphasis was placed on analysis of individual enterprises. Farm records were used on a very limited basis. Early records focused on the physical input and output of the farm's various enterprises; later records reflected the increased attention paid to income tax reporting.

In this early period, most farms were highly diversified. Diversification had grown out of a self-sufficient farm economy — an economy in which farms produced their own food and fiber and to some extent their own power. Diversification in crop production and rotation continued long after it was needed, partly because of the reluctance of some agronomists and soil conservationists to accept new ideas and partly because of the lack of communication about improved practices.

Farm-management budgeting developed from the detailed emphasis on enterprise analysis. Partial budgeting was probably the earliest planning method developed for individual farms, and even today it is still, in its various forms, the most versatile and most widely used tool in farm management. In fact, when we say farm budgeting, haven't we about said it all? The developers of budgeting were our own immediate predecessors in farm management,[2] and, in my opinion, most of the tools — computerized or otherwise — that we have developed in this second generation of management are mainly based on variations of farm budgeting.

RECENT HISTORY OF FARM-MANAGEMENT PLANNING METHODS

Budgeting

Farm budgeting, whether partial budgeting (the most widely used form) or whole-farm budgeting, has a distinct advantage over all other planning tools: it can be tailor-made on the spot to meet the existing situation or a specific problem. Because of this, its results may be more acceptable to the client than any planning information that comes out of a "black box." Also, there are few things more satisfying to the farm-management expert than sitting down to plot out a specific problem with the farmer and then watching him follow through on the plan suggested.

Yet farm budgeting alone, as it is often practiced, has some real pitfalls. A farm planner must carry about a great number of coefficients — either in his head or in his briefcase — in order to plan accurately. In recent years whole dictionaries of farm planning coefficients and

[2] Such persons as M. L. Mosher and H. C. M. Case at the University of Illinois, as well as others, must be given considerable credit for early development of farm record analysis and farm budgeting.

other farm planning references have been published.[3] But the best individual planner can't possibly remember all the relevant planning coefficients accurately, even if he has seen them all, which is unlikely. What's more, no farm-management expert has a briefcase large enough to hold all the coefficient dictionaries, let alone the strength to carry them around. Consequently, most on-the-spot farm budgeting using the "tried and true" pencil and paper method can be only a rough estimate. One hopes, of course, that the estimate will be good enough to point out the right direction in which to proceed, if not the actual amount of return to expect.

If the computer has done nothing else, it has at least brought home the GIGO principle: garbage in, garbage out. Inaccuracies in on-the-spot pencil and paper budgeting can easily go unnoticed, showing up only in the context of the whole farm or in relation to other partial budgets.

Another pitfall is the problem of omission. How many farm-management experts can remember all the credit and debit items that should be budgeted into each and every specific budget they work up — on the spot? Farm-management extension specialists have done much research on this problem. Cash-flow forms, continuous net worth statement forms, and many other systematic procedures have recently been developed to systematize data, prevent omissions, increase accuracy, and reduce the time required for farm budgeting (*2*).

Linear Programming

Mathematical programming (*3*) is a recently developed planning tool that has been widely used in research for individual farm planning since the middle 1950's. Its development has made possible the simultaneous optimum solution of a large number of enterprise budgets, within the resource constraints of the farm being programmed. The development of large computer programs in the early 1960's made possible the simultaneous solution of an almost unlimited number of partial budgets, subject to a large number of restrictions, yielding the optimum solution for the objective function designated.

Although linear programming is a well-developed mathematical tool, it has not been widely used yet in farm planning on a commercial basis. The Doane Agricultural Service made an early attempt to program farms. Despite relatively high fees, most of the programs were

[3] These include the Illinois Detailed Cost Studies, the Illinois Farm Management Manual, the Summaries of Illinois Farm Business Records, and such publications as AE-4074, "Resource Requirements, Investments, Costs and Expected Returns from Hog Production Systems in Illinois, 1965"; Illinois Bulletin 729, "The Economics of Machinery Choice in Corn Production"; and AERR-98, "The Economics of Corn Conditioning and Storage Alternatives for Farmers."

actually completed at a loss, and Doane has mostly discontinued individual farm programming. International Minerals attempted to develop a programming system for individual farm planning but abandoned the attempt. Estimates on the cost of that project range from $100,000 to $150,000.[4] The Northern Trust Company runs linear programs on some of the farms they manage, but cost data on the programming[5] are not available.

The Department of Agricultural Economics at Purdue University has developed a fairly simple and straightforward linear program for their "Top Farmer Program." Upon payment of a fee, farmers are invited to attend a meeting at Purdue and use the program for their own farms. Each farmer can vary the constraint levels, certain input-output coefficients, and the expected prices of elements in the objective function. Each program, therefore, is individualized in that the farmer receives a print-out that incorporates his individual constraints and coefficients. According to William Urhig, staff member at Purdue, in August of 1968, 100 farmers signed up for the program at a fee of $100 each; since then, many more have utilized the program.

The linear programming model has much to recommend it. It guarantees "optimum solutions," at least from a narrow point of view. It can either maximize profit or minimize cost. It is well developed and well known. Excellent computer programs are available to solve linear programming problems, and the optimization feature and art of linear programming appeals to the research scientist. Linear programming also has a certain popular appeal for the layman, because it utilizes that modern black box — the "gift of the gods" — the electronic computer. Probably most important of all, however, from the standpoint of commercial applicability and wide use on individual farms, is the fact that a linear program, assisted by a computer, can do more budget solving in 10 minutes than 10 farm-management experts can do in a month.

Linear programming is particularly well suited to examining various short-run alternatives, such as comparing the profitability and interaction of resource requirements and restrictions on various enterprises. Much research involving linear programming has therefore centered on the multiproduct farm.

Yet, just at the time we are abandoning the early farm-management focus on enterprise analysis in favor of trying to generate optimum

[4] Seminar by International Minerals at University of Illinois, 1966.

[5] Most farm programming assumes the profit maximization objective function. It is interesting to note in passing, however, that the widest commercial applications of linear programming have been in cost minimization: the transportation model and the livestock-ration formulation model. Numerous large, single-enterprise livestock farms in California and Colorado have used the cost-mimization feed-ration programs regularly for some time.

whole-farm interrelationships with linear programming, we find that farm diversification is rapidly dwindling and the single-product, or single-enterprise, firm is rapidly increasing.

If single-product firms in farming are the wave of the future, should we abandon the linear programming model that has been so well adapted to the multiproduct firm? Or do we have the ingenuity to modify or reformulate the activities and restrictions to use this elegant and efficient optimizing model to solve the problems of the single-product firm? Are those of us who have a vested interest in the linear programming model willing to look objectively at other alternatives? I for one hope we do have the ingenuity to formulate the relevant farm-management problems in the linear programming format. At the same time, however, I think we should "cover our bets" by looking at other tools that could be used in individual farm planning.

Linear programming can be formulated to handle the interperiod flow of resources and products as well as the economic problem of diminishing returns to an input, but it cannot very easily handle the problem of increasing returns. Increasing returns, or firm growth, is one of the important problems in the increasing scale of an enterprise. To handle increasing returns, some rather restrictive limits on the extent of change have to be placed on the program, or else interperiod limitations need to be placed on the increasing-returns activities. Also, fixed costs at varying levels of an activity cannot be properly assessed without iterative procedures. Thus, linear programming is not a particularly good method of analyzing alternative investment opportunities.

Other linear programming models have been formulated to do specialized jobs, including integer, multiperiod, and recursive programming. An interesting extension of the linear programming model recently developed by Boussard and Petit (*4*) includes a function of subjective loss on each enterprise outcome, along with limits on allowable losses from each enterprise and limits on total losses. These limits are on the lowest family income level designated as acceptable by the farm operator. The abbreviated formulation is as follows:

$$\begin{aligned}
\text{max. } Z &= c_{11}x_1 + c_{12}x_2 + c_{13}x_3 + 0x_4 \\
& c_{11}x_1 + c_{12}x_2 + c_{13}x_3 - 1x_4 \geqq Y \text{ min.} \\
& p_{11}x_1 - \tfrac{1}{3}x_4 \leqq 0 \\
& p_{22}x_2 - \tfrac{1}{3}x_4 \leqq 0 \\
& p_{33}x_3 - \tfrac{1}{3}x_4 \leqq 0 \\
& AX \leqq B
\end{aligned}$$

where x_4 is the loss activity, p_{ij} is the subjective possible loss associated with x_j, and the other notation is the usual linear programming notation. To use this model to assess risk, one must find a realistic way to generate values for p_{ij}, the expected possible loss for each enterprise. These are now obtained as subjective evaluations by the entrepreneur.

Other programming models that are not so well known use entirely different algorithms. One of these, quadratic programming, was used recently in a macro supply-and-demand equilibrium study of the U.S. agricultural sector (*5*). As the use of quadratic programming is developed further and as computer programs become more widely available, this kind of programming may be used to handle the increasing-returns problem. Also, various farm-planning problems under price and yield risk can be taken into account by using quadratic loss functions.

Another program, stochastic programming, takes into account the statistical nature of the input data. But it is so mathematically complex that no satisfactory computer-calculation method has yet been developed for a model large enough to use for any practical problem.

The demand for accurate data for linear programming input is similar to the data requirement for budgeting but is magnified many times according to the number of partial budgets or activities in the program. Similarly, the difficulties associated with data collection and information preparation are greater for linear programming than for partial budgeting. The data requirements for these models have been discussed elsewhere.

The mere fact that the data requirement is vast has stimulated, even forced, us to use the computer to handle the data for linear programming; and the desire to reduce budget preparation and programming formulation time has led us to generate the linear programming format itself on the computer. Much of the current research is to develop ways to make the computer do more of the work — to really computerize the model.

Simulation Models

Recently, techniques have been developed that are supposed to simulate various alternative choices on the computer. Simulation is sequential selection among alternatives as decisions proceed from one step to the next — like making a choice at a fork in the road and then going on to the next fork. As I understand it most simulation routines are closely tailored to the problem being investigated or the plan being proposed; thus programming the computer becomes itself a problem, since computer routines must often be changed or modified for each problem. Unless a large number of farms have almost the same specific problem, the fixed cost of simulation per problem run would be very high. Moreover, once a particular decision has been made, only a subset of alternatives still remain open to the manager, the final outcome of which may not be an economic optimum at all. Indeed, unlike linear programming, simulation does not guarantee a global optimum.

Simulation models have been used on several problems in recent research, including estimating firm growth under various conditions (*6*).

The only attempt I know of to use simulation on a mass basis is the Purdue University "Top Farmer Program," which in its current session is dealing with the specific problem of scheduling machinery and labor time for producing, harvesting, and handling corn. Unquestionably, a great amount of data — relating to weather, hybrid maturity, moisture drying, machinery systems costs, etc. — is needed for the simulator (*7, 8*), and an almost unbelievable amount of staff and programmer time in program development and coordination is necessary to make the program operative.

A corn farmer who attends a simulation program like the "Top Farmer Program" must come with an almost complete knowledge of his operation — how many acres of corn there will be, what yield he expects, when he wants to plant, the size of equipment to be used, the market pattern, and a number of other factors. This information must be systematized, either in his records or in his mind, and available for immediate retrieval.

The computer output shows the simulated outcome that would result, given the farmer's choices at the points in the simulation where choice is open. There is no guarantee, however, that the outcome is optimum, whether measured by profit or another criterion. The most serious drawback of the Purdue simulation model is that, apparently, no attempt has been made to determine what the optimum combination of corn hybrids, planting dates, labor and machinery, and other inputs would be for the given corn acreage and weather conditions. There is no way for the farmer to tell whether he could have done better or how much better he could have done. Labor and management returns could be given as a residual in the output so the farmer could compare this residual earning with some subjective value he thinks he should have or with some previously established norm. Such a model would increase the user's awareness of the importance of scheduling, labor availability, and the size of various machines and could highlight the importance of the systems approach and the variations that can result from the weather.

To improve decision making most effectively, there should be an optimum theoretical combination with which to compare the farmer-selected combination of inputs. It might be desirable, therefore, to imbed one or more linear programs within a simulation model. The demands for data are just as great for a simulator as for linear programming; moreover, linear programming might in the most general sense be called a type of simulator, perhaps an optimum simulator, since it is formulated to budget the best possible plan under given conditions. This combination would be most useful when dealing with problems that the simulation program can handle better than linear programming, particularly the increasing-returns problem, which involves the firm's growth and an assessment of alternative capital-investment opportunities.

This would be an excellent place to use the matrix-generator routine developed in our project on linear programming for individual farms. The generator routine could select and combine the set of activities, restrictions, and coefficients appropriate to the subset of decisions chosen. By imbedding such a versatile linear programming generator in a simulation model, we could guarantee at least local optima in the various branches of the simulation model.

Development of Other Models[6]

There are a number of other recently-developed computerized tools that can be modified to plan for individual farms. Most of these tools are much more specific than linear programming, even more than the tailored simulation models.

A large Mississippi farm with direct computer access is keeping an inventory of repair parts and a repair history on various pieces of farm machinery. The plan is to develop a prediction model that will show the most likely time for a machine to break down. Given such information and the length of down-time during critical periods, it should be possible to develop a better repair and trading schedule, as well as determine what over-capacity in machinery is economically feasible to offset critical time loss due to breakdown.

International Harvester has already developed such a model, a "trade-in time decision model," for the large truck fleets that do most of their business with that company. Their model operates on the basis of truck operating costs, mileage, and repair costs. It keeps a running estimate on the probability of breakdown and recommends when to trade. Except for the paucity of data, there is no reason why such a model could not be used with major farm equipment, at least for tractors and combines. The criterion for trading could be the point where the expected probability of the per-hour operating and repair costs for an old machine (including critical time loss) exceed the expected per-hour fixed and operating costs of comparable new equipment.

Another recently developed computer model being used by farmers to assess investment alternatives is receiving considerable favorable comment. The expected return, discounted at various interest rates, is compared with the cost of investment, taking into account investment-credit tax considerations. A convenient systematic budgeting form is provided on which the farmer estimates the costs and returns of the proposed capital investment.

Still another computerized tool is being developed to try to predict when corn should be planted, how long it will take the corn to mature, and what the yield will be. Input data for this model include soil

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[6] The models mentioned in this section were discussed at a recent conference of agricultural engineers on computer use in farm machinery decisions.

moisture measurement, past weather data, soil type, the genetic makeup of the corn variety, and the day of the year. Data for this model are currently available for only one soil type.

CLASSIFICATION OF FARMER CLIENTELE AND THEIR DEMAND FOR PLANNING METHODS

Assessing the demand for management tools — computerized or otherwise — is a difficult part of our current project on the development of linear programming for individual farms. One hundred farmers participated in Purdue's first "Top Farmer Program." Since that session was specifically limited to 100 participants, however, this number can hardly be construed as a measurement of demand; the number of requests to attend would be more informative.

To estimate the demand for management services in Illinois, some of the farm and farmer characteristics likely to affect demand need to be examined. Approximately 35 percent of Illinois farms are still less than 180 acres. Although 40 percent of Illinois farmers are full owners, they farm only about 24 percent of the state's farmland. Tenants, who are 30 percent of the farmers, farm 34 percent of the land; part-owner, part-tenants are 28 percent of the farmers, but they farm 41 percent of the land. One percent is operated by hired managers.

We know the average age of farmers in Illinois has been increasing. A recent sampling (*9*) of east-central Illinois record-keeping farmers disclosed that almost 40 percent of the owner-operators were 65 or older, and another 35 percent were older than 55. In other words, 75 percent of the farmers were at an age when most children in the family would have left home and were into a period of lessening pressure for higher income. The modal age for tenants was between 50 and 55.

A farm operator's age, point in family life-cycle, and tenure status are among the more important characteristics that affect his objectives for the farm business and, consequently, his likely demand for planning methods.

As one extension farm-management expert put it (and I take the liberty of paraphrasing his words), "We find the older owner-operators are the most difficult to work with — even when their income is relatively low. Their children are gone and their income requirements are less. Most of them have their limited amount of assets paid for, and they figure they can coast the rest of the way out. Others, because of health or preference, simply take more leisure time. The young farmer, although interested and easy to work with, does not yet have much pressure for income. Also, he may be on the fence about whether or not to stay in farming; he hasn't yet made a long term commitment. The middle-aged farmers who are committed to farming and have accumulated or gained control of a greater than average amount of assets are those most eager for management tools. They also have the most family-income pressure."

I'm sure that the future demand for management planning methods will be greatest from this last group. It is on this group that a commercially viable farm-management planning agency should concentrate most of its effort. In a theoretical demand model for management services based on income and assets, the demand for management services should be inversely proportional to the amount of discretionary family income and directly proportional to the amount of assets controlled. Discretionary income would be affected by both total income and the family life-cycle.

Within the high-demand group, the call for management services is likely to be quite diverse. Farms in Illinois range from a few acres to over 2,000 acres; from wholly rented to wholly owned and even incorporated ones; from the highly diversified, multiproduct firm to the highly specialized, virtually single-product firm in which this product may be corn, hogs, or something else. This sort of plethora, taken with the fact that few if any Illinois farms are able to provide their own computer facilities or to design and develop their own computerized management tools like the Mississippi farm mentioned earlier, is sure to result in demands for a multiplicity of management-planning methods.

SOME PROPOSALS

As a farm-planning tool, linear programming seems best suited for short-run allocation and production problems of the multiproduct firm. With some ingenuity, however, it can be formulated to solve many other short-run problems in the single-product firm, examples of which will be given in later seminars. The minimum-cost ration program represents a good use of linear programming in some single-product firms. This is a very simple, very economical program to run, and it could be made available commercially to subscribing farmers at a very low cost. Yet, to my knowledge, this has not been done, at least not in the Midwest.

Some persons are critical of the linear programming model because it works on profit-maximization. Behavioral and management scientists point out that few firms or individuals have profit maximization as their objective; rather, they have a whole set of objectives. Given that some desired level of income is met, a more important goal may be maximization of leisure time. Simon *(10)* is among the recent authors to promulgate this behavior model which has become known as the Simon Satisficer Theory of Behavior: the objective is a satisfactory level of income rather than maximum income.

The linear programming model can, however, be formulated to optimize behavior patterns other than profit maximization. A further modification of the Boussard risk model would make it a satisficer model of behavior. To do this, simply replace the Boussard objective function with a minimization function, which would minimize operators' labor time:

$$\text{minimize } Z = d_{11}x_1 + d_{12}x_2 + d_{13}x_3 + Ox_4,$$

where d_{ij} is the operator labor requirements. This would maximize leisure time yet produce an average income above the minimum allowable income. The resulting expected income would likely be at a more satisfactory level than the minimum allowable one yet still allow an income cushion for risk probabilities.

There will be a place for very specialized planning models for individual farms. In fact, if I were attempting to sell management services in the form of computerized planning models, I would try to develop a stable of some very special "thoroughbreds." They would be specialized toward a rather specific kind of problem — one that a very large number of farmers have every year, or even several times a year. A model could be developed, for example, to answer the often asked question: "How much fertilizer should I apply to my corn?" Given a few input values from the farmer — soil test, soil moisture, soil type, and expected corn price — the computer could provide the answer within seconds, perhaps on the same telephone call as when the question is asked. This would be an ideal kind of question for using experimental production-function data. The computer decision model might even be as simple as a multidimensional pre-stored matrix array of answers.

Other questions often asked are: "What herbicide should I apply? At what rate?" Again, the answers could be determined and communicated to the user almost immediately when a few input data are known, such as crop type, soil type, pre-emergence or post-emergence application, and the kind of weed that most needs to be controlled.

The minimum-cost feed-ration program mentioned earlier is one that would be used many times a year as the prices of the ingredients change. Two or three linear program rations could be developed for the hog producer. Given a low program cost, such programs would, I expect, have a very high rate of usage, even if only to confirm the hog producer's present feeding-program decisions.

The computerized budgeting and discounting of proposed capital-investment alternatives and the computerized machinery trade-in model are other examples of special planning tools. I am sure there are still other fairly simple but special problem programs that a management-services agency would want to have available. It may well be that a set of specialized problem-oriented tools, in conjunction with a general whole-farm planning method, would give a commercial-management company the best chance for success.

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Commercial Criteria to Be Satisfied by Computerized Planning Services

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THE TWO MOST OBVIOUS, and to me, the most important criteria to be satisfied by a planning system of any type are, first, that the system provide valid and useful answers to valid questions asked by farmers, and second, that the system provide returns to the planning agency at least equal to those possible in alternative commercial areas.

For a new system to be implemented, it should be able to provide farm planning solutions that are at least equal in quality to, and lower in cost than, solutions obtainable by other means. In the market, governed as it is by the laws of supply and demand, these considerations are the primary criteria to be used. We, and the farmers who form a potential market for planning services, are all sophisticated enough to realize that no system ever developed will be perfect in all respects.

The mix of services which might be provided within the framework of a commercial planning system includes:

1. Report systems, which are designed to capture, analyze, and retain data on physical production and financial transactions. These data should be collected, collated, and retained in such a way that they provide a data-base for subsequent financial and production analyses and for forward planning.
2. An accounting system, which details farm expenditures and receipts and provides the necessary framework for calculating depreciation and taxation data.
3. A forward planning system designed to utilize record data and data from secondary sources to produce short-term production plans.
4. Specialized planning methods designed to answer questions related primarily to long-term investment decisions such as the problems of machinery replacement and increases in livestock facilities.

These services are to some degree separable but should probably be provided in a related, integrated system. There seems to be little justification for a record system kept merely to provide records with no attached services. If a record system is used solely to provide data for an accounting system, its existence may be justifiable if the volume of business is sufficiently large to provide adequate returns to the commercial enterprise or if the service is provided by a non-profit organization such as a farmer cooperative.

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In any case, it is desirable that a record system be interfaced, either directly or indirectly, with both an accounting system and forward planning systems. A direct interface would involve the keeping and maintenance of records by a planning agency as a means of acquiring data for the planning systems. An indirect interface could develop and be viable in a situation where an established record system, originally designed primarily to provide data for some between-farm comparative analyses and perhaps some financial analysis as an essentially free service to farmers, has been modified to collect and retain data relevant for individual-farm forward planning.

Much of the data relevant for planning, such as fertilizer applications on individual crops and yields of individual crops by fields, are already collected by farmers and included in their records. In the process of summarizing the records, however, much of this information is, in effect, lost. Before the advent of computerized data management techniques, this loss was probably unavoidable and perhaps justified because of the manual labor required to maintain very large data files. Today, however, we have the available tools and techniques to collate, store, and retrieve huge amounts of data, and there seems to be no justification whatsoever for the loss of any datum that can be useful or even essential for forward planning.

Since forward planning techniques depend on the availability of reliable data, and since the data most relevant for individual-farm planning are individual-farm data, it is obvious that a prerequisite for having a viable forward planning system is a source of farm records.

As previously noted by other speakers, the most commonly used forward planning technique over past years has been budgeting, either the whole-farm or the enterprise type. In industry, most planning is now done with the assistance of computers, and modern data-processing techniques have effectively eliminated the need for the laborious calculation of budgets. The same data-processing techniques have begun to make inroads in agriculture, where computerized record and accounting systems have become almost commonplace. Using computers for forward planning, however, has not as yet had a very great impact in agriculture, primarily because of the high costs involved. Recently, the advent of the concept of generalized linear programming models for farm types and associated matrix-generator and report-generator systems has opened the door for the provision of very cheap and efficient general farm planning. The use of linear programming for this purpose supplants the hand budgeting technique which has been effective for so long.

A planning agency that provides farm planning services for individual farms needs either to develop its own record-keeping service or to have access to an existing system that can be easily modified. Such an agency also needs to have access to a large computer installation, either its own or one supplied by some sort of computer service bureau. In addition to year-to-year production planning (the agency's bread-and-butter source of income), the agency needs to provide specialized systems for analysis of long-term investment alternatives. Thus, an agency wishing to provide individual farm planning services needs access to a computer; access to a record system; a staff of competent fieldmen who would act as the link with the farmer; and a staff of trained operations research personnel who have considerable experience in computer use and who would develop the necessary systems and maintain and modify them as required.

With these requirements in mind, it seems to me that farm planning service agencies would best be organized and maintained within the framework of the existing corporate structure of agricultural supply firms. Such firms have trained personnel who are at least somewhat familiar with the problems and attitudes of farmers. Such personnel would be readily adaptable for collecting data and for establishing liaison with the farmers in order to interpret solutions and make subjective judgments about managerial ability. It is likely that some short period of training would be necessary to give the field personnel some feel for the systems and methods they would be using.

Another advantage enjoyed by many supply firms is the possession of quite adequate computer facilities for implementing the relevant systems. What most firms lack, however, are the highly specialized personnel necessary to develop and install the required applications systems. To fill this gap, it will be necessary either to employ possibly several specialists, all of whom are quite high-cost items, or to contract the development work to outside specialists, perhaps on a fixed-fee plus royalty basis. Of the two alternatives, the latter would probably be better for any corporation without a ready supply of the required personnel, as the time necessary for training in these specialized areas and the extent of the development work to be undertaken may prove to be rather severe limitations.

In addition to the agricultural supply firms that wish to enter the whole-farm planning area as an adjunct to their physical resource-supply functions, there is another large class of potential users of computerized farm planning services: the professional farm managers. These professionals typically do not command enough financial resources to develop complete systems, even though such systems would greatly help them to perform their duties with respect to the farmers, landlords, or financial institutions that employ them. There is, therefore, considerable scope for establishing independent firms that specialize in providing developmental and operational services to these professionals. The specialized firms supplying systems to large corporations may well develop such services, since these firms would have a comparative advantage over all others in this area.

Since much related research is currently being carried out in this and other universities, a comment about the role of the university is relevant here. In my opinion, the place of a university is in research and development, and its entry into the field of individual farm-planning on a service basis cannot be justified under the guise of education.

Farmer response to the provision of farm planning services by agricultural supply firms and specialized companies is likely to be far greater than many of the more conservative agricultural economists and extension specialists expect. Already, farmers have been conditioned to use the services provided by farm managers, farm consultants, agricultural supply firms, and many record services throughout the United States. In addition, farmers are becoming aware that, if they are to survive in the highly competitive world of agriculture, they must begin to regard farming as a business rather than as a way of life. These surviving farm businesses will need to utilize the same type of services as are utilized by businesses in other sectors of the economy, including computer-assisted production planning.

Requirements for Adapting Linear Programming Models for Mass Use

Ron Tongate

CHARACTERISTICS OF LINEAR PROGRAMMING PROBLEMS

If a situation exhibits a structure which can be represented by a mathematical model, and if the objective of the system can be quantified, then some computational method may be evolved for choosing the best schedule of actions among alternatives. The observation that a number of economic problems can be expressed by mathematical systems of linear inequalities has given rise to the development of linear programming.

Linear programming problems have the following characteristics:

1. There is an objective to be attained in the system being studied, such as minimum cost, minimum time, maximum profit, etc.
2. A large number of variables must be handled simultaneously. Some of these are outputs of the system (products) and some are inputs (commonly called resources).
3. At least some of the resources remain fixed over the planning period being investigated. Thus linear programming is used for short-run planning situations.
4. Alternative ways exist for obtaining the desired objective, and these alternatives compete with each other for the fixed resources.

Any problem in which these four components can be quantified can be expressed as a linear programming problem. If, however, the assumptions of linear programming — linearity, divisibility, finiteness, and single-value expectations — do not apply to a problem under consideration, linear programming may not provide a sufficiently precise solution.

The word *linear* means that problems can be put into the linear programming model only if the algebraic relationships between the variables are linear or closely approximate linearity over the relevant range. The ratio between each input and the product is fixed and hence is independent of the level at which the activity operates — that is, there are constant returns to scale. (This assumption does not mean, however, that we have constant marginal returns to any given variable factor.) It is also possible to reflect diminishing returns to a variable factor and decreasing returns to scale.

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The *divisibility* assumption means that the inputs used and the products produced come in quantities that can be divided into fractional units. This condition may often not be met. But that is not a serious limitation, since a program can ordinarily include nondivisible activities by rounding to whole numbers without causing serious decision-making errors.

The *finiteness* assumption means that there is a limit to the number of alternative activities which can be considered. However, this assumption is also not a very limiting one because, in practice, the decision maker is usually only interested in a fairly small subset of the total alternative activities. Moreover, this assumption becomes less limiting as computer facilities continue to become larger and more efficient.

Finally, the *single-value expectation* assumption implies that resource supplies, input-output coeffiecients, prices, and costs are known with certainty. This is perhaps the most limiting of the assumptions, but the same assumption is made for other planning techniques such as budgeting. The linear programming results are just as realistic in this respect as those calculated by alternative methods.

In trying to construct models of real-life situations, it is important to realize that life seldom if ever presents a clearly defined linear programming problem: simplifications and neglect of certain characteristics of reality are as necessary in the application of linear programming as they are in the use of any scientific tool for problem solving. The rule is to neglect the negligible.

POTENTIAL USE OF LINEAR PROGRAMMING IN THE FARM SECTOR

Midwest farms often present rather complicated planning problems. Historically, farmers in this section of the country have been fortunate in being able to choose from a large number of crop and livestock enterprises. More recently, the new technological developments that increase the productivity of our farms confront the farmer with an increasingly complex series of decisions. For example, recent advances in swine nutrition, disease control, and environmental control now give farmers the choice of farrowing pigs in any month of the year. Similarly, advances in crop fertilization, disease control, and insect and weed control have given farmers many alternatives of crop combinations.

Where there are diverse alternatives in the choice of crops and livestock, levels of fertilizer use, timing of production, quality of products, and production methods, the alternative plans technically possible for a particular farm situation may number in the millions. Hundreds of these may seem economically feasible, and, on the basis of knowledge, judgment, and personal experience, a farmer must try to reduce the alternatives to only a few. Through informal arithmetic or formal budgeting, he may be able to choose one plan which will make reasonably good use of his farm's resources, although this plan will not necessarily be the best one he could choose.

As the number of alternative farming activities increases and as total farm planning becomes more complex, more powerful and more precise planning tools are needed. Linear programming may be just the tool to do the job. The necessary framework for a linear programming model already exists, and its assumptions are reasonably realized in a number of short-run production decisions. Linear programming could enable farmers to consider a much wider range of alternatives than is possible in any other existing method. A programming solution would also give the planner insight into the effects that changes in quantities of scarce resources would have on the farm plan, and awareness of the sensitivity of the plans to changes in prices and inputs costs. The efficiency of solutions and the framework provided by the linear programming models more than outweigh the hard work of making an orderly, rigorous examination of a decision maker's planning situation.

Linear programming is currently being widely used by nonagricultural firms to determine optimal product and input mix, especially in the petroleum, food processing, and iron and steel industries. The most notable success in the farm sector has been confined to livestock feeding for the development of least-cost feed mixes. Many large-scale cattle feedlots in the west and poultry producers in the south use linear programming for ration formulation. A number of studies have used linear programming to determine, among other things, optimal fertilizer applications, machinery replacement, and herbicide and insecticide applications. A few whole-farm studies have been made. In general, the results of these research programming efforts have proved quite acceptable. Yet even though the technique appears applicable as a decision model for many such short-run allocation problems, very few commercial attempts have been made to utilize linear programming as a tool for decision making on either a partial or a whole-farm basis.[1]

CURRENT STATE OF DEVELOPMENT

The first commercial attempt to apply linear programming to individual farms was made by Doane Agricultural Services eight or ten

[1] It is important to see how a particular decision is related to other decisions made on the farm. An optimal solution for a particular decision may be entirely different when calculated considering only one part of the farm business than when calculated simultaneously with other parts. Short-run production decisions involve determining the optimal use of limited resources (land, labor, capital) available on the farm. Since all potential crop and livestock enterprises are competitors for these limited resources, the optimal use of each resource can be determined only when all alternative uses are considered simultaneously. The objective of a farmer is not to maximize net returns from any one enterprise but to maximize net returns from the entire farm.

years ago. The technique was applied to only a very few farms before it was discontinued. Many reasons were given for the discontinuation, but the major one was high costs — over $1,000 per farm. Research studies also indicate that costs are too high to make commercial application of individual farm programming economically feasible. The four major sources of costs are: preparing linear programming matrices and other relevant input for linear programming solutions; collecting and collating data; interpreting the solutions; and solving the model (that is, running the computer). In order to reduce these costs and thus become commercially viable, an individual farm programming system must possess the following characteristics:

1. Access to efficient computer facilities of sufficient capacity and capabilities.
2. Administration by a staff of sufficient numbers and training.
3. Utilization of a generalized model applicable to a large number of farms.
4. Model validity.
5. Ease of use.
6. Access to the relevant data.

Computer Facilities

Attempts to apply linear programming to farm planning date back several years before the Doane study. The first models, however, were so limited in their range of activities and restrictions that the resulting plans were crude and often useless. This was primarily because the computers lacked capabilities and speed; they were too slow to solve very large matrices economically. But through ingenuity and persistence, new devices for treating or circumventing old problems were developed and programming routines were extended and altered to deepen insight into planning problems. Greater computer speed and capacity have been essential to many of these improvements. The IBM 360, for example, can operate on matrices of up to 4,100 rows and virtually unlimited columns and can obtain solutions much faster than did previous systems. The 360/MPS application code allows for more computational and analytical capabilities, including parametric programming, determination of the ranges of the objective function row and the right-hand side elements for which a solution is optimal, bounding activities, multiple right-hand sides, and ranging right-hand sides.

Thus, as a result of the development of more efficient computers and increased computer capacity and capabilities, computer facilities are certainly adequate and economical enough for a commercially feasible system. Computer cost and capabilities do not now represent a major obstacle to a commercial programming system. Moreover, superior computers are continually being developed, so the solution cost should continue to decrease and computer capabilities expand.

Staff

One of the obstacles to initiating a planning service is the lack of appropriately trained personnel. At the present, only broad statements can be made about this requirement. The number of employees will depend on the volume of business and on whether such a system complements or competes with other functions of the sponsoring firm. Such a planning service requires personnel who are competent in agriculture, know linear programming, and are familiar enough with computer facilities and programming to communicate effectively with the computer programmer. Additional research is needed to determine the number and training of employees necessary for a particular volume of business.

Generality

A model is needed that is applicable to a large number of farms of the same type and to a large number of types of farms. The heterogeneity of farms necessitates the development of a generally applicable linear programming model, complete with coefficients. To construct such a model for each farm is much too costly, even if all the data were available and in the proper form. To reduce these costs, a matrix generator routine has been developed, utilizing a generalized linear programming model (*1*). With this routine, matrix generation is done by the computer, replacing much of the tedious and costly work of preparing data for the computer and thus reducing the chances for error.

The generalized model is constructed in such a way that it can be used to determine the optimum short-run crop production and crop disposal plan for any farm falling within the crop, crop-feeder-cattle, crop-swine, or crop-feeder-cattle-swine classifications. Since these are the principal types of farming in Illinois, this model should be applicable to most farms in the state.

The generalized model has 1,840 columns and 477 rows. It is structured to allow for up to 10 crop-growing activities, 8 cattle-feeding activities, 8 swine activities, 10 crop-selling activities, 10 grown-crop-feeding activities for cattle and swine, 10 bought-feed activities for cattle and swine, 8 cattle and swine inventory activities, plus the appropriate constraints to be considered.

The matrix generator routine generates an individual farm matrix, which is composed of a subset of alternatives and constraints from the generalized model. The particular activities and constraints to be considered for a particular farm are specified by code on input parameter cards, which are read by the matrix generator routine. The parameters specify the crop growing, livestock raising, crop disposal, and feed source alternatives. Only the columns corresponding to the specified activities and the rows corresponding to the relevant constraints are generated for a particular farm matrix. The unit coefficients and stored ("canned") data associated with these various activities are automatically entered into the appropriate locations of the matrix.[2] Individual farm data input and the parameter cards are also placed in the appropriate areas.

Dozens of farms can be programmed during the same computer run merely by entering the appropriate parameter and data cards in sequence. Because running any computer program entails certain fixed costs, it is more economical, as well as more convenient, to incorporate more than one set of data in a single run. The matrix generator routine is designed to run 1 to 20 or more sets of data at once, depending only upon system storage limitations.

The matrix generator procedure represents a significant cost reduction over the conventional method. For example, in an actual farm program, five crop growing activities at two levels each, four cattle types, and two swine types were considered as production alternatives.[3] After the relevant activities and constraints were determined, 35 to 40 hours were required to formulate the model, prepare the matrices (for both the Crop Production and the Crop Disposal runs), and insert the relevant coefficients. The matrix generator routine, however, required approximately one-half minute of computer time to perform the same tasks. Thus, model formulation and matrix generation need no longer represent a major cost item in a commercial programming system.

Model Validity

No matter how low the cost of a programming system per farm, the model must produce valid and acceptable results before farmers will pay anything for it.

It is difficult to determine, however, just what is a satisfactory way of validating a model and just what evidence is necessary. One way would be to program several actual farms, put these optimal plans into operation, and compare results (incomes) at the end of a year with re-

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[2] Activities were defined so as to reduce to unity as many of the non-zero coefficients as possible. These unit coefficients apply to all farms and therefore can be placed in the appropriate matrix locations during matrix generation. Coefficients which would be approximately the same for each farm are supplied in the matrix generation procedure in the form of "canned" data; these data are stored in arrays and are called for by the appropriate code during matrix generation. Examples of canned data would include the various nutrient levels of homegrown and purchased feeds and the various nutrient requirements of livestock being fed at a particular rate.

[3] Production levels were defined as variables such as rates of fertilizer application, plant population, row spacing, etc., which affect the yield or growing cost of a particular crop. Types were defined as variables such as rates of gain, buying and selling weights, length of feeding period, etc., which affect the objective function value.

sults of past years. If, after accounting for any general price increases or exceptionally good weather, most of the farms reported higher incomes for that year than for past years, the model would be accepted as valid. In order to eliminate income variations due to price and weather fluctuations, the computer could simulate results of plans that the farmers themselves had drawn up for that year without consulting the model.

A second method of validating the model would be to simulate the optimum crop-livestock production and disposal plans on several farms and compare the results with those actually obtained on these same farms. This method would also eliminate variations in income related to weather and price.

A third method would be to program several farms and compare the solutions with the programs being currently followed on the farms. Farmers would be selected whose programs were considered to be closest to the expected optimal solution for a particular type and size of farm. If the suggested linear programming plans closely paralleled those found on the individual farms, the model would be considered valid. Solutions that did not resemble those found on the particular farms but indicated results of higher or at least equal income would be accepted as evidence if the plans appeared reasonable to the farmers involved.

In the short time that the generalized model has been operational, the latter method has been the only test of validity. Three actual farms were programmed, and the results were discussed in detail with farmers and professional farm managers. The validity of the model was assumed on the basis that, in terms of profit, the solutions generated were as good as or superior to those plans actually being followed on the farms, and the farm operators considered the solutions to be very reasonable.

Ease of Use

A commercial system must be easy to use and should require a minimum of labor. Once a model has been formulated and the matrix prepared in a conventional linear programming input (one in which the matrix generator is not used), several hours are spent transferring data to the coding forms used for card punching since it is usually too difficult to keypunch cards directly from the matrices themselves. In this operation each coefficient and its identification — the column and row in which it appears — must be punched on a separate card and verified before it is fed into the computer. It doesn't take a very large model to use thousands of cards. The farm program mentioned earlier required almost 12,000 cards for the Crop Disposal and Crop Production plan.

The matrix generator procedure, however, utilizes a very efficient data input system. Since all unit coefficients are generated in the appropriate matrix location automatically and since relevant "canned" data are input merely by identifying the appropriate array by a code, the number of coefficients that must be input is reduced substantially. Thus, with the matrix generator procedure, only 160 to 170 cards are required to program that same farm using exactly the same production alternatives. Obviously, this method reduces considerably the time spent on coding, keypunching, and verification.

To be effectively utilized, the linear programming solution needs to be in a form which enables the farmer or the farm manager to evaluate the expected economic consequences of the particular recommended actions. As output by the computer, however, the solution is in a form understandable only to the designer of the model and to those who have been specially trained to interpret the model. Even for trained personnel, the interpretation of this output is very time-consuming. The time (cost) spent in interpreting the solution to the farmer is even greater: the coded computer activity and constraint identification must be matched against the original terms that are recognizable to the farmer, and the solution must be reorganized into a meaningful form.

During 1968-1969, report generator routines were designed to reduce the time of interpretation. Two routines have been completed, in which the computer solution is output directly in the form of a Budget and a Production Plan. A third report, a Constraint and Activity Analysis, has been written but not programmed. These report generator routines use the computer to sort out information from solutions and to prepare self-explanatory reports. The activity and constraint terms, familiar to the farmers, are matched against the respective coded linear programming output and printed out on decoded reports.

The Budget Report is a financial summary of expected receipts and expenses for the period programmed for three factors: crops, cattle, and swine. An expected returns figure is calculated for each enterprise and for the farm as a whole.[4]

The Production Plan Report contains physical information specific to each enterprise. It has four sections: crop production, cattle production, swine production, and a monthly livestock feeding plan. Crop production information is given by field, crop, level, and acres. Livestock production data are recorded as livestock buying, selling, and farrowing months; purchase and selling weight; purchase and selling price; number of head; and pounds produced. A separate monthly feeding plan is given for cattle and swine and is designated as grown or purchased. This report also specifies the price and cost ranges over which the given solution is stable.

[4] The expected net profit for each enterprise and for the total farm is calculated by deducting fixed costs from these expected returns figures.

After the optimal solution for a farm has been obtained, the farmer or farm manager may be interested in additional information about the solution, such as the effect of increasing or decreasing a particular constraint level or the effect of a change in a particular cost or price. The Constraint and Activity Analysis Report is designed to provide such information. This report will include the following:

1. The effects of cost and price changes on the optimum activity levels.
2. The decrease in profit as a result of changing an activity from the optimum level, and the activity range for which this profit decrease is valid.
3. The change in profit resulting from changing a constraint level, and the interval for which this change is valid.

This type of information indicates when a model for a particular farm should be rerun because of cost or price changes. It produces the effects that adjustments in the optimum solution have on profits. This report can also identify the limiting constraints and thus determine the more "critical"[5] coefficients. This operation may indicate whether the coefficients of some constraints should be increased.

It may be necessary to give the farmers some training in understanding the reports printed from the computer routines, but since most farmers are already familiar with budgets and production plans, such instruction for the first two reports will probably be minimal. Furthermore, any training should be required only at the initial computer run; subsequent plans could then be mailed directly to the farmers. The Constraint and Analysis Activity Report, however, is designed to be used by the person providing the programming service and is, at this time, perhaps too technical for the average farmer to comprehend.

Using report generator routines substantially reduces the cost of decoding, reorganizing, and carrying out the necessary calculations on the computer. Whereas conventional methods take 18 to 20 hours to perform these tasks for three Crop Production reports and three Crop Disposal reports, the computer time for each report is approximately 10 seconds. Thus, just as the commercial application of linear programming need not be hindered by solution, model formulation, and matrix generation costs, neither is the cost of coding, keypunching, verifying, and interpreting the solution a real barrier.

Availability of Relevant Data

Superior and cheaper management guides developed by linear programming depend upon the accuracy of the data used. The infor-

[5] "Critical" here means that a relatively small change in the value of a coefficient produces a significant change in the output results. Technically, all coefficients may be "critical"; actually, there is variation from farm to farm.

mation needed for linear programming models does not, unfortunately, flow automatically from conventional accounting systems. Because of the gap between the types of data provided by commercial record systems and the data needed for individual farm programming, the costs and coefficients needed are difficult and expensive to obtain for an individual farm.

Specifically, linear programming models require information on:

1. Variable production costs for individual enterprises.
2. Expected prices for products and costs of inputs.
3. Production constraints.
4. Technical coefficients for various enterprises.
5. Production and other physical data for individual enterprises.

Ideally, as many of these coefficients as possible should come from the individual farm record books. Some, however, will necessarily come from forecasts, "canned" sources, and individual farm interviews.

Reducing costs of obtaining data. Any system which would significantly reduce the cost of collecting and preparing the above data, through reducing either the amount of individual farm data needed or the cost of gathering and preparing a certain amount of data, would greatly help to make individual farm programming economically feasible. Both methods were used in our study here.

The generalized model has been structured to minimize the amount of data needed from an individual farm. Since the activity definition and the row units assigned in a linear programming model determine the coefficients required, activities are defined so as to reduce as many non-zero coefficients as possible to unity — thus allowing the use of a matrix generator routine. Moreover, "canned" data are used for coefficients assumed to be the same for all farms or for individual farm data that just are not available. Using "canned" data instead of individual farm data reduces programming costs for a farm because the amount of data that must be collected from each farm is reduced.

We attempted to determine the most "critical" coefficients so that we could further reduce the amount of individual farm data needed: the idea was that "canned" data could be substituted for the less critical coefficients and placed in the matrix during matrix generation. By repeating runs of various coefficients on three test farms and by using the RANGE[6] facility available on the MPS/360, we observed the effects of changing various coefficients. As might be expected, the effects of changing a particular coefficient varied from farm to farm and changed from run to run on the same farm when other coefficients were varied.

[6] The post-optimal RANGE facility computes and outputs the ranges over which the various objective function elements and right-hand side elements may vary with no change in basis required to maintain optimality.

Based on the limited amount of testing done, no generalizations on the most critical coefficients are possible. And, of course, the most critical coefficients for a particular farm cannot be predicted prior to programming. After the farm has been programmed once, however, the most critical coefficients can be determined by using the Constraint and Activity Analysis Report. This information becomes very useful in subsequent runs.

To reduce the costs of collecting and preparing data, the coefficients determined to be most critical for a particular farm can be emphasized when data are collected and prepared for subsequent runs. The number of coefficients for which values are needed remains the same for each run, but the time spent gathering and preparing data on the less critical coefficients can be shortened. A high degree of precision and refinement may be unnecessary for these less critical coefficients. Indeed, perhaps even "canned" data may be used for these coefficients without fear of sub-optima in the basic farm organization.

Better record-keeping. The increasing emphasis on sound managerial decisions utilizing modern decision-making tools such as linear programming has placed the development and use of accounting systems for agriculture in a new perspective. The farmer faces short-run production decisions which determine his future actions and which are based on his expectations. His information, however, must come from the past. The information generated by his record system must effectively describe the results of past decisions, provide a basis for evaluating those decisions, and allow for estimating the results to be expected from alternative courses of action in the future. An effective record system must therefore provide the kinds of data required for decisions about resource allocations, whether the decisions are made by means of analytical techniques such as linear programming or by less formalized procedures.

Both physical and financial information are necessary for such a decision model. In the past, however, financial data gathered on individual farms have not been in a form that is useful for decision-making purposes, and most of the physical information needed has not been available at all in most farm record systems.

It is common in record keeping to report the total cost of each input without listing the costs of specific enterprises. It is also common to record the total cost of production without identifying which resources within the production process are fixed and which are variable. Such records are of little help in calculating linear programming coefficients and must be supplemented. In order to make short-run management decisions it is necessary to know what each enterprise is contributing to the farm's overall objective. Thus, the record system should be designed to list the variable cost and revenue accounts by enterprise. Our study suggests that additional accounts are needed in current systems. The development of enterprise summary forms for recording, among other things, relevant per acre and per hundredweight cost and price information proved helpful. Such summary forms could be prepared by the computer for each enterprise on a particular farm. Linear programming coefficients would then be collected directly from these summary forms.

Individual enterprise cost data should ideally come from individual farm records. Data from a particular farm, however, are limited to the alternatives with which the farmer has had experience and must be supplemented when the alternatives to be considered are beyond the farmer's own experience. It will be necessary to use "canned" data for enterprises for which records are not available. The greater the detail in which the costs for the present enterprises are kept, however, the easier it is to adjust "canned" data to the individual farm.

The following information on the fixed resources of any individual farm is required: the amount of each resource available for use, and the rate of use of the various resources by each enterprise — that is, the technical coefficients.

For the generalized model developed here, production constraints such as labor available per month, field acreages, storage capacities, etc. are needed. Such information can usually be collected rather easily during a farm interview, but it could also be recorded on a pre-survey form supplied to the farmer in the back of his record book.

There are generally no records of the rates at which individual enterprises use various fixed resources. For the generalized model used here, the only non-unit and non-zero technical coefficients required are those for crop and livestock labor and the nutrient requirements for various livestock types. The livestock nutrient information would be almost impossible to collect on individual farms even if forms were provided for its calculation. Thus "canned" data will probably always have to be used, with adjustments made for differences between farms — such as differing managerial abilities of the operators. The necessary labor technical coefficients, however, are collectable: a form to record monthly labor usage for each enterprise could be inserted in the record books, and a summary form of labor usage per acre or per hundredweight could be prepared by the computer at the end of the year just as with enterprise cost data. Many of the physical production data needed for the generalized model are not available. Pounds of fertilizer elements, crop yields by fertilizer level and field, pounds of chemicals applied per acre, plant population, etc., if recorded, would be very useful in determining coefficients for linear programming purposes. Similar information, such as average rate of gain, grade of animals fed, size of litters weaned, etc., would be useful for livestock. Information for crops and livestock would help determine the expectations for coefficients needed in the decision model.

The farm interview. A farm interview will probably be a necessity for any programming system. To minimize data collection, an efficient data form must be used. It would be best to assemble all the information that can be gathered from the individual farm records, "canned" data, and general forecasts before the farm interview. (This assumes that the programming is being done by a firm with prior access to the individual farm's records.) The interview itself can then be devoted to gathering the remaining necessary data and discussing the previously assembled data with the farmer. The discussion should determine if the farmer anticipates any changes in management practices and if the expectations or restrictions used in the data conform to those of the farmer. Any of these could entail data changes.

In summary, if individual farm programming is to generate meaningful results, some minimum level of data must be available from the farm being programmed. If this minimum level is assumed to be the financial and production record for the total farm, then *well-trained* interviewers will be needed, since much "canned" data will have to be adjusted to reflect the particular farm's coefficients as accurately as possible. Almost all of the data collection and preparation work must be carried out by trained interviewers rather than by clerical help. Data collection and preparation costs would be substantially lowered if enterprise cost summary forms and detailed labor records for the previous two or three years were available. The time required to analyze these data would be less, and a large part of the burden could be shifted from the interviewers to the clerical staff. For example, previewing relevant data from past records and placing them on the appropriate data collection form could be completed by clerical workers. Perhaps the relevant information could even be retrieved directly by the computer from data files and printed out. (Of course, this assumes that a computerized record system is necessary to provide the enterprise summary forms.) Such a record system and recording procedures would substantially reduce data collection and preparation costs to the programming firm and, in turn, reduce the fee paid by farmers for the programming service.

Excessive data collection and preparation costs presently represent the major obstacles in implementing a programming service for individual farms. Suggestions have been made in our study for modifying record systems to include the requisite information, but unfortunately these costs will not be reduced substantially until these modifications are actually implemented by farmers. A few such commercial record systems are already available, however, and more are sure to follow. Computerization of the data processing phase has advanced substantially in the past few years. It appears that the last cost barrier to a commercially feasible individual farm programming system may be about to fall.

NEEDS OF THE FUTURE

A considerable amount of research remains before we can conclude that a linear programming service similar to the one discussed here would be commercially feasible. Only three actual farms have been programmed using the system, so the cost estimates and the conclusion that the model is valid are based on a very small sample. A pilot study (*1*), involving 10 farms, is being conducted to secure more reliable cost estimates.

From this pilot study, farmer acceptance of the linear programming solutions and the amount that farmers are willing to pay for such a planning service will be determined, as well as the returns and volume of business required before such a service can be offered. Improved estimates can be made as to the size and specific training of the staff and the minimum computer facilities necessary to provide such a commercial planning service. Necessary refinements and modifications in the model can also be made during the pilot study. Even in the limited amount of testing carried out thus far, shortcomings have been found in the model, and others will probably be encountered as additional farms are programmed.

Additional linear programming techniques should be investigated to increase the value of such a programming service to farmers. However, based on the limited amount of actual farm programming carried out here and the practical applications that others have made, it appears that farmers are already willing to accept the technique and pay a fee which will allow the planning service to earn an acceptable profit.

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Educational Implications of Computer Solutions to Planning Problems

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IN OUR PRESENT ENVIRONMENT, changes are occurring so rapidly that no industry or corporation can be analyzed in a vacuum. Developments within one industry have an increasingly significant effect on other industries, especially in terms of market displacement, creation of new markets, and cost reduction and profit improvement. Provincialism in a corporation, as on the farm, is as obsolete as political isolationism; and the most important factors determining the relative success of corporations today are the quality and relevance of information coming into the corporations and the utilization of that information. Knowledge, particularly as applied by management, is a competitive resource of greater importance than most raw materials.

In this environment of change, farming has been undergoing a metamorphosis, with a trend toward specialization and larger investments that has been accelerating since 1960. The structure of most nonfarm corporations has been adapted to accommodate modern management's most essential task: dealing with change. This structure has developed because advances in business techniques have increased management's operating range. The profit center concept, improvements in budgeting and reporting, and better techniques for measuring performance have provided management with more effective tools for controlling diverse operations. Also, management's understanding of economics and of economics's ability to interpret industry trends, supplemented by the increasing use of outside consultants, has improved its operating perspective. Overlaying all of this is the application of the computer, one of modern management's essential tools of analysis and communication.

Computer Applications to Agriculture

In the summer of 1968, I reviewed for the Department of Agricultural Economics at Michigan State University computer applications for processing and disseminating farm record data. Most of the development work in this field, which started in 1955, is now completed. We are now in the implementation state on a rather broad scale and

[1] I have benefited from work with the staff at Michigan State University in some of the insights presented here.

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are moving just as rapidly as the farmers and their local leaders become willing to pay the cost involved and adopt a change. It is evident, however, that this technology is accepted very slowly by farmers. L. M. Eisgruber (*1*) has stated that the potential usefulness of any information system is severely limited if the user is not educated as to its benefits. Rates of adoption are likely to depend on extension education efforts in this area.

The development of time-sharing with a single computer, alluded to by C. B. Baker and others, is reducing the cost of direct communication with the computer. Remote control stations far from the computer can be used to input or receive data from the central computer facility. Though six or seven users may be sending information at the same time, the central computer processor works so rapidly that each user may feel that he is the only one using the computer. Each user is charged, of course, only for the actual time used. Time-sharing is further enhanced by using improved teletype or encoding keytape machines for communicating with the computer or with other keytape machines at distant locations. Ian Marceau and others tell us that recent developments of large capacity storage devices and reasonably structured file systems are also aiding human use of computers. I myself recently observed voice and pictorial output from computers at a conference on communications held by the state of Michigan, but this development is still in its infancy.

Some Examples of Computer Uses in Agricultural Interests

The remote control station was demonstrated at Michigan State University, where a farm management game utilized the SIMFARM farm simulator on a computer at Ann Arbor, some 50 miles away. The game has been used in farm management classes and even in a short course.

Operational gaming is supposed to represent a more dynamic concept than linear programming. Students are motivated to learn what features in the model cause answers to change. Data from research, records, surveys, or other sources are banked for retrieval, and the model is used to build a series of systems and sub-systems as related to farm buinesses. SIMFARM has reached a stage of development now where it could be experimentally tested with groups of farmers for demonstration purposes. It will take much effort, refinement, and testing, however, to make it operationally functional for individual farms. At least the students who have had contact with SIMFARM should have a positive attitude toward using a computer for planning.

The Dairyland Insurance Company in Lansing, Michigan, encodes (keypunches) the day's business on magnetic tape, calls its Madison, Wisconsin, office, and transmits the inscribed tape of the day's business over the telephone to a tape at the home office in about 15 minutes.

The following night, the Madison office transmits back the data on the computer output tape. A Mohawk keytape encoder then decodes the tape, and an IBM typewriter produces the print-out. The errors are then corrected on the print-out, and the data on the final tape are sent again to Madison for final recording.

A computer-operated egg-trading exchange has been developed by Henry Lazerleer and others at Michigan State. A standard touch-key telephone is used to keypunch the message offering to sell or buy eggs through a computer-operated exchange. The computer matches bids with offers for sale, keeps dealer account balances, confirms transactions by computer voice, and functions as a central exchange. One group of four people sold three lots of eggs at two markets, Chicago and Detroit, at a cost of computer time of $2.50. The telephone voice amplifier reported the message sent back from the computer. It took 30 minutes to study the code and the prescribed procedure for operating this program and complete the transactions.

Three Mohawk keytape encoding (keypunch) machines were placed in three county extension offices on January 1, 1969. All farm record data in these areas were keypunched on tape from the input forms sent in by the farmer and coded by the clerk. Input and output tape information was transmitted to and from the computer center on the campus by telephones hooked to the Mohawk. An IBM typewriter in the extension office printed the information directly from the output tape with the Mohawk keytape machine and the typewriter hooked together. These machines are hoped to be preliminary to an expanded information network that will link farm operators with nearby colleges of agriculture via their county extension office. Professor Tinsley at MSU estimates variable costs would be $2.00 per year per farm to send all the farm record input and output data by telephone in 1968 for a limited number of record keepers.

The College of Education at Michigan State University has developed the Basic Information Retrieval System (BIRS), which is designed to retrieve information for both farm management and agriculture in general. All extension publications in horticulture, for example, have been abstracted, converted to punch cards, and indexed according to key words. The computer print-out provides reference by author, kind of fruit, phases of the business, etc. BIRS presents many possibilities for modernizing antiquated bulletin procedures and information retrieval methods.

There are many other references (*2, 3, 4, 5*) to work on the development of a "Management Information System," a method of displaying business and scientific data in a format that will best facilitate decision making. A recent issue of *Better Crops with Plant Food* (*6*) describes three examples of systems analysis used at Ohio State University to evaluate a farmer's crop production enterprise. Similar articles have been published by researchers in our own agricultural college. Nearly every week the newspapers carry articles on developments in applications of computer technology — including struggles by legislatures and private business to control this new communications giant.

These experiments and published materials should indicate to you the interest now being generated in this area even though specific uses at the individual level have not yet been fully developed. The educational implications of computer solutions to planning problems is broader than many people think. Many refinements and improvements will probably be necessary over a long period before computer planning solutions are widely accepted by individual farmers.

Management Education Work with Illinois Farmers

If research and extension workers are to labor together in this computer age, a review of some lessons learned in the past may help us understand how to attack some of the current problems. Professor John Scott, Jr., has already summarized the research and development to date in planning methods for individual farms. Let us now look at the early development of farm records.

Professors M. L. Mosher and the late H. C. M. Case were instrumental in developing some of the planning methods with records in Illinois. Professor Case's early work was done from about 1915 through the 1920's when complete inventory, production, and financial records were almost nonexistent. Farm leaders from all parts of the country came to see how he got farmers to keep a detailed farm record. The meticulous manner of Professor Mosher, who worked with Professor Case, provided a foundation for work that was well planned and well executed. A little professional assistance in validating the accuracy of information recorded in a record book, combined with a teaching session on interpreting the results, supplied the motivation needed to get the farmer to cooperate. These ideas gave birth to the Illinois Farm Business Farm Management Association, which would maintain and expand the program.

Since 1924 this organization has been able to enlist Illinois farm operators in the basic idea originally demonstrated by Case and Mosher. By 1964 one-third of the 3,832 Illinois farm operators who sold over $60,000 of farm products per farm (according to a 1964 U.S. census), one-fourth of the 6,152 operators selling between $40,000 and $60,000 per farm, and one-tenth of the 25,457 operators selling between $20,000 and $40,000 per farm were enrolled in the program. Less than 2 percent of the operators of farms selling under $20,000 were enrolled, however, although well over half of all Illinois farms are in this group. Estimated enrollment percentages were about the same in 1969 as in 1964, with probably fewer small farms and more large ones.

The program has made famous the Illinois system of flexible standards for comparative analysis. Although land, labor, and capital were quantified and easily stratified in most early systems, the management input was still relatively unquantifiable. The fieldman, therefore, has become an important factor in a complete system of flexible standards, for he evaluates an individual farmer's management performance. Interaction with the farmer allows interpretation of results according to the perceived knowledge, beliefs, and behavior of the farm operator. In return, farmer involvement is related to the fieldman's ability to gain the confidence of the farmer and his family in order to best represent the interest of the farmer. This clinical approach — a diagnosis of strong and weak points plus some prescriptive comments from the fieldman — may be considered out-of-date by some, but it is still the method most widely accepted by Cornbelt farmers. Of course, we cannot stop here; we must use modern analytic and planning tools to build on the present system.

Educational Basis for Fieldman-Farmer Interaction

The Farm Business Farm Management Association program is supported by a philosophy of education based on humanistic psychology. Mahan and Bollman *(7)* assert that the ability of the learner to apply knowledge is as necessary as the quality of the information presented for the success of extension programs. This philosophy of learning assumes that in many situations the learners have more to offer each other than an extension educator can supply. Moreover, the subject matter may not always be the key factor for learning — the "process" is what is meaningful and what contributes to behavior changes. I might add, the recent vote of confidence given by Illinois farmers to their FBFM leaders to continue working closely with the University of Illinois tends to support the value of the "process" point of view in an educational-service program.

A process orientation to education, instead of an information orientation, requires more time, more effort, more involvement, and more commitment from the educator. In such a situation, he is not merely a source of information; rather, he helps people search through their knowledge and experiences so they can reach an understanding themselves.

Mahan and Bollman state further,

> Centuries ago, the educational practitioner — the medicine man or tribal priest — handed down "truth" from on high and this was accepted on faith. However, a new concept of the practitioner is emerging. According to Bugenthal [*American Psychologist,* 18:563-69, September, 1963], we can no longer merely diagnose a patient's problems, scrawl an illegible prescription, and send the patient dutifully off to a phar-

> macist for a medicine which the patient takes with complete ignorance. Today, he points out, we are recognizing that "the patient's own responsible involvement in the change process" is essential to the educational process. This view implies the dynamic quality of the educator/learner relationship, especially the involvement of the learner. There is some evidence that it is precisely at this point that the educational process may fail: *not in the content competencies of the educator nor in the learning ability or motivation of the learner, but in the relationship between the two.*

We must ask ourselves, what audiences in the emerging future will remain to be served by the traditional approach of information giving? Can computer technology be developed to function within the framework of the preceding arguments?

The FBFM program in this state continues to involve 300 to 500 new farmers each year. It is made relevant to farmers' needs through the participative leadership of the employees and the cooperation of the elected leadership with our Department of Agricultural Economics and the Cooperative Extension Service. The program supports the principle that a participant earns the right to receive additional help in using and interpreting his farm record information as long as he agrees to keep and complete a record that is acceptable for a valid analysis of the total farm unit. This means complete production, inventory, and financial data for both the operator and all landlords. Moreover, there is a mutual educational experience for both farmer and fieldman when new ideas for using farm record data are tested. This setting has provided an excellent outlet for information on new ideas, provided the fieldman himself has seen the idea used successfully.

To summarize, the Farm Management Association in Illinois has demonstrated the capabilities and limitations of an educational-service unit relationship. Based on the willingness of Illinois farmers to support these units under the ground-rules outlined, both the farm operators and the College of Agriculture benefit from an educationally oriented service program in management education. There are indications, for instance, that the economic literacy of farmers who have interacted with association fieldmen is higher than that of most non-cooperating farmers. Changes on farms, attendance at meetings, and ability to comprehend economic subject matter all tend to be greater among cooperating farmers.

Computer solutions of planning problems are likely to intensify the demand for detailed farm record data. Past experiences from association work that might influence development of new uses of records tell us that:

1. Farmers can keep more detailed data if they can receive help in validating the accuracy of the input.

2. Farmers adopt new ways to record data very slowly; much depends on the confidence they have in the person directly assisting them.

3. Record programs are more widely accepted when the leaders working directly with the farmers feel they have a stake in the development and use of the program.

4. Attitudes toward uses of farm records tend to be related to size of business. Expenditures for farm record and planning services on the smaller tenant-operated farms compete with family living expenses.

What Lies Ahead

Future management and educational-service programs for farmers will probably need to be more flexible on a special-problem basis. This need is likely to increase as the farm clientele becomes more diverse in farm size, educational level, degree of specialization, and methods of acquiring and transferring property.

The highly specialized, aggressive, and well-educated farmers who generally take the initiative in seeking out answers to management problems require little follow-up help in using information. These are the farmers most likely to use a planning solution from a computer. While they are important contributors to total agricultural production, they probably number less than 5 percent of a county's Economic Class I farmers, or about 5 to 20 farms per county depending on the county's size and location. Low-income or poorly motivated farmers, however, require substantial follow-up help, not only in using the information, but especially in being stimulated with the desire to change.

Evidence that change is the result of intensive contacts with farmers suggests that major computer programs will continue to demand a high input of time from educators. While FBFM work does provide a tremendous base for conducting a management/educational-service program at a low cost, more imaginative and creative leadership is still needed to meet this challenge. It is time for us to implement new methods and see that they are adopted into the mainstream of agricultural production.

Questions Farmers Ask About Planning

The planning questions farmers ask today are similar to those of the past but involve greater risks. Most planning tools available are ahead of the farmer's ability or desire to use them. This is especially true of the tools now being developed to simulate more dynamic planning to deal with uncertainties due to changes in price, technology, and institutional and human factors.

The following four categories of questions are listed in order of frequency of inquiry.

Category I includes questions involving operational short-run decisions regarding intensity of resource use and substitution of inputs, such as:

— levels of fertilization to use
— levels of plant populations
— least-cost rations
— compliance with government programs
— decisions about grain (corn vs. soybeans, etc.)
— ration formulation
— schedules of labor, machinery, and equipment use

These questions are relevant to many farmers and occur nearly every year. Feed, fertilizer, and supply companies now help farmers determine needs, but the burden of determining optimum solutions generally rests with the farmer himself. Mass media information, extension advisers, farm management association fieldmen, and other educationally-oriented workers are the main source of ideas about factors to be considered in decision making. Few farmers pay for professional consultants or managers, and tools that can furnish optimum solutions or budgets for complex farm operations are not yet available at low costs. Lenders help farmers prepare financial budgets but generally do not help select inputs.

Running a management problem through a computer and getting a printed budget or plan would be a new concept to farmers. In my opinion, it will be necessary to make quite a few computer runs under a cost subsidization plan for a relatively long time before a commercial firm can operate this program on a self-supporting basis. Educational personnel will be instrumental in getting farmers to see the benefits of such a plan in relation to cost. It may be necessary for extension workers or perhaps farm management association fieldmen who are already familiar with data processing to cultivate farmer attitudes.

The University of Illinois could run this program on a fee basis for four or five years for a limited number of farmers, with advisers or fieldmen selecting perhaps five farmers in their county each year. A two- to four-year enrollment period would be desirable, since it often takes several years of farmer involvement before results are acceptable.

A fieldman might try this idea on a pilot basis and then discuss the results at county meetings, as is now done with FBFM cooperators. This technique could teach farmers more about management, illustrate what such a plan might be worth on their farms, and establish the idea that $100 or $200 per year could be a valid expenditure on some farms. Broadscale adoption of this service is unlikely without such educational work from the extension service or an educational-service unit to pave the way.

Thus, educational personnel must first be involved and their confidence gained before they can gain the confidence of the farmers. This is again the "process" point of view outlined by Mahan and Bollman. It is marked by an educator with an individual acquaintance with and concern for the learner, a focus on personal growth rather than on problems, and a high concern for the learner's perceptions rather than his responses. Further, such an educator assumes that the experience will modify the learner's attitudes and perhaps his own as well.

The University of Illinois summarized farm records for Illinois farmers for 25 years at $5 per record in a farm accounting project in order to both encourage the practice of farm record keeping among farmers and accumulate data. And until 10 years ago soil testing laboratories were operated in county extension offices to promote better soil management. It seems logical, therefore, that the University support a program of farm planning on a cost basis to educate the farm public as to its benefits.

The farm planning program can be cultivated and nurtured by commercial agencies with the help of the extension service when it becomes evident that farmers will accept the idea. This planning technique can be a valuable educational tool to be used by advisers, vo-ag teachers, farm management association fieldmen, students, etc., in demonstration classroom teaching and in educational-service activities. Looking at the broad range of uses the public may have for computers, we might ask about the advisability of making the computer a utility which would be available to all. This is a proposal I would like to see explored in more detail.

Category II includes questions associated with scale of production, such as:

— can I produce more?
— should I produce more livestock or should I farm more land?
— how much money and labor would be needed in a bigger business?
— what financing do I need?
— what insurance do I need to cover risk?
— how will my added income compare with added costs?
— how can I increase the size of my business and get my landlord to go along?
— what prices can I expect for what I produce?

These questions probably have the highest potential payoff for planning services but may affect fewer farmers than those under Category I. While a static short-run analysis such as that used in the present Marceau-Tongate model (*8*) can be very useful for this type of question, a dynamic analysis would more clearly fit the situation. Growth of the farm firm in regard to investment decisions is uppermost in the minds of our leading farmers. Problems associated with financing this growth, gaining insights into the elements of uncertainty, and all the other problems of firm growth are important here, since farmers are becoming more interested in knowing the probabilities of results before they make large investments. This is the planning area that stimulates well-trained extension workers and researchers to work with top farmers.

Planning models that involve a more dynamic economic analysis may come closer to reflecting the environment in which these individual farmers are operating, but an improved feed-back or environmental sensing system must be provided to keep the planning on the right track. I have often thought that farm management association fieldmen could be in a unique position to demonstrate the value of such planning models, but I doubt that their level of training is at this time adequate to handle this type of work confidently.

As far as I know, professional managers and consultants are about the only groups offering detailed services in this area now with the conventional planning tools. The role for educational personnel would be the same here as in Category I. Since this type of planning might be more costly, it would probably be necessary for research and extension people to work more directly with outside agencies in using this model.

Category III includes questions about method or technique of production, such as:

— what row-width or size of machinery to use
— what power units to use
— what method of hog or dairy production to use

These questions primarily involve technical relationships and factor costs. They pertain to capital and labor requirements, two of the dearest resources on most farms. Planning needs in this category are similar to those in Category II and occur about as frequently. Techniques of solution would also probably require the same research-extension relationships and an agency to provide computerized solutions.

Category IV contains questions about choice of enterprises, including non-farm choices. This category may be the least applicable to Illinois farms, assuming most farmers want to remain committed to farming. Except for making adjustments in a scale of production for the various crops or livestock already being produced on a farm, most farmers aren't in a position to make major changes in enterprises. The suitability of an area for particular enterprises pretty well dictates the use of resources, a view supported by the specialization already prevalent on farms in the state. This does not preclude, however, the need for farmers to consider all alternative investments available and to overcome their tendency not to venture into the unknown.

Vincent and Connor (*9*) state, "The pooled experience of the farmer and his adviser may be adequate for prescription and a new course will be directed. In many cases, budgeting will be performed to evaluate the expected change in costs and returns from a limited number of alternatives. Normally the prescriptive information which leads to choice is generated on the farm by using descriptive and predictive data available from judgment and the specialists' notebook."

One of the greatest uses for planning solutions regarding choice of enterprise might be in educational planning schools. The present tedious pencil methods are slow and provide little opportunity to evaluate more than one or two alternatives. People can be stimulated to think more about changes if they can see the results of several alternative plans.

The county extension adviser might be able to develop a successful management education program if he could have access to a computer from a remote control input center. If simple questions were submitted on what crops or livestock to produce with given sets of resources, the planning data stored in the computer in connection with a simple planning model could provide solutions for discussion in meetings with farmers. The constraint factors listed on print-outs could help teach farmers what makes a high profit plan.

We have gone about as far as we can with our present planning booklets. We need new planning methods that involve input data gathering sheets and computer print-outs if we ever hope to see a market develop for computer planning solutions on a pay basis.

Research-Extension Relationships

Real progress in computer solutions for planning problems seems to depend on a close working relationship between research and extension personnel. We have on our hands an almost inconceivably large scientific animal. John Doneth *(10)* elaborates:

> If we can manage this animal and make it truly operational, it is estimated that a high percent of the questions and problems brought to us might be answered quicker and better. But, the instituting and implementation of major computer application in agricultural extension work will require major changes in extension methodology. This in turn, will involve change in organizational and institutional structures and operations both in the field and here at the University. This assumes, of course, that there is some level of computer capability available. It would be essential that there be strong administrative recognition of what is being attempted with full support and backing to motivate and involve the staff. . . .
>
> It seems that there are so many different kinds and levels of clientele, and so many critical problems and needs of each that some priority must be assigned. Once determined, then the best possible "input" information is needed to give the best possible "output" or answer to each question or problem.
>
> Research and extension scientists must primarily do this. When departmental lines are crossed, it may be necessary to pull researchers and extension specialists out of their departments and team them up with extension agents pulled out of the field. This would probably be only temporary. In addition, I can see the possibility of staff individuals in capacities such as technical and staff sergeants in the Army who would be responsible for keeping the data bank information continuously

up to date, in consultation with the individuals originally involved in developing it.

Doneth's concept of growth in computer activities involves an initial development largely through extension. Michigan, like Illinois, has learned that the best place to input information is at, or as close as possible to, the point of activity: the farm, the extension office, the bank, or elsewhere in the field. People in the field, such as extension agents or bankers, would be primarily responsible for getting the input information fed into the system to begin with. Eventually farmers or agribusiness firm operators could do this. Once the volume of input grows substantially, it may be necessary to add field technicians to focus on data input mechanics. This is now being field tested by a girl technician in one of Michigan's field extension offices.

Statistics from communication leaders give us some insights into the acceptance of data transmission by telephone. Fifteen years ago telephone lines were used entirely for voice transmission; in 1969 only 50 percent are used for voice, and by 1970 the figures will be 20 percent voice, 80 percent data transmission, primarily because of industrial use. The extension service, however, usually a leader in communications, is using few or no telephone lines for data transmission today that I know of.

How fast will these field machine installations occur and other computer applications develop? It seems to me that extension can hardly avoid rapid developments in this area if it is to maintain a position of leadership in communications. A recent report (*11*) recommends that extension make the best use of available staff by utilizing new electronic teaching devices, new communications systems, and new teaching techniques.

As I stated earlier, the educational implications of computer planning solutions are broader than some of us may realize. It is important that research and extension workers in farm management prepare a plan of work that follows some definite established priorities in this area. This seminar series is a beginning of an information program, but we also need follow-up. We need to reorient our own staff through seminars, short courses, etc. Programmers and systems analysts should be readily available to the staff to help document computer programs if there is to be any semblance of coordinated activities.

There is cooperative activity among staff members in more and more states each year. These states do not wish to become involved in your business, but they welcome the chance to work together. If Illinois does not want to be bypassed in sharing knowledge from other states, it is time for staff to help their administrators plot the course for cooperation. Although we must make available technology relevant to our local situation, we need not try to invent the wheel all over again in our own shop. Our farm record program is particularly vulnerable to this charge.

Summary

In summary, this emerging computer technology can potentially make an impact that will change human and organizational relationships, but none of us can predict exactly how we will be affected. We should be able to learn from our past experience what it takes to influence the rate of adoption of this new technology.

Extension agents have special talents for getting new technology adopted. Just as educational workers have been able to get farmers to keep farm records, they can be expected to get farmers to use their records for computer planning solutions. This can be important in estimating how long it may take for farmers to have enough knowledge about the value of computer planning solutions to be willing to pay the cost for such planning service. All staff members and students need to become more knowledgeable about developments in this area so they can begin to give guidance to administrators for supporting work relevant to future developments.

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Record Systems: Their Relationship to Computerized Planning Methods

Allan G. Mueller

This series of seminars has focused on computer-assisted planning methods for individual farms. Previous papers have established that the linear programming model is appropriate for certain planning problems, that the computer hardware needed to solve linear programming problems for farm planning is available, and that the software is available or can be developed by computer technicians. The unsolved issues are whether the important management problems of farmers fit what can be specified in linear programming models and whether the input data needed to meet the programming requirements can be made available to computer operators at a cost that will permit computer-assisted planning methods to stand a cost-benefit evaluation in the business world.[1]

It is the availability of input data that I wish to pursue. Herein lies a paradox: Until computer-assisted farm planning methodology is sufficiently developed to specify essential input data requirements, the job of developing a data collection system for computer planning remains undefined. Hence it is impossible to give specific answers to the data collection problem until we have completed our homework on the development and testing of appropriate linear programming systems or other computer-assisted methods that can provide planning assistance for the problems faced by management decision makers.

The preceding observation suggests that the data collection system is in the same stage of development as computer planning methods, namely, that of specification and definition. There is little doubt that when specific data requirements can be identified, data collection systems can and will be developed to provide the needed data. It is my firm conviction that, given the present computer-assisted planning methods for farmers, there is no real justification for asserting that record systems should already be about their business of collecting the kinds of data that are uniquely required for programming purposes.

Basic Concepts of Accounting

Accounting has been in existence for centuries. It has been applied to farm businesses since the turn of the century. Computer-assisted

[1] For a different view of this problem, see the paper by Vincent and Conner (5) of Michigan State.

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solutions of linear programming problems have been available during the past two decades. At the risk of invoking the hen and egg controversy over record systems for computer planning, I think it is appropriate that we explore the basic definitions of accounting. Moonitz provides the following definition (*2,* p. 23):

> The function of accounting is (1) to measure the resources held by specific entities; (2) to reflect the claims against and the interests in those entities; (3) to measure the changes in those resources, claims, and interests; (4) to assign the changes to specifiable periods of time; and (5) to express the foregoing in terms of money as a common denominator.

The fifth point, expressing information in terms of money as the common denominator, is a basic concept supported by accountants. They further define this concept as follows, (*2,* p. 17):

> The measurement of capital and its changes must be made in a common denominator, a "money of account." Measurement in physical units (e.g., weight, quantity, density, dimension) can have only limited application unless a unit is found that is common to all objects to be measured. When such a unit is found, it can be used as the "money of account" for that group of objects.
>
> Nonmonetary units are technically feasible, and might even be used for special projects. But accounting for economic (business) activity is based on money as a unit of account.
>
> While there are other types of data utilized by management (e.g., production reports and market statistics), accounting is distinguished from other internal data-supplying functions by the fact that accounting data are stated largely in monetary terms while the other data are stated largely in quantitative terms.

The literature in accounting methodology is filled with debates on the problem of valuation of physical assets and services. Such statements as "exchange does not make values; at best it merely reveals them" and "subjective values are undoubtedly useful in welfare economics but they have no place in accounting" are evidence of this continuing debate.

Although the emphasis in accounting is on monetary values of the activities of the business firm (as reflected by the accounting statements of profit and loss, balance sheets, and statements of sources and applications of funds), accountants do recognize the need for other types of data. Quantitative measurement of the units of goods purchased or sold, the units of goods in inventory stocks, and other similar measurements are collected primarily for the establishment of total values. Everyone is familiar with the "price x quantity" aspect of valuation of inventories.

There is another fundamental reason for the interests of accountants in the collection of physical data. Accountants, especially CPA's, are concerned with full disclosure of facts in financial statements. This requires that audit trails be established so that the requirement of full and complete disclosure is met. However, accountants are concerned first with quantification in dollar terms; physical data is of secondary interest.

Cost accounting is also a major field of activity by accountants (*1*). In general accounting, income and costs are assigned to accounting periods. In cost accounting, income and costs are assigned to intra-period operations, states of completion of the production process, and specific subsets of activities. Allocations are made on the basis of business facts, suppositions, and prejudices. That is to say, there is an arbitrary element in cost accounting that is invoked to serve the needs of a specific person or purpose.

The unique needs of linear programming for accounting data appear to be centered in the area of cost accounting. Financial and physical data must be assigned to activities or production processes within the accounting period and within the total business enterprise. The farm cost accounting activities in our farm management research program at Illinois have provided the major "canned data" sources for a large part of the linear programming activities previously conducted at this station and even in some of the surrounding states.

Another area of accounting methodology of interest to our seminar theme is the relationship of accounting to economic activity and decision making in the economic arena. Moonitz illustrates the accountants' concern for the decision problems of economics (*2*, p. 26):

> Previously the importance of quantitative data to support the calculations needed to make rational economic decisions was stressed. These decisions involve the identification of the alternative lines of action that are open, the determination of the consequences which will flow from each line of action, and the selection of the action which will in fact be taken. Financial reports can supply some of the data needed to make these decisions. The "financial reports" in question are those which give some information concerning the resources of an economic entity and changes therein. Thus calculations are essential in order to decide how to allocate resources and to measure the results of those allocations to determine if the objectives have been accomplished. Accounting has traditionally been geared to the measurement of the results of the allocation actually made. Perhaps it can also be used in more positive fashion to make better allocations in the future.
>
> At this point the ideas of "purpose" and of "usefulness" begin to take on concrete meaning. The kinds of economic (business) decisions to be made can be specified, as well as who is to make them. Given these specifications, the kinds of information needed can be spelled out. Given these needs, we can determine (a) the extent to which accounting can at present supply the necessary information (e.g., the financial resources — money and claims to money — of existing businesses); (b) the extent to which accounting could be made to supply the data not now available (e.g., the factory buildings in existence stated in constant

dollars or at replacement costs); and (c) the extent to which accounting can probably never satisfy the needs (e.g., the size of the available work force three years hence).

This particular statement was written by a CPA. Many farm management economists would agree, however, that this could have been written by any production economist concerned with decision making at the farm level. The point is, farm management specialists who are concerned with computer methods in farm planning might also allocate some time for cross fertilization with our colleagues in accounting. The accountants are concerned about economic problems, but they do not appreciate being considered the economists' handmaiden. Briefly stated, our approach should be one of bringing to bear all of the powers of accounting, economics, and computer science on the management problems of the farm firm. An attempt to make a computer-oriented farm planning service operational must involve all the disciplines uniformly.

Farm Record Systems

Farm record systems as we know them today serve multiple objectives. One list of the functions of farm records appears below (*3*):

FUNCTIONS SERVED BY FARM ACCOUNTING SYSTEMS FOR INDIVIDUAL FARMERS

I. Control of Financial Affairs
   A. Record of bills paid, income received
   B. Accounts payable, accounts receivable
   C. Inventory control
   D. Partnerships, profit-sharing agreements, landlord-tenant settlements, farm corporations
II. Legal and Institutional Requirements
   A. Income tax: capital gains, investment credit, and investment credit recapture
   B. Social Security: self-employed and employee accounts
   C. Historical records: estate settlement, cost basis of real property, ASCS programs
   D. Insurance: coverage, damage claims, and evidence of losses
III. Farm Business Analysis
   A. Total farm business; trend and comparative analysis, detecting strong and weak points in organization and management performance
   B. Enterprise analysis
   C. Lease evaluation
   D. Financial position of business (balance sheet)
IV. Basis for Forward Planning and Budgeting
   A. Information provided by records
      1. Basic profit and loss statement on farm unit
      2. Selected input-output relationships

3. Inventory of physical and financial resources available
4. Management performance of operator

B. Applications of record data in planning
1. Projected production and operating plans
2. Alternative resource and product combinations compared with existing unit
3. Projected financial and cash flow requirements, credit requirements, and debt repayment schedules

In reviewing this list of functions, the need for control of financial affairs and meeting institutional requirements is obvious. Farmers clearly require accounting data for day-to-day control of their business affairs and for their relationships with landlords and other parties related to the farm business. They are also fully aware of the needs for supporting evidence in preparing income tax returns and the related problems of capital gains, investment credits, and self-employed Social Security tax payments.

Business analysis is also firmly embedded in the farmer's acceptance of the function of records. The accounting profession suggests that financial statements may be analyzed by comparative analysis as well as internal analysis. Comparative analysis refers to the analysis of historical financial statements by comparing them with performance in a previous year (trend analysis), with projected plans, with performance standards from other business units, or with rule of thumb standards derived from the business world. Comparative analysis has been a keystone in the development of farm record systems over the past 50 years.

There is nothing unique or academically sophisticated about comparative analysis other than that it has stood the test of time and has been accepted in the business world by farmers. This alone is compelling evidence of its value to farmers. No doubt this acceptance came about as a result of intensive educational efforts by early farm management specialists.

The fourth group of functions, those concerned with forward planning and budgeting, are also widely accepted. However, the concept of forward planning is not a single-value term. It can mean many things. Financial planning is one example. The activities of the farm business can be reflected in a projected cash flow (*4*). Cash flow as a planning device embodies no production plans of its own other than matching sources and uses of funds in the planning period. Funds must be matched with regard to both the magnitude of the funds and the intraperiod timing of sources and uses. The projected profit and loss statement and the balance sheet present the operating plans and business goals of the farm business. Financial planning of the type involved in a statement of projected sources and uses of funds typically does not require detailed data on specific production processes. Farmers and credit agencies find that this useful financial planning device can be readily predicted with historical records as the starting base.

The kinds of planning or budgets that evaluate alternative production plans or specify a profit-maximizing plan of action (like the results of linear programming models), are best described as projected modifications of the profit and loss statement. The types of decision problems for which record data can be used are many and varied in their scope and development. The single-period income-optimization models adapted to most linear programming activities are only one of the many planning objectives of farmers. It is the planning model, however, that is receiving major attention in this seminar, and we turn our attention to this specific planning method.

The Relationship of Farm Records and Linear Programming Systems

The present state of the arts with regard to economically viable computer-assisted planning methods for farmers can be characterized by the proverb, "You can lead a horse to water but you can't make him drink." We can lead farmers to the programming tank but it remains to be seen what they expect there or are willing to draw from it. I am firmly convinced that, once the required data needs for effective management-oriented linear programming are specified, our data-gathering activities can be developed to provide the necessary information.

I am also convinced that farm record activities and computer planning activities can and should be considered as integral parts of a total management system. I strongly take issue with any implication that linear programming planning methods are already here and operational and that the currently limiting activity is the data collection process. Farmers, I believe, agree with me. They object to being constantly asked to make the effort to collect data from which they receive no useful applications or benefits. The data problems associated with linear programming systems are a small part of the total problem. The major issue is whether or not the planning method will satisfy a felt need of farmers — one that can be quantified in a demand schedule for different amounts and different degrees of planning services. In other words, the data requirements are simply part of the problem of a planning system and are not necessarily the problem of an accounting system *per se*.

Although I have strongly implied that record systems, when the data requirements are adequately defined, can provide the data needed for linear programming management services, some conceptual and methodological problems remain to be solved. Among them is the problem of selecting a predetermined accounting period that is consistent with a production period. For example, fall-applied fertilizer is properly related to the corn crop produced in the succeeding year although, from an accounting point of view, it is a cash expenditure in the year preceding the corn crop. Accounting methodology can show this transaction as a prepaid expense and transfer it to a later production period, but this method is contrary to the farmer's intentions since he uses prepaid expenses as a tax planning device to control financial affairs. Similar problems arise with other operations (such as livestock feeding) that are carried out during more than one fiscal period.

There is also the problem of specification. The resource inputs in the production of crops may be in many forms. If a linear programming requirement is that fertilizer inputs of N, P, and K be specified in pounds, can any accounting system actually identify the different forms of chemicals with their many substitute sources? Also, the intended use at time of purchase may not be consistent with the subsequent use of the fertilizer.

Another problem is the definition of fixed and variable inputs. A machinery input may be fixed for one farmer and variable for a second farmer who acquires his machinery through leasing or custom work. Perhaps the accounting system could assume that the two forms of machine services are resource substitutes and select one of the two forms as input data for the linear programming model. Joint activities that require the transfer of a product from one enterprise to a resource input for a second enterprise is another accounting problem. We can agree that these problems are not unique to linear programming but affect all management uses of record data. The issue becomes important, however, if we intend to mold all farm record systems into data generating systems for a specific linear programming model.

Summary

I have presented some basic concepts of accounting methodology, listed some of the multi-functional uses of farm records by farmers, very briefly reviewed the wide range of farmers' planning activities, and looked at the specialized decision problems that can be treated by the linear programming method. At this point we come to grips with the specific topic of input requirements for linear programming planning methods. Since it is not clear at this time precisely what individual farm data are critical for successful programming, or in what form the data will be collected, I can only respond with the assertion that when the needed data are clearly specified, they can and will be provided. The collection and processing of these data must be integrated into the planning service and are not necessarily functions of a separate activity.

Fortunately, unique complementary relationships exist between the data needs for conventional record objectives and the data needs for linear programming. Any additional data collection activities that are specified for computer-assisted farm planning methods must be included as part of the cost of the planning service. Farmers, however, are likely to be pragmatic and insist that benefits exceed the cost and efforts required to collect and process the additional data requirements.

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Future Prospects for Computerized Planning Methods on Individual Farms

Meredith Smith[1]

Except for a few individuals, mankind since the earliest times has regarded arithmetic as an immense source of drudgery, to be avoided at all costs and by any means available. The most primitive attempt to simplify calculation was the abacus, which remains the primary means of calculation in many areas of the world today. In the more developed countries, man has surrounded himself with computing devices for many tasks in daily life, from a modern gas pump in the filling station to the fantastically large electronic computers that can control the destinies of men orbiting earth and the moon. As soon as you place a telephone call, you have used a device that adds and subtracts digits to help you complete your call. The point is that you do not have to be a gifted mathematician, an atomic scientist, or a physicist to utilize today's computers; you can even be "just" a farmer.

Agriculture has been dependent on mathematics throughout history, even though when compared with the physical sciences, the biological sciences are notably short of mathematical descriptions — so much so, in fact, that teachers have tended to direct a farm boy with mathematical ability to a career as an engineer, a physicist, or some other technical position. Recently, however, rapid developments in mathematical descriptions of biological and managerial processes are changing this attitude.

An example of computer availability. It is logical to ask how a farmer can utilize a computer when he hasn't even seen one and can never afford to own one. The not so obvious answer is that the computer can be as close to him, and as affordable, as a telephone outlet.

An example of computer use is related to the changeover in weed control from cultivation to chemical herbicides. These herbicides are very sophisticated chemicals, and not every farmer who uses them knows what they are or how they work to kill a particular weed. At the same time, many salesmen who sell these chemicals have even less knowledge than the farmers about their effects.

To improve this situation, one herbicide company has constructed a data collection form that even includes pictures of weeds so that a farmer can recognize the types of weeds he has. The farmer records specific data about the weed class, the moisture content of the soil, the

[1] Thanks go to Dr. C. B. Baker for the hours of editing original material.

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stage of growth of the crop, and even what crop he intends to grow on this land in the future. (More than one farmer has treated broad leaf weeds in corn one year and wondered why he couldn't grow soybeans the next.)

By taking this information to a "terminal," which is nothing more than a special typewriter, the farmer can place a long distance call to a computer in Chicago. When the computer answers — and it is very unlikely that he will get a busy signal: this computer can accept up to 40 calls at the same time — the farmer places the headset in a data phone transducer, which connects the typewriter keyboard to the computer. He then types the information into the computer as it is given on the data sheet. After the data are entered, it takes the computer less than three minutes to select a program, analyze the particular problem, and type a complete answer on a terminal in the farmer's office or home. The answer includes what chemical to use at what concentration to get maximum efficacy at the least cost without harming the present crop or leaving a serious residue to harm the next year's crop.

Let's look at what occurs in this program. The computer utilizes the knowledge of seven leading authorities on weed control, thus making a very complex technology available to anyone in the country. Transferring technology is extremely important in agriculture. While most of us, including myself, do not have degrees in chemistry or plant physiology and do not understand the technology involved, we can use computer-stored data to benefit from those who do.

Computers in Management

The computer can play an even more important role in production management. Agriculture is competing in a business world where other enterprises have more built-in management capacity than agriculture does. Certainly this capacity is more concentrated outside agriculture. Businessmen usually have more facts than farmers do on which to base decisions and more systems to provide numerous guides and measurements which they use daily to help control their businesses. These business executives didn't build such management tools simply because they were smart. They had to stretch their management capacity in order to remain competitive in a faster moving business world. If a farmer could also stretch his management capacity, it could mean the difference between profit and loss under today's conditions of volatile operating costs and prices.

Agriculture today requires that the manager concentrate on a wide spectrum of interrelated detail, keeping up-to-date on new fields of science, events in the marketplace, and yes, even politics. As a result, the farm manager finds himself in a business quite different from what it was even a few years ago: it is fast-moving, high-leveraged, and generally operating at low unit profits. The point is that managing under these conditions, with the urgent need for immediate profitability, more than justifies a set of management tools for agriculture that can be used pragmatically and practically.

Farm managers today recognize that they make their money before they put their seed in the ground. They are profit-oriented, and as such are market-oriented today rather than totally production-oriented as in years past. A manager used to produce a crop and then look for a place to sell it. Today, he selects crops that will produce the most profit with the land, labor, and capital he has available. If one thing has changed to mark the coming age of agriculture, it is production planning. The technological age of the 50's will yield to the planning age of the 70's.

Production aids. We are now at a point in agricultural technology where we know how to produce much more than we know what to produce. Production planning is complex in agriculture because it is not simply one function, but three sets of functions: those things that will be done off the farm and are normally provided as services, those that will be done with a financial advisor, probably a banker, and those that the farmer will do himself.

Let's start with services. Market planning requires analysis of short term behavior of the market and analysis of what the long term market position will be. This analytic service requires expert evaluation of the economic position of a commodity — the political or governmental position — in a context of world demand for the commodity. Computers have greatly helped digest such data, but I know of no good model in operation for analyzing these data. At present, analyzing today's markets and future markets is a skill, and the farm manager would do well to use several sources to condition his proverbial optimism.

Another service is laboratory analysis, which requires specific technological knowledge. For example, what nutrient level exists in the soils? What total digestible nutrient values are in a particular feed grain or feed mix formula? Because of the high cost of analytical instruments, I seriously doubt that every farmer would care to set up his own laboratory or hire a laboratory technician, although, to be sure, some integrated agricultural enterprises do have their own laboratory facilities.

Still another service, environment evaluation, generates technological projections on such items as soil moisture, ground temperature, and areas of insect and disease infestation. It is also meant to include the technological environment, that is, what new technologies are being developed and what their worth is.

We will still need past performance records on each enterprise before we can do an adequate job of planning. Cost records are obviously necessary, but equally important are records of production performance of crop varieties and productive capabilities of animals.

With this basic information we can start to make decisions as to herd constituents and what crops should be raised on what fields at what fertility levels for a maximum overall profit. Once these decisions have been made, we pretty well know what we need to purchase. A good purchase plan, however, must consider inventory position so that we know when purchases will most likely be made. With this additional information we can estimate the monthly cash flow requirements during the year and project anticipated profits. This in turn gives a sound basis on which to establish a line of credit to support the production plan. Finally, we can start to look at our long-range capital improvement possibilities, for we have a sound base for estimating profit improvement.

All the above functions have been computerized to some degree of sophistication, but that is not the total story. At this time, I know of no one who has successfully tied all these functional units into one total computer program for production planning. Many of the agricultural programs that have been written have been severely criticized because of their lack of firm-wide comprehensiveness. For example, if you get your soil analyzed but do not use the results to plan your fertility program, the soil analysis is absoutely worthless to you. If you go into farm record keeping and do not use the information for planning, you are just left with pages of computer information of little or no value to you. If you make purchases without having a production plan in mind, you are most likely wasting some of your money. If you build or buy equipment without having some idea of the profitability of your present operation, chances are you are in financial trouble. All of these functions are intrinsically tied into production and financial management; a program is needed to incorporate all of them before we can utilize each to the utmost.

Two Programs in Detail

To show you how some of these computer programs operate, let's discuss some of the more unusual or less obvious functions, such as environment planning and laboratory analysis. This does not mean that I am minimizing the importance of farm record keeping or purchase input planning. It's just that those applications have already been widely publicized and are fairly well understood by most users.

Environment planning makes possible, as one result, the computing of soil moisture and ground temperature. Moisture enters the ground, where it satisfies the roots of the plants and percolates to the subsoil. The water supply in the root zone is depleted by direct evaporation from the soil and transpiration by the plants. At the bottom of the subsoil is what is called a mantle. It carries moisture away by underground aquafers to supply the wells, springs, and creeks in the local area. Moisture going out through the mantle is never available to the plants in that area.

To trace the flow of moisture and measure its accessibility to plants, a computer program was designed that would store data from experimental sources and a normal weather information network. Each three weather stations defined a macro area of the United States in such a way that the area could be described by what was occurring at each station. A weather station apex was averaged for each triangle to give the conditions existing in the enclosed area.

Because we did not know the moisture-holding capacity of the soils in each of these areas, an analog model of the soil moisture system was constructed in which each area was represented by a tank. The set of hydraulic equations was the same for each tank, but a different size tank was used for each area studied. A control rate membrane was put on top of the tank to simulate run-off conditions. If there is a deluge of six inches of rain in two hours, most of that moisture will not be absorbed by the soil because the soil cannot take it that fast. A membrane between the root zone and the subsoil controlled the transfer of moisture from the subsoil up to the root zone as well as the percolation of moisture from the root zone down to the subsoil. At the bottom of the tank was a fixed-size orifice, analogous to the mantle flow. We then sized the tank from past data so that the theoretical world of the computer corresponded exactly with what had gone on in the real world.

This computer program was then used to compute soil moisture and ground temperature across the eastern two-thirds of the United States to the Rockies. (Agriculture on the far side of the Rockies is largely irrigated agriculture; without knowing the amount of moisture put into the system by irrigation, the computer results for this area would be meaningless.) The result of the program was that the computer could tell more about the moisture conditions of an area than could a farmer standing in his field. We could determine the effect of any given rainfall in terms of what is would mean to the plants. A one-inch rainfall can saturate the ground if the subsoils are full. On the other hand, it could completely disappear in three days if the subsoils are dry.

It has been observed that, normally, floods are not created in the spring nor are droughts created in the summer. What this means is that if the soil is full of moisture in the late fall, there will be little loss of moisture from the soil because no crops are growing to transpire moisture and the evaporation is very low at cool temperatures. Thus soil will tend to build moisture over the winter. When the traditional spring rains and melting snow are added to the saturated soil, the moisture system will have to relieve itself through the watershed. Thus these areas which were near saturation in late November have a high probability of flooding in the spring from the heavy run-off. They are also candidates for a delayed planting season. The farmers in such areas will likely have to wait until the ground warms up to above the normal planting temperature so that the soil can be properly prepared.

We also know that during the summer, plants and evaporation tend to exhaust the reserve on the total soil moisture system. The probability of the soil's building a reserve of moisture in summer is extremely low.

Therefore, if we go into the planting season with a poor moisture base because of not enough snow or rain over the winter, we can almost bet that the area will be a drought area during the growing season. Any rain that falls will rapidly disappear from the root zone of the plant and percolate into the subsoil.

Many points that might affect farm planning are already apparent. If you ask how moisture levels affect fertilizer programs, however, the answer is less obvious. All fertilizers are salts, and all plants have a limited salt tolerance. When the salt tolerance is exceeded, fertilizer can do more damage than good. Grass that has been burned from over-fertilizing, for example, has had its salt tolerance exceeded. Pouring on table salt instead of fertilizer would do the same thing.

A rather far-fetched example will clarify the relationship of fertilizer and salts to soil moisture. If I have one pound of salt dissolved in one gallon of water, I have a fixed concentration of one pound per gallon. If, however, half of the water evaporates, leaving only a half-gallon, the concentration of salt in the mixture has doubled. This is now equivalent to two pounds per gallon. If you anticipate drought conditions, therefore, you must be extremely careful not to build fertilizer concentrations in the soil that will exceed the salt tolerance of the crop. There are many things that can be done to get around this problem, so please don't jump to the conclusion that you don't need fertilizer under dry conditions — as a matter of fact, you probably need more.

Not all fertilizer ions have the same salt index. The chloride ion, for example, is a much faster moving ion — a "saltier" ion — than the sulfate ion. Therefore, not only do chloride compounds taste saltier, they also create more osmotic pressure on the roots. At equal concentrations, therefore, the chloride ions will exceed the root tolerance before the sulfate ions will. Stated another way, roots are tolerant of higher concentrations of sulfate ions than of chloride ions. Corn can be grown in a greenhouse, with experimentally controlled moisture, to show the effect of substituting a sulfate ion for a chloride ion.

A computer program has been developed to indicate the desired ionic balance in the soil for a given crop. Given a soil analysis, we can program fertilizer materials for any given moisture condition to produce a given yield. This information can then be used to select a fertilizer program for maximum profit.

Fertilizer technology has taken a new step forward in soil analysis, too. The gentlemen who developed the ion balance technique no longer analyze for nutrients in the soil, as is traditional. Instead they sample the soil moisture to determine what ions have been dissolved, which is directly related to the nutrients *available* to the plant. Not only is the analysis of ions in soil liquor a much simpler and more accurate analysis than was previously available, but it also indicates how much nutrient is locked up in the soil and not available to the plant. Thus, one can specify not only what ions should be in the fertilizer to bring a proper balance for best plant growth, but also what application rate is needed to compensate for the nutrient deficiency of the soil.

Yield analysis. The computer has told us a lot at this point, but it has not answered the big question: What yield level will give maximum profit? Because the computer has a programmed yield response curve for different levels of fertility, it can now pick out the optimum yield to shoot for under given moisture conditions.

From our market analysis we have estimated what price to expect when we sell a crop. Multiplying price per bushel by bushels per acre gives the gross income from a particular crop in a particular field at any given fertility level. Costs are computed by adding the cost of all inputs to the variable cost of fertilizer. Maximum profit, of course, is where there is the greatest spread between income and cost. This is *not* at the point of maximum production, however, and never will be unless fertilizer is free.

By selecting, say, five crops that could be grown in a particular field, we can evaluate which crop will potentially produce the highest profit. Growing the most profitable crop for each field is not necessarily the best production plan, however, because there may be limits of capital, manpower, and credit involved. Even under these limiting conditions the computer can help us select the best crops for each field by using linear programming, which is discussed elsewhere.

Cattle Feeding Problems

Maximizing profit in cattle feeding is much more complicated than in growing crops, both because alternatives in timing are so important and because there are so many more factors to consider. The animal body reacts to every meteorological factor, from changes in atmospheric pressure to how long it is wet in a rainstorm. It is somewhat superficial to say that a cattle feeder makes decisions on the basis of maximizing profit. Rather, expenses for feed, feeders, and other items and the rate of weight gain that can be achieved in a particular growing environment must be balanced against the selling price for a particular grade of cattle at a given time. In short, the feeder must correctly answer the following questions:

1. What initial weight should be purchased?
2. At what final weight should the animal be sold?
3. How long should completion time be?
4. How many feeding periods should the total time be divided into?
5. How long should each feeding period be?
6. What ration level and quantity of feed should be fed in each growing period?

The problem is, all of these questions are tied to each other; an answer to any of them affects the potential answers for all the others.

Let's take for example what weight should be purchased. Cattle feeders can either go broke or make their money the day they decide what size of animal to feed in a certain environment. As you know, for every pound of feed an animal takes in, a certain portion of the feed energy must be used to maintain the animal. Only what is left over can be utilized for production. Consequently, if you raise a small animal in a severe winter environment, he will have to use most of the caloric energy in his feed to keep warm and maintain biological operation. He can be starving to death with a full stomach. A heavier animal that produces a greater metabolic surplus will likely perform better under such conditions. On the other hand, should too heavy an animal, one with a great deal of body heat to expel, be fed out in hot weather, that animal can control his heat only by reducing his caloric intake — which, unfortunately, exponentially reduces his rate of gain.

Another consideration is the age of the animal. It makes a sizable difference in profitable feeding whether we start with an old emaciated animal or a fat young animal. Initial weight also plays a role. An emaciated animal put on high quality rations will normally have a higher rate of gain than an animal that is too fat. This is nothing new. Cattle raisers have long used the rule of the thumb, "Don't feed a fat calf." But we can't just follow this blindly. We must consider the environment in which the animal is to grow.

As if all these factors weren't enough, the purchaser must also keep in mind what the current and anticipated market is going to do during the growing period. I hope I am building the case for computer analysis.

Suppose a feeder has an opportunity to buy a certain weight of cattle at a given price. He wonders, "Will this lot be profitable to me under what I anticipate the environment will be during this growing period?" Our program's first step is to determine whether an animal this size can maintain thermoneutrality in its environment. If so, we can estimate from weight and age alone the normal feed intake and the average maintenance energy required by the animal during the given period of time.

Given the pounds of feed required per day, we can select, from several computer-developed rations, one ration to test. The program that produces a least-cost ration operates somewhat separately from the primary program. It produces cost and energy values for a whole spectrum of rations, letting the computer judge the level of ration the animal should be fed, at any given weight, for optimal results. The feed program answers two questions:

1. Given several rations at the same energy level, what is the cost of the selected ration?

2. What is the maintenance energy provided per unit weight of this ration?

At this point we don't yet know the weight at which we will sell the animals. This requires incorporating future market prices, or the value of a hedge on the futures market.

So far, feed costs are the only variable costs accounted for in the program. We must now integrate such semi-variable costs as interest, labor, death-loss reserves, veterinary costs, and other costs that stop when the animal is sold.

Fixed costs continue whether we are feeding one animal or a thousand. They do not affect the operational plan for one lot of cattle but do, however, affect decisions on lot capacity. All this information is needed for projections of anticipated profits under specified conditions.

Under certain market conditions we can lose our shirts feeding minimum cost per pound of gain rations. Considering all the costs in at this point, the computer may decide that maximum rate of gain is a better program.

Accounting for deviations. The most important output of the computer is the operational plan. It provides the basis on which we can judge what to do when animals or costs deviate from the plan. The operational plan is a theory, which means that we must continually check to see if things in the real world are going as planned. By feeding in data on actual feed consumption, rate of gain, and costs, we can obtain a list of deviations. Depending on what is deviating, we can decide what specific actions should be taken to maintain maximum profits.

Deviations from expected rates of gain or feed consumption may be due to weather conditions. We can check the biological simulation part of the program (see below) and use actual weather data rather than climatic data to determine how the environment has affected the animals' maintenance requirements. If the deviations cannot be accounted for by variance in maintenance energy, then we know that the production energy portion of the feeds has been incorrectly estimated.

There can really be only two causes of variance in production energy: either the feed did not supply the energy we anticipated, or the animals were incapable of assimilating all they were fed. This latter may have many causes, including genetic deficiencies or diseases occurring during the feeding program. The computer does not tell you why production energy varied. It merely indicates that the nutritionist will have to change feed ingredient levels.

By calculating both the absolute and the percent deviations from anticipated energy, we can re-run the model once the new ration has been specified and get a new profit projection. The manager then knows exactly how much he is helped or hurt, and we are back where we started.

Admittedly, I have given you only an overview of the total program. Perhaps the best way to examine some of the segments in detail is to start from the output and work back.

Biological simulation program. If we must decide early what is the best weight to buy and the best price to pay for feeders for any growing period, we will have to estimate an optimal feeding plan. We have recently developed a program to do this, in which we "grow" the animal in a computer as we anticipate it will grow in real life. That is, its biological development is mathematically simulated. We calculate, by hundred-pound increments, the daily rate of gain, the daily maintenance energy requirement, and associated costs per day. The computer program is designed on the basis of time intervals instead of hundred-pound intervals, but the results are the same. Incremental cost per pound is calculated by dividing the total cost of feed by the rate of gain. The computer identifies the day to sell by comparing the incremental cost with the market price of the next pound of gain. The key information is the daily rate of gain, the maintenance energy requirements, and the production energy values required for that daily rate of gain.

The computer decides which ration to feed, and how long the feeding period should be, as follows. Graphing megacals of maintenance energy requirements against weight of the animal reveals an increase in requirements as the animal becomes heavier and acquires more body cells. The rate of increase is a function of the rate of gain.

As the animal grows, so does his feed intake. The rate of feed intake energy diverges gradually from the rate of maintenance energy requirements until the latter begins to increase at a rate that exceeds feed intake energy. At this point the maximum rate of gain from the given ration has been reached, and the animal should be fed a higher energy level ration. Thus, even though the animal's feed intake rate will remain relatively constant, the higher energy intake from the new ration will increase his daily rate of gain.

If the animal were in a cold environment where he could not maintain thermoneutrality, the maintenance energy curve would be steeper, and we would have to put the animal on a hotter ration sooner. If the animal were going off his feed, his energy-intake line would decrease. In this case, we would step down to a ration with lower energy but with higher levels of protein and minerals. Calculating this is time-consuming by hand, but extremely fast with a computer.

Maintenance curves. The computer's real worth comes in calculating maintenance curves. It costs more to heat a large house than a small house, but a small house cools off more quickly than a large house once the heat is shut off. The same principle applies to animals. A calf, which has a high surface to volume ratio, suffers more in cold weather than a larger animal, which has a lower surface to volume ratio.

Because an animal's major source of heat transfer is his surface, we look at him in the computer as though he is nothing more than a cylinder. The head, legs, and tail sticking out of this cylinder don't change the calculations appreciably and can be ignored. We can compute how this cylinder reacts in an environment and relate the results to an actual animal's responses in the same environment.

First the computer calculates the estimated surface area for a given age and weight of animal. Once this is done we can use the heat transfer equations for a cylinder, which have been known since Newton. We calculate the heat lost through the respiratory system just as we would for an air conditioning system. When we calculate the heat lost to wind, we must assume that the animal will behave sensibly and will minimize his heat loss by turning his tail to the wind. This means we have to consider only the tail end of the cylinder as the transfer surface area. When he is wet from rain, we divide the surface area in half, assuming that only the upper portion of the animal loses heat to water. Again, only half the surface area is used to compute energy gained from sun radiation, since the sun can shine on only one side at a time.

After calculating all four systems of heat transfer, we have an idea of what heat the environment will require from a "free-standing" animal. Here the sensible behavior complicates things. When they get cold, they huddle with other animals. When they get too warm, they seek shade. Animals avoid stress and will do anything in their power to maintain thermoneutrality. So we calculate our animal as being in a huddle. It doesn't matter if it is a tight huddle or a loose one, for the animals in the inside will move and the ones on the outside will butt their way in if they get too cold. By formulating all these qualities into our model, we can complete our heat transfer calculations and establish the maintenance energy curves. This in turn determines what the animal's rations should be, their cost, and finally, what price we seek for the animal at a given time.

Conclusion

Perhaps the most valuable aspect of computerization is not the calculation of results but the development of the program in which calculations are done. The program described here has opened the door to some interesting research questions and has indicated that we are using wrong criteria in our present system of feeding animals.

There are many uses for computers in the future or agriculture. I have tried to show you how development of management tools in agricultural operations can take place. We in agriculture have a wealth of technical knowledge, but we must put it together in a management system. We are often awed by the complexity of farm management and computers, and we are tempted to say, "Why bother?" But we should bother. If there is any business that needs more up-to-date information and detailed analysis, it is agriculture.

The Role of Financial Intermediaries in Providing Planning Services for Individual Farmers

Lester L. Arnold

Technological development in agricultural production and farmers' acceptance of this technology have occurred more rapidly than development in managerial sciences. What record-keeping programs there are have largely been developed by university research and investments. It is estimated that between 25,000 and 30,000 farm records are being serviced by computer facilities in the various programs provided by the universities, the farm organizations, the financial institutions, and other organizations. This is about 3 percent of the farms in the United States with annual farm sales of $10,000 or more. Although doubling the number of farm records would still involve only a small percent of the total number of farms, it is doubtful that we have the facilities, programs, and trained manpower to move even at that rate.

The decision-making process for farmers has become more complex as farms become larger, capital requirements increase, and new technology becomes available. The lender too faces new problems in financing the changing farm firm. Not only must he keep abreast of changing technology and its economic implications, he must also understand how these innovations will fit into an individual farmer's operation so that he can be in a position to appraise the profit and repayment potential. To serve a farmer's credit needs today, the lender must know and understand a lot more about the farmer's business.

Credit, like agricultural production, has become concentrated in the hands of a few farmers. In the case of members of Production Credit Associations (PCA), about 5 percent of the borrowers hold 38 percent of the amount of loans outstanding, in the form of loans in amounts of $50,000 or more. In terms of new money loaned during a year, about 5 percent of the members are borrowing about 45 percent of the new money, in amounts of $50,000 or more.

A Case for Farm Record Programs

The Federal Intermediate Credit Banks and the PCA's are owned by the farmers who borrow from these associations. This system is interested in all types of sound programs that will enhance the position of the farmer, including research on and development of record-keeping programs. Farmers have been encouraged to keep good records as a basis for making sound farm and financial decisions and as a basis for

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credit decisions. To further these aims, the credit banks in three Farm Credit Districts in 1966 initiated an electronic farm record program on a limited scale and made it available to PCA borrowers. By 1969 the program had expanded to 10 districts with about 4500 PCA members enrolled.

I do not consider the relative merits of computerized farm record systems over other systems as being open to debate. By using electronic data processing equipment and the necessary software, basic input data can now be processed and made available to the farmer more quickly, in more detail, and in a timelier manner.

The basic reason for research and development of computer-assisted planning methods for individual farms is to provide the farmer with adequate tools for planning his farm business. Other benefits are secondary. I do not intend by this to imply that such secondary uses should not be explored and developed to the hilt. Indeed, the results of such research could benefit the farmer in many ways, including the extension of credit.

Providing Planning Services

An institution interested in providing farm record services for farmers should be in a position to meet several criteria, including:

1. A knowledge of agriculture.
2. A strategically located field force.
3. Willingness to invest some risk capital.
4. A potential volume of business that will provide for economies of scale.
5. An existing "by-product use" for the data.

A financial institution that extends credit to farmers and ranchers might well justify providing planning services for individuals for the following reasons:

1. To provide an essential service for borrowers.
2. To expand the base from which this service may be obtained.
3. To make a field staff available.
4. To provide the individualized information that is essential in making a credit decision.
5. To provide data for research.
6. To expand sales or services.
7. To increase profits.

A financial intermediary should also, however, consider several problems inherent in providing planning services:

1. The quality of service that can be provided.
2. The competition for available time.
3. The competition for competent personnel.
4. The training of personnel.
5. Keeping up-to-date on new technology in the farm record field.

Getting Farmer Participation

Farmers have generally found record keeping a somewhat difficult undertaking. In part this is a consequence of regarding record keeping as another chore without sufficiently recognizing the value that can result from the effort put into it. Also, I feel, the excuse of lack of time has often been used as a cover-up for doing a poor job of accounting for the farm business.

Without a doubt farmers are undergoing a dramatic change in their attitudes toward farm records, to some degree because economic pressures have sharpened the drive for survival. Farmers recognize that expanding farm size and capital requirements is only a means of going broke at an accelerated pace, unless the expansion is accompanied by adequate returns and higher operating efficiencies. Consequently, records of past performance and analyses of these records as a basis for forward planning have taken on additional meaning. Interest in better record systems also, of course, stems in part from tax reporting requirements.

With farmers expressing greater interest in keeping better records and with the growing complexity of today's record-keeping systems, it is essential that the providers of the record services and the farmer participants be educated in these complexities so they can work closely together. In farm records, this education will involve:

1. Understanding the mechanics of providing all input data.
2. Understanding the reasons for providing these data in the format prescribed.
3. Understanding the output reports.
4. Understanding any limitations of the program as a whole.

The farmer participant will have many questions in the early stages of the program. Group educational meetings during this period prove very effective. In later stages, it is extremely important that someone trained in the record-keeping procedure work closely with the farmer. A lending institution with a field staff located close to its borrowers fulfills this basic requirement. We feel that much of the progress in the Credit Bank-PCA system's record-keeping program can be attributed to having trained personnel working closely with the farmer-members.

The Credit Bank-PCA program currently underway has been quite successful to this point. It started simply, adding some of the more sophisticated features along the way. Sometimes the farmers do the coding, sometimes the local Association does. Input data are supplied on specified forms filled out by the farmer or on copies of bank checks and deposit slips. The farmer receives the following reports:

1. Monthly and year-to-year data: a detailed list of monthly entries, a summary report, and a flow of funds statement.
2. Annual reports: a financial statement, a farm business analysis, tax worksheets and a tentative depreciation schedule (issued one or two

months before the tax year closing), a tax summary report, and a final depreciation schedule.

3. Optional reports: enterprise analysis (livestock or crop), machine cost accounting, payroll records, and family living records.

Research and Development

The Credit Banks have joined together to inaugurate a program of research and development in farm planning. The objective is to formulate, conduct, and direct research to develop and coordinate an electronic farm record (EFR) system for farmer members of the PCA's. A research director was recently hired to work full time toward this objective. His short term efforts will involve appraising present operations and defining areas for additions and improvements in present EFR systems. For the long range, he will be expected to make recommendations on year-end and enterprise analysis, depreciation schedules, double-entry systems, systems to serve the needs of members for best farm and financial management decisions, and means of coordinating these efforts with credit operations.

At present, one bank is already using a year-end Financial Analysis and Loan Application form on which the computer provides a 3-year comparative record of a farm's profit and loss statement, an abbreviated financial statement, and a record of loan purpose and performance. This procedure can provide a direct link between the farmer's records and his application for credit. It should also provide more accurate data than that previously available and should save some time for both the borrower and the lender in processing repeat and renewal loan applications.

Summary

Financial intermediaries are a natural source for farm record services that farmers can use for forward planning. It is a matter of committing resources necessary to do the job. Beyond commitment and purpose, the financial institution generally has a field force which, with training, is capable of providing the necessary close liaison between farm operator and record-keeper.

The lender should know about the potential problems involved in providing such planning services, foremost of which is the quality of service that can be provided. Quality will be highly dependent on the availability of qualified personnel. In addition, lenders will need to keep abreast of the farmers' needs in regard to forward planning and the changes in technology in the farm record-keeping field.

Alternatives of a Farm Supply Cooperative in Providing Planning Services for Individual Farms

ROBERT C. MATTHES

OTHER PAPERS IN THIS SEMINAR SERIES have adequately addressed the methodological aspects of building computer-oriented farm planning models for individual farms. In this presentation I shall discuss the role of farm supply firms in providing these services and some general problems and opportunities I see in applying these models.

My experience in this area is related to two specific applications of "planning" models for individual farms: the Mathematically Optimized Research Employment (M.O.R.E.) Profit Program developed by International Minerals and Chemical Corporation; and the Computerized Dial-A-Yield II Program, which has just been released for commercial use by FS Services.[1] These models are similar in structure and purpose. Both are designed to be implemented by field sales personnel. Both provide "crop production plans." Both are designed to provide the best combination of crop production inputs tailored to a particular farmer's needs.

Description of Cropping System Models

Although these models lack the comprehensive approach offered by "total" farm planning models, they do provide some insight into the problems of implementing planning models at the farm level. To provide a better understanding of these problems, it is helpful to first describe the typical structure of these models. The major components, organized as in Figure 1, are as follows:

I. Input (from individual farm)
   A. Demographics
   B. Machinery configuration
   C. Farming practices
   D. Diagnosis of weed and insect infestations
II. Input (derived off-farm)
   A. Demographics coding
   B. Machinery cost/operating equations
   C. Weed and insect "models"

[1] This program is available through most FS member companies in Illinois, Iowa, and Wisconsin.

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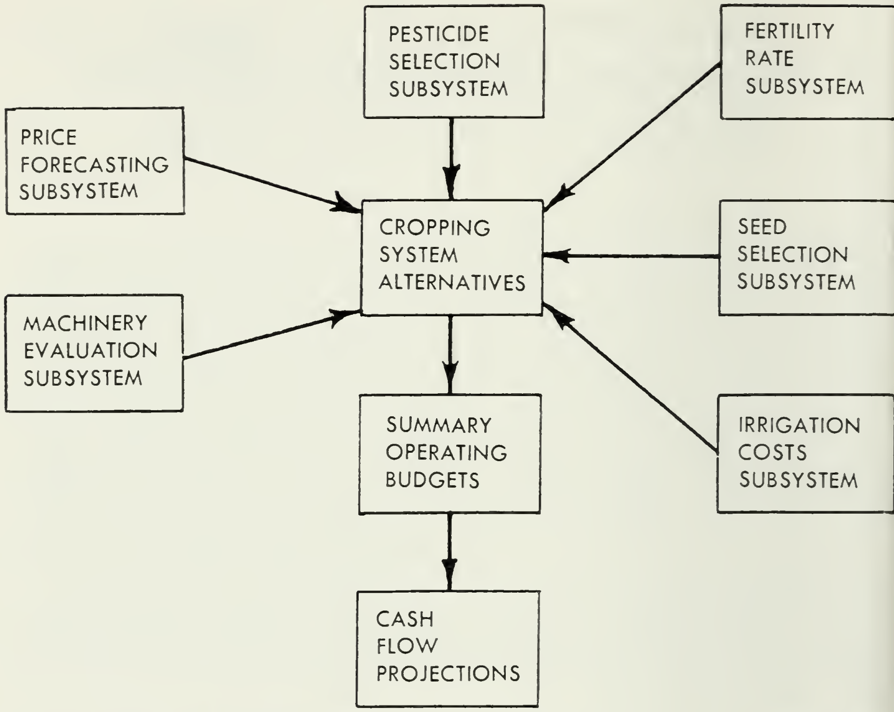

Components of Crop Production Planning System. (Fig. 1)

D. Fertilizer response "models"
E. Irrigation "models"
F. Cash flow "models"
G. Variable costs of inputs
H. Local retail outlet data (prices, product line, etc.)

III. Output
A. Farmer's name, other demographics, and codes
B. Listing of inputs submitted
C. Cropping system recommendations
1. Fertilizer carriers
2. Rates of application
3. Method of application
4. Time of application
5. Seed selection
6. Plant population
7. Weed and insect control
8. Total costs per acre
9. Gross and net income
10. Cost per bushel of production

Data retrieval. The format for the FS Dial-A-Yield II Program input form (included at the end of this paper) is designed to facilitate key punching directly from the input form. The forms are designed to be filled out either by the farmer himself or by the salesman. As some of the questions — such as the organic matter content or the soil type — are subject to judgment where data are not available, our experience suggests that better results are obtained when the salesman helps the farmer fill out the input form.

Besides supplying input for the model, the input form also gives the supplier relevant information about the farmer's cropping program. Over time, a data bank can be developed to aid salesman programs and model validation and refinement. Historical data on crop rotation, fertility levels, application rates, weed and insect problems, program compliance, etc. can provide useful guidelines for refining present models and identifying future directions in model development.

Output format. The output format varies according to geographical areas, retail companies, and models being used. A typical first page of the computer output includes the demographic variables of the farmer and a complete enumeration of the answers previously submitted in the input form. It may also contain predicted harvest prices and explanations of methods of calculations used in the report.

The specific recommendations made by the Dial-A-Yield II Program appear on pages 2-4 of the report. The output format of the M.O.R.E. program is similar, except that it gives a summary of the machine costs per acre for production of alternative crops. The principle difference between the two programs is that the Dial-A-Yield II Program gives more specific recommendations for a particular crop (chosen by the farmer), while the M.O.R.E. Program gives several alternative crops for a given field. M.O.R.E. also provides more analysis of the economics of crop production.

Benefits of the Program

Cropping system models offer several advantages when viewed as sales tools by farm supply firms. They allow salesmen to make more effective use of their time in meeting and selling farmers by providing technical backup in all facets of crop production; salesmen become specialists, backed up by the thinking of agronomists, economists, and farm planning specialists. In addition the farmer's thinking is oriented toward setting goals, thus helping improve his methods of crop production; referring to a cropping system — a total program geared to an individual farmer's needs — de-emphasizes price; and the farmer is assisted in keeping farm records. Finally, the system models provide a means of data collection for model validation, which also gives a basis for evaluating the program.

Dial-A-Yield II Program Output: Page 1

```
NAME:  Joe Farmer
ADDRESS:  Anyplace, Illinois      COUNTY:  McLean        TOWNSHIP:  Bloomington     M/C CODE:  54
CUSTOMER NO.:  183                FARM NO.:  0001        FIELD NO.:  01             DATE:  09/12/69
ACRES IN THIS FIELD:  60          CORN ACRES:  350       TILLABLE ACRES:  500       YIELD GOAL:  140

                              COMPUTER INFORMATION
                        FARM EQUIPMENT THAT IS AVAILABLE

          SIDE-BAND    DRY     PLANTER FERTILIZER ATTACH.       SUPP. NITROGEN APPLICATOR
          CAN INCORPORATE A BROADCAST HERBICIDE WITH A DISC
          GRANULAR BAND        INSECTICIDE APPLICATOR
          SPRAY BROADCAST      HERBICIDE APPLICATOR             COMBINE

                               FIELD INFORMATION
CROP
     1.   CORN YIELD:  NORMAL YR. 120 LAST YR. 120 GOAL 140
     2.   CROP ROTATION CORN      CORN    SOYBEANS              3.   YIELD OF MOST RECENT CROP
SOIL
     1.   SOIL TEST:  PH,    (N),     (P), 25 (K), 175          4.   TONS OF MANURE WILL BE APPLIED
     2.   GOOD DRAINAGE     FALL PLOW NO OVERFLOW               5.   SOIL TYPE SILT LOAM
     3.   WISCONSIN VALUES:                                     6.   ORGANIC MATTER 2-4%
             (N)        (PHOS.)      (POT.)
SEED PREFERENCE
     1.   SINGLE & SPECIAL                                           MEDIUM MATURITY
WEED PROBLEMS (ANNUAL GRASSES ARE GENERAL)
     1.   GIANT FOXTAIL  60%     2.  GR. OR YFL. FOXTAIL  10%   3.   PIGWEED 10%
     4.   SMARTWEED      10%     5.  VELVET LEAF          10%   6.   CANADA THISTLE
INSECT PROBLEMS
     1.   W CORN ROOTWORM OR RESISTANT N CORN ROOTWORM               CUTWORM
GENERAL
     1.   FIELD    NOT ASSOC. WITH DAIRY FARM                   3.   INTENDS TO PLANT BEFORE MAY 10
     2.   CORN STALKS WILL NOT BE PASTURED                      4.   DOES    PLAN TO CULTIVATE

                               COST INFORMATION

     1.   LAND VALUE $700.00 TAXES $08.00                       3.   CASH RENT $    .00  SHARE RENT   %
     2.   THIS FARM IS NOT OPERATED ON A CASH GRAIN BASIS.
```

Dial-A-Yield II Program Output: Page 2

```
NAME:  Joe Farmer
CUSTOMER NO.:  183        FARM NO.:  0001        FIELD NO.:  01           DATE:  09/12/69

                    S E E D   R E C O M M E N D A T I O N S

     PLANT VARIETY            FS 688       FS 840

     HARVEST POPULATION       22000

     ROW WIDTH                30"

% INCREASE IN PLANTING RATE TO OBTAIN DESIRED NUMBER OF PLANTS PER ACRE AT HARVEST

     PLANTING DATE            INCREASE

     BEFORE MAY 1                20%
     MAY 1-10                    17%
     MAY 10-20                   14%
     AFTER MAY 20                10%

              P L A N T   F O O D   R E C O M M E N D A T I O N S

     LIMESTONE FOR TOP CORN YIELDS MAINTAIN A PH OF 6.2 - 7.0

PLANT FOOD REQUIRED

     NITROGEN               178 LBS PER ACRE
     PHOSPHATE              120 LBS PER ACRE
     POTASH                 134 LBS PER ACRE

PRODUCT & METHOD OF APPLICATION

     BAND IN ROW AT PLANTING     150 LBS/ACRE OF FS SPECIAL NO. 1
     BROADCAST BEFORE TILLAGE    193 LBS/ACRE OF 0-0-60
     BROADCAST BEFORE TILLAGE    111 LBS/ACRE OF 18-46-0
     PRE-PLANT OR SIDEDRESS      180 LBS/ACRE OF AMMONIA
```

Dial-A-Yield II Program Output: Page 3

```
NAME:  Joe Farmer
CUSTOMER NO.:  183        FARM NO.:  0001        FIELD NO.:  01       DATE:  09/12/69

        I N S E C T I C I D E   R E C O M M E N D A T I O N S
        ALWAYS READ, UNDERSTAND AND FOLLOW LABEL INSTRUCTIONS

APPLY IN BAND              THIMET            AT PLANTING TIME
  APPLY AT THE RATE OF  8.60 LBS.  PER ACRE

BROADCAST & DISK INTO SOIL  ALDRIN LIQUID    PRIOR TO PLANTING

  APPLY AT THE RATE OF  64.00 OUNCES PER ACRE

    TO EFFECTIVELY CONTROL BLACK CUTWORM A BROADCAST TREATMENT IS PREFERRED


          H E R B I C I D E   R E C O M M E N D A T I O N S

FOR CANADA THISTLE INFESTED AREAS, SPRAY NEW GROWTH IN SPRING WITH 1 GAL. OF AMI-
TROL T PER ACRE IN 20 TO 40 GALS. OF WATER, WAIT 2 WEEKS THEN PLOW & PLANT.  SPRAY
THISTLE PLANTS THAT SURVIVE WITH 1 PINT OF FS AMINE 400 2,4-D PER ACRE.

ALSO USE THE FOLLOWING CHEMICALS FOR OTHER WEEDS INDICATED.

FOR CONTROL OF ANNUAL GRASSES & CERTAIN BROADLEAF WEEDS:
  USE SUTAN+ATRAZINE AS A PREPLANT INCORPORATED TREATMENT.  MAKE APPLICATION BY
  MIXING 1/2 GALLON OF SUTAN WITH 1.25 LBS. OF ATRAZINE IN 20 GALLONS OF WATER PER
  ACRE AND INCORPORATE IMMEDIATELY WITH A DISC.  A SECOND DISCING AT AN ANGLE TO
  THE FIRST IS SUGGESTED BEFORE PLANTING TO THOROUGHLY MIX THE HERBICIDES IN THE
  SOIL.
```

Dial-A-Yield II Program Output: Page 4

NAME: Joe Farmer
CUSTOMER NO.: 183 FARM NO.: 0001 FIELD NO.: 01 DATE: 09/12/69

E C O N O M I C S O F Y I E L D G O A L

	PER ACRE	TOTAL	PER BU.
FERTILIZER COST	22.06	1323.60	
SEED COST	6.18	370.80	
HERBICIDE COST	8.83	529.80	
INSECTICIDE COST	6.41	384.60	
COST OF PROGRAM	43.48	2608.80	.31
OTHER VARIABLE COSTS	11.00	660.00	.08
FIXED COST	63.90	3834.00	.46
NET INCOME	21.62	1297.20	.15

EFFECTIVE PRICE DATE: 10-17-68

INCOME BASED ON A CORN PRICE OF $1.00/BU.

SEED CORN IS PRICES ON A 50# BAG MED. FLAT BASIS

IT IS EXPRESSLY UNDERSTOOD, THAT THE PARTY PROVIDING THIS SERVICE IN NO WAY WARRANTS, OR PROMISES THAT ANY PARTICULAR RESULTS WILL BE OBTAINED BY THE USE OF THE SUGGESTED PROGRAM, AND SAID PARTY SHALL NOT BE HELD LIABLE FOR THE FAILURE OF THE SUGGESTED PROGRAM TO ACHIEVE ANY PARTICULAR OR DESIRED RESULTS.

M.O.R.E. Profit Program: Machine Costs

10101A JOE FARMER R.R. 2 ANYPLACE, ILL. 60600 9/30/66 239810076

SUMMARY OF MACHINE COSTS PER ACRE

CROP	IMPLEMENT	FREQ.	MACHINE TIME	PERCENT LOAD ON TRACTOR	FUEL COST	OIL COST	R AND M TRACTOR	R AND M IMPLEMENT	CUSTOM COST	TOTAL
CORN	MOLDBOARD PLOW	1.0	.64	94	.42	.06	.23	.32		1.03
CORN	SPRINGTOOTH HAR	2.0	.34	46	.13	.02	.14	.06		.35
CORN	STALK SHREDDER	1.0	.35	46	.13	.02	.14	.11		.40
CORN	MULCHER	1.0	.71	76	.40	.06	.25	.37		1.08
CORN	SURFACE PLANTER	1.0	.40	47	.16	.02	.09	.22		.49
CORN	ROTARY HOE	1.0	.13	35	.05	.01	.03	.03		.12
CORN	CULTIVATOR	2.0	.52	44	.23	.04	.19	.29		.75
CORN	FIELD SPRAYER	1.0	.17	13	.04	.01	.06	.03		.14
CORN	FAN-TYPE APPL.	1.0							1.50	1.50
CORN	SP COMB CORN HD	.5							2.50	2.50
CORN	CORN PICKER-PTO	.5	.26	56	.13	.02	.09	.22		.46
TOTALS	FOR SOIL TYPE I	LIGHT	3.19		1.40	.22	1.11	1.48	4.00	8.21
TOTALS	FOR SOIL TYPE II + III	MEDIUM	3.52		1.69	.26	1.22	1.65	4.00	8.82
TOTALS	FOR SOIL TYPE IV	HEAVY	4.12		2.13	.32	1.44	1.96	4.00	9.85

CROP	IMPLEMENT	FREQ.	MACHINE TIME	PERCENT LOAD ON TRACTOR	FUEL COST	OIL COST	R AND M TRACTOR	R AND M IMPLEMENT	CUSTOM COST	TOTAL
SOYBEANS	MOLDBOARD PLOW	1.0	.64	98	.42	.06	.23	.32		1.03
SOYBEANS	SPRINGTOOTH HAR	1.0	.17	46	.07	.01	.07	.03		.18
SOYBEANS	SURFACE PLANTER	1.0	.40	47	.16	.02	.09	.22		.49
SOYBEANS	ROTARY HOE	2.0	.26	35	.10	.01	.06	.07		.24
SOYBEANS	CULTIVATOR	2.0	.52	44	.23	.04	.19	.29		.75
SOYBEANS	S.P. COMBINE	1.0							5.00	5.00
TOTALS	FOR SOIL TYPE I	LIGHT	1.90		.83	.12	.61	.88	5.00	7.44
TOTALS	FOR SOIL TYPE II + III	MEDIUM	1.99		.98	.14	.64	.93	5.00	7.69
TOTALS	FOR SOIL TYPE IV	HEAVY	2.28		1.22	.17	.74	1.07	5.00	8.20

M.O.R.E. Profit Program: Summary Budgets

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SUMMARY BUDGET OF COMPUTERS CHOICE OF CROP AND YIELD LEVEL FOR 1967
(NO COMPLIANCE WITH GOVT. AGRI. PROGRAMS)

FLD NO	ACRE	CROP PLANNED FOR 1966	YIELD PER ACRE	FERTILIZER NEEDED LBS./ACRE NITROGEN	PHOSPHATE	POTASH	ESTIMATED FERTILIZER COST LANDLORD	OPERATOR	ESTIMATED TOTAL COST LANDLORD	OPERATOR	ESTIMATED GOVERNMENT PAYMENT LANDLORD	OPERATOR	ESTIMATED GROSS PROFIT LANDLORD	OPERATOR
1	40	SOYBEANS	40	0	36	56	124.40	124.40	330.80	646.40	.00	.00	1973.20	1657.60
2	45	CORN	125	145	50	37	443.90	443.90	848.20	848.20	.00	.00	2976.80	2976.80
3	37	CORN	125	145	50	37	365.00	365.00	697.40	697.40	.00	.00	2447.60	2447.60
4	25	ALFALFA	5	0	120	125	.00	444.00	.00	910.50	.00	.00	.00	1714.50
5	30	WHEAT	50	50	121	20	.00	519.60	.00	819.60	.00	.00	.00	1625.40
6	52	CORN	125	145	58	50	549.40	549.40	1043.40	1043.40	.00	.00	3376.60	3376.60
7	30	CORN	125	145	59	37	309.20	309.20	569.70	569.70	.00	.00	1980.30	1980.30
8	55	CORN	125	145	72	37	601.70	601.70	1095.90	1095.90	.00	.00	3579.10	3579.10
9	42	CORN	125	145	79	42	479.00	479.00	856.40	856.40	.00	.00	2713.60	2713.60
10	65	CORN	150	195	115	95	1084.90	1084.90	1690.00	1690.00	.00	.00	4940.00	4940.00
11	22	CORN	125	145	85	60	266.90	266.90	457.90	457.90	.00	.00	1412.10	1412.10
TOT	443						4224.40	5188.00	7589.70	9635.40	.00	.00	25399.30	28423.60

M.O.R.E. Profit Program: Cash Flow Schedule

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CASH FLOW SCHEDULE OF FARM PRODUCTION FOR SUMMARY BUDGET I

	TOTAL	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
OPERTG RECEIPTS													
CROPS	33549.70					1291.10	900.00	3926.00	400.00	1209.60	20638.00	5185.00	
LIVESTOCK													
OTHER													
TOT OPERTG RCPT	33549.70					1291.10	900.00	3926.00	400.00	1209.60	20638.00	5185.00	
OPERTG EXPENSES													
HIRED LABOR													
FEED PURCHASED													
SEED PURCHASED	880.80				145.50	640.80				94.50	215.50	506.00	
MACHINE HIRE	1024.20							302.70			50.00	50.00	100.00
REPAIRS - MACH	740.20	100.00	100.00	50.00	50.00	50.00	50.00	50.00	40.20	50.00			
REPAIRS - BLDG													
PUMPING	.00												
LIVSTK EXPENSE													
FERTILIZER	3875.70					1350.00		1175.70					1350.00
HERBICIDE	498.20					498.20							
INSECTICIDE	261.80					261.80							
FUEL	418.30			10.00	25.00	75.00	60.00	50.00	15.00	38.30	65.00	80.00	
OIL AND FILTER	66.90				5.00	10.00	10.00	10.00		5.00	10.00	16.90	
FUNGICIDE	.00												
TAXES (REAL)													
INSURANCE	.00												
AUTO													
ELECT AND PHON													
RENT	.00												
OTHER FRM EXP													
FEEDER LIVSTK													

M.O.R.E. Profit Program: Cost Production Summaries

10101A JOE FARMER R.R. 2 ANYPLACE, ILL. 60600 9/30/66 510076

SUMMARY OF CROP PRODUCTION CASH EXPENSES AND REVENUES BY CROP FOR CASH FLOW SCHEDULE OF SUMMARY BUDGET I

COST ITEMS	CORN 239. ACRES	SOYBEANS 42. ACRES	OATS 30. ACRES	WHEAT 30. ACRES	ALFALFA 25. ACRES	RED CLOVER . ACRES	CAN PEAS . ACRES	SWEET CORN . ACRES	SIL. CORN . ACRES	DIVERTED 77. ACRES	TOTAL COSTS 443. ACRES
SEED	530.80	110.00	76.50	94.50	69.00	.00	.00	.00	.00	.00	880.80
FERTILIZER	2748.40	177.90	158.70	413.40	377.30	.00	.00	.00	.00	.00	3875.70
HERBICIDE	358.50	106.70	15.00	18.00	.00	.00	.00	.00	.00	.00	498.20
INSECTICIDE	149.30	.00	.00	.00	112.50	.00	.00	.00	.00	.00	261.80
FUNGICIDE	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PUMPING	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CROP INSUR	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CASH RENT	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
FUEL	225.80	42.20	6.00	5.20	74.70	.00	.00	.00	.00	64.40	418.30
OIL + FILT	34.50	6.00	.90	.60	15.90	.00	.00	.00	.00	9.00	66.90
RM TRACTOR	160.20	27.60	6.30	4.30	43.00	.00	.00	.00	.00	41.70	283.10
RM IMPLMNT	217.10	40.10	9.00	8.20	95.20	.00	.00	.00	.00	87.50	457.10
CUST MACH	506.00	215.50	150.00	152.70	.00	.00	.00	.00	.00	.00	1024.20
TOTAL COST	4930.60	726.00	422.40	696.90	787.60	.00	.00	.00	.00	202.60	7766.10
REVENUE	20740.00	2419.20	1170.00	1956.00	2100.00	.00	.00	.00	.00	5164.50	33549.70
GROSS PROF	15809.40	1693.20	747.60	1259.10	1312.40	.00	.00	.00	.00	4961.90	25783.60
PROF/ACRE	66.14	40.31	24.92	41.97	52.49	.00	.00	.00	.00	64.44	58.20

Problems of Implementation

Probably the greatest obstacle to successful implementation of these programs has been the fact that farm supply firms attempt to implement these "service-oriented" programs in a "product-oriented" company organization structure. Under these circumstances, the service aspects of the program (enterprise management, technical knowledge, financial planning, etc.) may be emphasized only to the extent that they complement product sales. The "sales tool" concept may degenerate to a "sales gimmick" approach, where the program is used merely to sell more fertilizer, etc. This will continue to be a limitation as long as these programs emphasize commodities.

Sales training is essential if the program is to be a success. FS, for example, has allocated considerable resources to orienting retail company managers, sales managers, and salesmen in the philosophy of the program, its objectives, its benefits, and its limitations.

Timeliness is very important to the success of the program. The program necessitates the salesman's making a follow-up call, at which time he returns the computer output to the farmer, explains the results, and closes the sale. Turnaround from the time the input is submitted until the output is returned to the farmer should be a week to 10 days. Remote access and time sharing capabilities should alleviate this problem in the future by reducing turnaround time. Equally important is the factor of getting the program initiated in late winter or early spring before farm work begins.

"Whole-Farm" versus "Sub-Farm"

The two illustrations presented in this paper are examples of the "sub-farm" approach, that is, of the cropping subsystem of the entire farm operation. With few exceptions, farm supply firms have used the sub-farm approach in building these farm planning models. The models have been developed as sales tools to aid farmers in selecting the best combination of inputs to serve their needs; hence, these models are oriented toward short-run decisions: pesticide control, level of fertilization, etc.

We at FS feel that the payoff from a sub-farm model is more immediate than from an overall farm planning model. There are some rather obvious reasons for this. At the present time, farmers are reluctant to pay for whole-farm services. We do not feel we could recover the costs of developing a total farm planning model. Moreover, total farm planning models have not yet been successfully implemented at the farm level. Costs are still prohibitive. The level of aggregation does not give specific answers that farmers can utilize on a routine basis.

In developing the Dial-A-Yield II Program at FS, we have chosen to develop "components" of a total farm planning model, constructing the models in such a way that they are additive and can be integrated into a total farm planning model later. We feel that this gives the benefit of experience in developing, monitoring, and implementing less complex models as we work toward a more comprehensive system.

Comparative Advantages in Offering These Services

The comparative advantages of farm supply firms in offering these services have been discussed earlier by Dr. Baker. Historically, the development of these models has been closely associated with the inputs being sold by supply firms. Farm supply firms at present clearly have the comparative advantage in offering cropping system models since they possess both the necessary backup of technical information and the field force to implement the program.

A more important question is where the advantage will lie in the future. Several factors point to increased use of farm planning models: increasing size of farms, increasing pressures on profits (cost-price squeeze), greater need for capital, and a trend away from the owner-operator concept toward a separate managerial function in the farm enterprise. Increased emphasis on the systems approach will encourage more comprehensive model development capable of analyzing more aspects of the farming operation.

This trend to "total farm planning" models, services, or programs may shift the comparative advantage away from farm supply companies. This suggests an advantage for those agencies offering the farmer the most complete service and product package: supplies, technical services, custom application, credit needs, management assistance, and marketing services. Such a complete service package may or may not emerge. Even if it does, there remains the question of the depth of concern of the various agencies serving agriculture. As a farm cooperative, we are operating in the best interests of the farmer and hence have a strong orientation toward service programs.

Farm supply firms have been reluctant to offer farm planning services on a "stand alone" basis. Farmers have demonstrated repeatedly that they are *not* willing to pay for such services. As a result, few suppliers have "unbundled" their services. FS is attempting to change this philosophy by establishing an image for Dial-A-Yield II as a program that is worth something to the farmer.

In my opinion, we may see more farm planning services being offered by independent agencies in the future — say, a professional farm management service or a computer software company. Such agencies have some distinct advantages in not attempting to sell the farmer a particular product or a commodity-oriented program. They are vitally interested in management services as a profitable venture and thus have a vital interest in the efficiency of the models (programs) being offered. Finally, by not being tied to a particular supplier or marketer, they allow the farmer-manager to maintain flexibility in his procurement and marketing activities.

DIAL-A-YIELD II
COMPUTER INFORMATION

Column		
1	1	Date ___-___-___
2-21	Name ______	
22-41	Address ______	
42-51 52-61	County ______	Township ______
66-68	Member Company Code	
69-74	FS Customer Number	
75-78	Farm Number	
79-80	Field Number	
	Member Company Name ______	

Col	BE SURE EVERYTHING IN RED IS ANSWERED*
1	2
	1. What planter fertilizer placement will be used? (Check one)
2	(1) Side-band ☐ (2) With seed ☐ (3) None ☐
	2. Planter fertilizer: (Check one unless "None" is checked in Question 1)
3	(1) Dry ☐ (2) Liquid ☐
	3. Can a supplemental nitrogen applicator be used? (Check one)
4	(1) Yes ☐ (2) No ☐
	4. Do you have an ammonia plow applicator available? (Check one)
5	(1) Yes ☐ (2) No ☐
	5. Harvesting method: (Check one)
6	(1) Combine ☐ (2) Field sheller ☐ (3) Picker ☐
	6. What method do you prefer for soil insecticide application? (Check one)
7	(1) Granular band ☐ (2) Spray band ☐ (3) Granular broadcast ☐ (4) Spray broadcast ☐

Col	
	7. What method do you prefer for herbicide application? (Check one)
8	(1) Granular band ☐ (2) Spray band ☐ (3) Granular broadcast ☐ (4) Spray broadcast ☐
	8. Could you incorporate a broadcast pre-plant herbicide treatment with a disc in your seedbed preparation? (Check one)
9	(1) Yes ☐ (2) No ☐
	9. Could you incorporate a preplant herbicide treatment with a power driven rotary tiller such as a "Sidewinder" in your seedbed preparation?
10	Band: (1) Yes ☐ (2) No ☐ (Check one
11	Broadcast: (1) Yes ☐ (2) No ☐ (Check one
12-14	10. Land value: ☐☐☐ per acre (nearest $50
15-16	Taxes: ☐☐ per acre (nearest $1)
17-19	Cash rent: ☐☐☐ per acre (nearest $1)
20-21	Share rent: ☐☐ percent (renter's shar
66-68	Member Company Code
69-74	FS Customer Number
75-78	Farm Number
79-80	Field Number

Underlined text was red in the original.

DIAL-A-YIELD II

Page 2

Name ______________________________

Column	
	BE SURE EVERYTHING IN RED IS ANSWERED
1	3
2-4	1. Crop rotation: Last year ☐ Program year ☐ Next year ☐ (1) Corn grain (2) Oats (3) Corn silage (4) Grass (5) Soybeans (6) Legume (7) Wheat (8) Diverted acreage (9) Sorghum silage (0) Hybrid corn for seed production
5-13	2. Corn yield: Normal year ☐☐☐ Last year, if in corn ☐☐☐ Goal ☐☐☐
14-16	3. Yield of most recent crop if other than corn: ☐☐☐ bushels ☐☐☐ tons
17	4. Organic matter: (Check one) (1) 0-2% ☐ (2) 2-4% ☐ (3) 4%+ ☐
18	5. Soil type: (Check one) (1) Sand ☐ (2) Silt loam ☐ (3) Clay loam ☐ (4) Clay ☐ (5) Sandy loam ☐ (6) Peat or muck ☐
19	6. Drainage: (Check one) (1) Good ☐ (2) Poor ☐
20	A. Is it suitable for fall plowing? (Check one) (1) Yes ☐ (2) No ☐
21	B. Is it subject to overflow? (Check one) (1) Yes ☐ (2) No ☐
22	C. Is it irrigated? (Check one) (1) Yes ☐ (2) No ☐
23-33	7. Soil test within the last year: pH ☐☐ N ☐☐☐ P_1 ☐☐☐ K ☐☐☐
34-35	8. Manure to be applied: ☐☐ tons/acre
36-44	9. Wisconsin soil test recommendations: N ☐☐☐ P_2O_5 ☐☐☐ K_2O ☐☐☐
45	10. Width of row: (Check one) (1) Under 20 ☐ (2) 20 ☐ (3) 24 ☐ (4) 28 ☐ (5) 30 ☐ (6) 32 ☐ (7) 36 ☐ (8) 38 ☐ (9) 40 ☐
46	11. Intended planting date: (Check one) (1) Before May 10 ☐ (2) After May 10 ☐
47	12. Corn preference: (Check one) (1) Single and special ☐ (2) Double cross ☐
48	13. Do you plan to cultivate? (Check one) (1) Yes ☐ (2) No ☐
49	14. Is this field associated with a dairy farm operation? (Check one) (1) Yes ☐ (2) No ☐
50	15. Which maturity of seed corn is preferred? (Check one) (1) Early ☐ (2) Medium ☐ (3) Full ☐
51	16. Will the corn stalks be pastured? (Check one) (1) Yes ☐ (2) No ☐
52-55	17. How many tillable acres do you farm? ☐☐☐☐ acres
56-59	A. How many of these acres are in corn? ☐☐☐☐ acres
60-62	18. How many acres are in this field? ☐☐☐ acres
63	19. Is this a cash grain operation? (Check one) (1) Yes ☐ (2) No ☐
66-68	Member Company Code ☐☐☐
69-74	FS Customer Number ☐☐☐☐☐☐
75-78	Farm Number ☐☐☐☐
79-80	Field Number ☐☐

DIAL-A-YIELD II

Page 3

Name ______________________________

Column

BE SURE EVERYTHING IN RED IS ANSWERED

1 4

1. Have you experienced or do you anticipate problems with the Western Corn Rootworm or the Resistant Northern Corn Rootworm? (Check one)

2 (1) Yes ☐ (2) No ☐

2. Does this field have a past history of serious cutworm damage? (Check one)

3 (1) Yes ☐ (2) No ☐

3. Are annual grasses, such as foxtail, a serious enough problem to require the use of a grass control herbicide which could cost $3 to $5 per treated acre as a row application ($5 to $10 per treated acre broadcast)? (Check one)

4 (1) No ☐
(2) Yes, but only in spot areas such as end rows ☐
(3) Yes, it is a general overall field problem ☐

4. Rate the weed problem. If 100 represents the total weed problem, assign a portion of that number to each weed species with which you are concerned. Example: "If 50% of the weed problem is Giant Foxtail 40% is Smartweed, and 10% is Pigweed, then write these numbers opposite those weeds listed." If there is no weed problem, check "None."

Column		Weed Species	Percentage (must total 100)
5	(1)	None ☐	
6-7	(2)	Giant Foxtail	____
8-9		Green or Yellow Foxtail	____
10-11		Barnyard Grass	____
12-13	(3)	Crabgrass	____
14-15		Panicum Grass	____
16-17	(4)	Pigweed (Hogweed)	____
18-19		Lambsquarter	____
20-21	(5)	Smartweed	____
22-23		Jimsonweed	____
24-25		Velvetleaf (Buttonweed)	____
26-27	(6)	Cocklebur	____
28-29		Annual Morning Glory	____
30-31		Common Ragweed	____
32-33		Giant Ragweed (Horseweed)	____

5. Are any of the following weeds, which may require an added or special treatment, a problem in this field? (Check no more than three)

34-36 (1) Quackgrass ☐
(2) Wild Cane ☐
(3) Johnson Grass ☐
(4) Canada Thistle ☐
(5) Yellow Nutgrass ☐
(6) Field Bindweed ☐
(7) Wirestem Muhly or Mexican Dropseed ☐

66-68 Member Company Code ☐☐☐

69 74 FS Customer Number ☐☐☐☐☐☐

75-78 Farm Number ☐☐☐☐

79-80 Field Number ☐☐

It is expressly understood that the program to be suggested on the basis of this questionnaire is not a guarantee, warranty, or promise that such program will achieve any particular or desired result.

Uses of Computerized Planning Services by Professional Farm Managers

Jesse M. Dowell, Jr.[1]

As discussed by Dr. Scott previously, many of us in farm management come from very diverse backgrounds with minor training in economics, statistics, mathematics, business, and accounting. Consequently, it is very difficult for us to realize and understand the full range of possibilities of computers.

Most practicing farm managers are very adept at longhand budgeting. They formulate many budgets every year, evaluating net income possibilities for clients (and in a few cases for themselves), estimating long-term debt retirement, and even estimating annual, quarterly, or monthly cash flows. Many longhand budgets estimating long-term net income that is capitalized are also prepared each year to determine land valuations for possible investors, inheritance tax appraisals, sales purposes, condemnation appraisals, and other appraisal needs.

In sum, most professional farm managers are adept at longhand budgets but are very lacking in knowledge about the use of computers and their potential. We realize that the computer is a very "fast pencil," but that is about the extent of our present knowledge.

Needs of Professional Farm Managers

Professional farm managers need to be able to design a farm plan that will maximize profits — the usual objective of farm owners. (There are exceptions, of course, in so-called hobby farms, but it appears that Uncle Sam will soon put an end to these.) One of our main needs is for any tool that will help us maximize net income in the short run.

Capital improvements are often considered a way of increasing net income in the long run. Again, projections of expected increased returns, increased expenses, and the effect on net income are already done by longhand. Computers, by performing these tasks more efficiently, would be a good tool for long-run needs.

Another possible computer use is in enterprise analysis, which is still a desirable way to spot trouble or a farmer's extra good managerial abilities.

[1] Thanks go to Professor C. B. Baker for his suggestions as to the items that might be included in this paper and to Dr. Ian Marceau and Dr. Ron Tongate for assistance in preparing this paper.

Jesse M. Dowell, Jr., is a professional farm manager, Champaign, Illinois.

We realize we can "longhand" only so many budgets per winter. This is tedious work, as I'm sure all of you know, and very time-consuming; so we usually do only two or three for each landowner each year to decide whether to comply with a government program. By using computers, however, one can prepare a vast number of budgets with the flick of a switch or the punch of a button. All possible alternatives can be considered, so that the danger of inadvertently overlooking a more profitable possibility is avoided. The importance of this advantage is increasing, as costs become a higher percentage of farm income.

Let me cite one example: Ian Marceau, Ron Tongate, and I have been computerizing two large farms in Ford County. One of the farms is 906 acres with mostly Ashkum, Bryce, Swigart, and some Elliott soil. Almost all of it has been in corn and beans since 1957, except for 25 acres of wheat grown primarily to produce bedding for hogs and cattle and to establish new hog pasture. The corn yield has averaged 97 bushels per acre on these heavy rolling soils; beans, 33 bushels; and wheat, 58 bushels. We have sold approximately 1,000 hogs and 100 cattle a year, as well as surplus corn for an average near $1.10, beans for $2.50, and wheat for an average of $1.37.

What do you think the "magic box" indicated as the most profitable system for this farm for 1970? Wheat! A section and a half of wheat! I suppose I could have run a dozen longhand budgets or more before I would ever have thought of planting 900 acres of wheat and buying corn to feed.

The point of this one example is to indicate the ability of the computer to consider all alternatives for which it has received historical data, and its freedom from a "creature-of-habit" limitation.

I have indicated three needs of professional farm managers so far: short-term plans, long-term plans, and evaluation of capital improvement possibilities. The fourth need, which I think is all important, is to have a tool that can accept rapidly changing price conditions at any time, masticate the changes, digest them, and give an answer that can be implemented at the proper time.

Such practices as fall fertilizing and fall plowing cannot be delayed. So we need to know how price changes during the summer affect plans based on spring prices. We can "longhand" a couple of new budgets with new prices in probably 2 to 3 hours per farm to decide whether to comply or not, and start fertilizing and plowing right behind the wheat and bean combines. With a computer, we should be able to make these adjustments more quickly.

A fifth need of farm managers could possibly be a tool for bookkeeping, reporting to the owners, and filing income tax reports, but the computer costs which I have had quoted for these are too high so far, and the cost per farm is cheaper using the longhand, double-entry method. The current method of complete double-entry bookkeeping, with copies of all entries going to the landowner and the farmer, monthly reports of depreciation schedules, and a separate list to interested owners of all breeding livestock sales, costs about $100 per farm per year, or $8.33 per month.

Limitations

It would be nice if we could ask the computer whether it would be money well spent to make another complete run for the year ahead! Seriously, computer services are competing with the few free, longhand budgets that farm managers already do. So the cost of the computer services to a landowner or farm manager must be commensurate with the cost of two or three hours of longhand work, plus the value of knowing that all likely alternatives have been considered.

I don't believe that computers will replace professional farm management completely. Rather, I believe that, as in industry, computers will be a tool to make management more effective. As mentioned, all programmed possibilities can be considered, and the computer may determine, for example, that a farm should go to all corn in 1970. But the corn harvest must be started as early as possible, broken tile lines must be checked as they appear, and corn must be cultivated if chemicals do not kill weeds. Also, if 2- to 25-year loans are to be assumed, judgments must be made on values for corn prices 2 to 25 years ahead, as well as on the future prices for cattle, hogs, beans, and wheat. These are all tasks that a pencil, or an adding machine, or a calculator, or a computer cannot do. If we had a futures market 25 years ahead for corn, cattle, and all income, and for all costs such as fertilizer, real estate taxes, and labor, then hedging could lock in profits, insure paying off a long-term debt, and eliminate judgment values.

Who Will Supply This Tool to Farm Managers?

We know farms are enlarging rapidly in Illinois. As this trend continues, those remaining in business will be better informed and more willing to make changes and even seek innovations. We have seen this in the hybrid seed corn business, soybeans, soluble fertilizer, herbicides, and insecticides. The newest developments in all of these are now grasped quickly by today's largest Illinois farmers and professional farm managers.

Similarly, leading farmers now see forward planning assistance, along with financial planning assistance, as an increasing need. Computerized planning services can be supplied to professional farm managers by banks, private computer services, commercial firms (such as fertilizer and feed companies), and the University of Illinois through FBFM.

Banks have entered professional farm management and have quickly gained management of much land in Illinois, especially the east-central part. With many banks already using computers for other purposes, forward planning for their farms can easily be another service offered at a reduced cost.

Private computer firms that I have contacted quote costs so high that they can't be used. These firms may, however, be able to quote lower prices later, with the advent of new computers.

Commercial firms that have computers in use may be able to offer computer service at reduced costs to try to lock up business with customers for a period of time. I think it should be mentioned, however, that some farmers suspect the results of tests done by commercial firms. Although the suspicion is most likely unfounded, farmers believe that soil test results supplied by a fertilizer company, for example, may be slanted, if only a little, toward promoting a larger fertilizer sale. As a result, the farmers would rather have their soil tests done by the Extension Service or Farm Bureaus, which they consider to be completely unbiased. I think that the same general feeling about fertilizer and feed companies would carry over to any computer services they might offer.

Therefore, I suspect that private firms, banks, or the FBFM will be the most acceptable source of computer services, with banks and the FBFM having the decided advantage due to their fringe benefits, which permit reduced costs. I should think the FBFM could do the best job, as when FBFM records were first started, but banks will likely be very tough competition due to their sizable fringe benefits (use of large checking accounts, loans, trust work, etc.).

In summary, professional farm managers generally lack knowledge of computer possibilities. As with other new tools of production (the advent of tractors, nitrogen fertilizers, hybrid seed corn, etc.), a large-scale educational program is needed for both professional farm managers and farmers in general. The computer appears to be a good tool, and if the acid test of economics will bear it out, it will become as widely used as all the other new production developments of the last few years.

The Role of the University in Providing Planning Services for Individual Farms: Panel Discussion

C. B. Baker

In my role as moderator I intend only to outline the general objectives of today's session, at the outset, and to conclude the panel's contribution to the session with such summary comments as may not have been made by other panelists. The objectives of today's session can readily be summarized in terms of the objectives of the entire series of seminars:

1. To outline prospective changes in technologies by which management information is fed to farmers.

2. To identify the comparative advantages that farm-related firms have in the information network which involves farmers as managers.

3. To appraise alternative university policies with respect to research and development in planning methods for individual farmers.

John T. Scott, Jr.

Computer-assisted planning means using the computer in planning. The computer is used for the following reasons:

1. It provides a faster, more accurate way to assess alternatives than does the use of paper and pencil, once models have been developed.

2. It vastly speeds up repetitive types of work, such as depreciation calculation and the calculation of analysis factors from a large number of farm records.

3. It can retrieve desired historical information from storage easily and quickly.

4. It increases manyfold the number of alternatives that can be assessed by a manager.

Computer-assisted planning is not, however, a substitute for good management nor can it replace inaccurate or missing data (although it may have substitute data available in storage).

At present we have available a linear programming program which is, in some sense, a general model. But it has the advantage that it is specific to a farm through use of a linear programming matrix generator and is further specific to the farm by a report generator. It accommodates alternatives in a crop program and in cattle feeding and hog raising. It provides for restraints in labor, capacities, and nutritional requirements. It can be run very rapidly on a large number of farms. The model is limited in that it does not now include among its alternatives either dairy or beef cow operations. It does not have a financial component, and it does not provide for ready evaluation of fixed investment alternatives.

At present, we are testing the system with 10 farms. Future work is planned to add farm types; add technological alternatives, such as irrigation; add other models, either separately or as input into this model (for example, investment models, replacement models, or price prediction models); and assess or estimate the demand for such services. Decisions are needed on the rate at which these added objectives are to be pursued, which in turn depends on resources to allocate to the research and development activity.

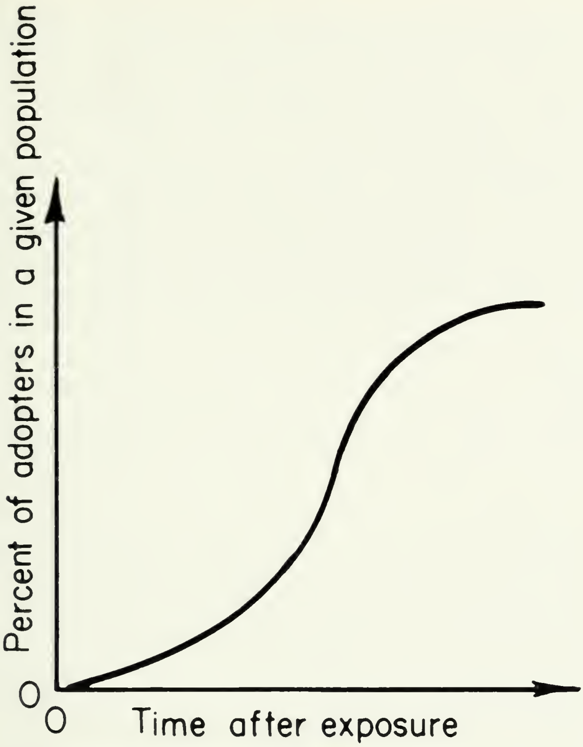
F. C. Fliegel[1]

Correlations so far estimated have suggested limited explanatory power of models of the knowledge-diffusion process. Neither personal characteristics nor type of technology has yet yielded the basis for inferences that can be made with great confidence. On the other hand, it is possible, on the basis of empirical research, to suggest that the rate at which a population accepts a given technology can be described by a S-curve in a diagram relating percent of a population adopting to time following exposure to the knowledge (see Fig. 1). At least rough inferences can be made about various factors involved in this process.

It is commonly assumed that the acceleration that occurs after a low initial rate of adoption is a "follow-the-leader" process. If so, it would occur perhaps earlier and with a stronger acceleration if the process were reinforced with demonstrations. The deceleration represented by the upper end of the curve describes an asymptotic approach to 100 percent acceptance. If the variable on the vertical axis is percent of all eventual adopters, for a given time period, the upper end of the curve reaches 100 by definition. Implicit in this concept is the presumption, in the diagram, that the time span chosen for the diagram is considered to be sufficient to span the whole diffusion process for a population for which the innovation is relevant.

It is plausible to suppose that the shape of the S-curve is related to initial cost of the innovation, expected increments to net returns, complexity of the innovation, and divisibility of the innovation — the extent to which it can be made "piecemeal" — among other characteristics of the innovation. Acceptance of a computer-assisted planning service might be characterized as a complex, fairly expensive innovation, with minimal divisibility and an increment to net returns that may be difficult to predict. Given these characteristics, the results of past research on diffusion suggest that such an innovation is most immediately rele-

[1] F. C. Fliegel is Professor of Rural Sociology, Departments of Agricultural Economics and Sociology, University of Illinois at Urbana-Champaign.



Time path diffusion for new technologies. Fig. 1

vant to operators of middle-size and large farms. The high initial costs would not deter these operators the way they would small farm operators. Also, the need to see a quick return on investment may not be as important for operators of large farms as it is for operators of smaller farms.

It is difficult to lay out the entire picture in a short time. The main point is that a given characteristic of an innovation is associated with speed of adoption in one way for one size group and in another way for other size groups. Obviously, farm size is a factor. Less obviously, middle-sized to large farm operators seem to be much more oriented to long-term investments than to an innovation-by-innovation weighing and balancing of pros and cons. The adoption behavior of the middle-sized to large farm operator may possibly be better understood in terms of basic decisions to farm or not to farm. Once having decided to farm, the operators more or less accept that which comes to be defined as part of the "business of agriculture." The small farmer, on the other hand, is more readily understandable in terms of "bits and pieces" decision making. My guess is that among middle-scale farmers the rate of adoption of computerized planning will depend on whether aggressive sales personnel convince the farmer that this is part of the package of farming. If so, the shape of innovation curve for this type of farmer is, after a perhaps slow initial start, a straight line, the slope of which depends on sales pressure.

In general, there may be reason to question the commonly assumed decision model for this type of farmer. Since he is increasingly the modal type, this conclusion is important in predicting the rate of adoption of an innovation. The name of the game may be changing, and the old model, good perhaps 10 or more years ago, may not be applicable now.

Robert Matthes

Farm supply firms have approached the planning process for farmers by means of subfarm models. This is in keeping with a fractional interest in the farm business, associated with the product orientation of an input supplier, and is consistent with the quality of personnel directly available to the farm supply firm. The farm supply firm's direct contact with the farmer is through sales personnel. The most relevant planning process, in the view of sales personnel, is directly associated with the product being sold. Ideally for them, planning is confined to this scope and provided without cost. To extend the scope requires adding expertise. To add a cost adds a barrier to successful competition with other input suppliers.

Thus one limitation of farm supply firms that emphasize total farm planning models is the quality level of field staff administering the program. In other words, for a total farm planning system to be successfully implemented at the farm level, a field staff of professional farm managers is probably needed. Farm supply salesmen are not qualified nor do they care to learn the various aspects of computerized models and other training needed to make such a program successful.

Another limitation, of course, is the one Lorne Ahlrichs of Monsanto pointed out — namely, that farm supply organizations are product-oriented and as such have definite limitations to a total farm approach. This is very evident in our present plans to expand our Dial-A-Yield program at FS. In most of our member companies, separate petroleum, chemical, plant food, and seed salesmen call on the farmer.

Such are the limitations of a merchandising firm in providing planning services for individual farmers. Clearly, input suppliers do have some advantages. We have a field staff already in contact with farmers, one which already possesses technical expertise in the products sold and serviced. This expertise is valuable in any planning process and would need to be supplied, at least in part, by any contending planning agent. Finally, the provision of a planning service would complement the selling process, at least over a significant range of the planning service, so that the benefits of providing the planning service might well be reflected in added sales. Companies with across-the-board salesmen, however, could present a more applicable program, since, to be most effective, the farm model (plan) must be presented intact as a unit. If the farmer does benefit highly when a whole-farm planning procedure is provided, the farm supply firm will find it necessary to provide one to stay in contention as a planning agent. So far, however, input suppliers have been slow to respond with such a planning service. After all, it is a costly process; it requires personnel not now available in farm supply firms; among those in contact with farmers there appears to be resistance to the imposition of costs on services offered farmers; and the farmers have so far revealed no strong demand for such a service. We would like to know where we are on Professor Fliegel's S-curve.

D. F. Wilken

Computer planning solutions have educational implications for farmers and for extension workers. Farmers or farm managers make decisions to change their farming operations when their management information system helps them recognize that something is wrong with the business — that the "as is" status is not what "ought to be." Farm planning models designed for use with the computer should be able to strengthen this management information system by providing better concepts of the "ought to be" status for given sets of resources.

As managers concentrate on trying to understand the planning solutions, they can be motivated to learn some of the basic principles of management. An inquisitive mind is a prerequisite to a good learning situation. This learning situation, however, is apt to be sustained only as long as the manager perceives that there are benefits that might exceed the cost of the learning.

Extension workers will probably have an important role in helping farmers understand and evaluate the benefits from computer planning solutions, especially until the technology has been generally accepted by commercial farmers. It will take much patience and time to teach farmers how to use these solutions, and it may be necessary to subsidize initial work in order to encourage acceptance. The result, however, may be the opening of an entirely new era in which new methods will be used for teaching management principles to farmers. Extension has most of the prerequisites for getting farmers to accept this planning technique, including the historical dependence of farmers on extension workers to help them evaluate a new technology.

Farmers have been slow to adopt record and planning services that are not free. These costs appear to be more competitive with family living costs on small farms than on large farms. Previous experience in record-keeping associations indicates that the initial interest in buying computer planning solutions is apt to be limited to less than 5 percent of Economic Class I farms. This would be 20 to 25 farms in each of the better agricultural counties in Illinois. Development of this technology, therefore, would probably revolve around a small nucleus of farmers in each county that would expand slowly over time. The rate of acceptance would probably be related to the amount of assistance provided in submitting and interpreting the data.

The role of the extension adviser and farm management association fieldman is important in this initial development. As new techniques provide more efficient communication with the computer at lower costs, the educational uses of farm planning solutions may in the future become integrated with other aspects of a total information network.

C. B. Baker

Our panel is incomplete in that it lacks a representative from financial intermediaries or from professional farm managers. Nor has anyone mentioned the prospects for a new service agency specializing in the provision of computer-assisted planning services for individual farmers. Let me address a few remarks to these alternatives before turning to policy choices of the university in research and development.

It seems clear that financial intermediaries do have three strong advantages. They more nearly share with the farmer a joint interest in whole-farm planning than do farm supply firms. They also are strategically located with respect to flows of information relevant to managerial choices. Finally, many banks already employ professional farm managers, thus providing important technical expertise. On the other hand, financial intermediaries may suffer from limitations. While the financial intermediary shares the farmer's interest as far as scope of planning is concerned, its depth of involvement differs considerably. The lender does not participate directly in profit expectations, since returns on loans are fixed in dollar terms. Moreover, the requirements in computer capacity and associated personnel exceed current facilities in financial intermediaries. This problem could, however, be handled by access to a computing center with sufficient capacity on a time sharing basis.

Jesse M. Dowell provided an example of the way in which a professional farm manager might relate to computer-assisted planning services. In most respects, the manager's concern is with whole-farm effects of management choices. He is constrained, however, to the direct involvement of his client, who is typically, at present, the landowner in a tenant-operated farm. It seems most likely that the professional farm manager will serve as a "retailer" in a "wholesale-retail" informational service, subscribing to the services of a computer center, specialized or otherwise, which will provide numerical solutions of models designed to meet the decision needs of his clients. With decreasing costs and increasingly versatile planning models, the range of clients may well expand from current patterns.

All the contenders so far identified are potential subscribers to a computer facility with capabilities to solve decision-relevant planning models. Most of the requirements for such a facility suggest that it might well be designed for non-agricultural as well as agricultural problems. Seasonal variations in demand would alone suggest important economies from a wider access. But this topic may well be the subject for future seminars.

There remains to be discussed an appropriate university policy with respect to research and development. We here are unlikely to resolve the issue, but we can outline the alternatives presently visible. As a minimum, the university might develop a documented system that is operational and that can be described in terms of cost to operate it and of output generated. We are already nearing completion of this first phase, incidentally, subject to the model limitations indicated by Professor Scott.

A second step by the university seems defensible: establishing pilot studies designed to test operational systems and to improve them in terms of cost and output. Parenthetically, let me add that we are presently engaged in such a study. Already the "real world" problems have suggested modifications in the planning system we have developed. It is clear that the second step is not only defensible but absolutely essential to success in research and development. Both the first and second steps, moreover, provide an excellent basis for enriching the research experience of graduate students. Incidentally, complementarities with respect to other aspects of graduate student programs provide the university with a comparative advantage in some phases of research and development.

A third stage might consist of demonstrations. In the present context this is a subtle concept. The audience for the demonstrations might be farmers, by analogy with demonstrations in the historic patterns of land-grant universities. In this instance, however, the audience might be potential *innovators* of the system, rather than *users* of the service provided by the system. In such a case, the farms and farmers would be the substance of the demonstrations, and the end result would be a display of the system as a technology for innovation by potential planning agencies. Should the university conceive of its role as extending still further, however, the audience would indeed be farmers, and the purpose of the demonstration would be to educate farmers as to the properties of the computer-assisted planning service.

A fourth stage, perhaps more debatable than the preceding, is market measurement. Dr. Matthes already has suggested that the demand for computer-assisted planning services is more visible in the popular farm press than it is among farmers! Yet the positive response we have had to the modest proposal to do a pilot study suggests a significant demand. The point is, the demand for planning services is not well identified. In fact, it has been difficult, until now, to identify a service precisely enough to elicit an intelligent response from a farmer. We may now be nearing the point at which this can be done. Should the university engage in such a demand study? Or should the potential innovators of the system be left to perform this function? The answer may depend on how much further the university feels its role extends.

A fifth and final stage would be actually providing the service itself. Should the university do this, it could choose from several alternatives: (1) the complete service, including numerical results and help in interpretation; (2) a computer system and library of decision-relevant models; or (3) a bank of data retrievable by subscribers to the data. Finally, whatever of these components of the system that might be provided, it might be done by the university with a subsidy, at cost, or at a profit that could in turn be used to support other research that may or may not be related to the planning system. Precedents are available for all these alternatives. However, arguments by analogy from the precedents should be examined with considerable care.

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