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Understanding, Quantification, and Modelling in Farming Systems Research: Results of a Simulation Study in Northern Nigeria

by

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ABSTRACT

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The paper discusses understanding versus quantification in farming systems research. The strengths and weaknesses of a large-scale and rapid exploratory surveys are compared. The value of a comprehensive rather than partial approach is illustrated with results from a recent simulation study of farm households in northern Nigeria.

Biographical Information

Eric W. Crawford is an Assistant Professor of Agricultural Economics at Michigan State University. He holds a B.A. from Pomona College (1967), and an M.P.A. from Princeton University (1969). He received his Ph.D. from Cornell University in 1980. His field is international agriculture and farm management.

Understanding, Quantification, and Modelling in Farming Systems Research: Results of a Simulation Study in Northern Nigeria*

Introduction

There has been a growing tendency to recommend that research on small farm development in the Third World should be undertaken within a farming systems context (Norman, 1978, 1980; CGIAR/TAC). One of the key elements of the farming systems research (FSR) approach is its holistic focus. FSR examines the full range of household activities--including livestock production, off-farm enterprises, and domestic tasks--and the interactions among them, rather than studying only cropping activities within the farm operation (Gilbert, Norman, and Winch).

It is clear that subsistence or semi-commercialized farm households are complex systems whose activities, goals, and decision-making processes must be thoroughly understood if policy interventions or technology development are to benefit them (Vincent). However, to what extent comprehensive data collection and analysis is needed in order to achieve this understanding is a matter of current debate. Do we need to analyze whole farm models constructed from detailed field data, or can we achieve sufficient understanding by focussing more narrowly on key constraints and activities identified through rapid exploratory surveys carried out directly with farmers?[1] Collinson stresses the need for "understanding rather than quantifying the farming system" (p. 4), and asks whether whole farm modelling and the quantification it requires can do more than marginally improve understanding.

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[1]Methods developed at ICTA (Hildebrand) and CIMMYT (Collinson; CIMMYT) are two examples of the latter approach.

This paper presents some evidence on the strengths and weaknesses of modelling and large-scale farm management surveys with respect to understanding farm household behavior, based on a recent simulation study of farm households in northern Nigeria (Crawford, 1980a,b). Without citing the full results of the study, it is possible to suggest circumstances in which quantitative modelling has a useful role to play in conjunction with other FSR activities taking place on the experiment station or in farmers' fields.

The paper first describes the objectives and setting of the study and the main components of the model, in part to illustrate how the farming systems approach was incorporated. Second, the analysis undertaken with the model is outlined and selected results discussed to illustrate the value of a comprehensive rather than partial approach. Third, implications of the study for rapid versus detailed survey methodologies are considered. Conclusions are then presented.

Objectives and Setting of the Study

The objective of the study was to examine the effect of variable crop yields, physical resource limitations, and family size on the growth of income and consumption among traditional small farm households in the dryland savanna zone of northern Nigeria. Particular emphasis was given to seasonal cash and subsistence food requirements, and to the interaction of these constraints with weather-induced variability in crop yields and returns over time.

The study was based on data obtained from a comprehensive farm survey conducted during 1974/75, as described in Matlon. Households in the area produce both for home consumption and for the market, using traditional hoe technology. Principal crops (grown in mixtures) are millet, sorghum, groundnuts, cowpeas, onions, sugar cane, and vegetables. Off-farm activities are an important source of income.

The Model

The study develops a simulation model which covers a series of farm household situations common to the area. The principal components of the model are shown in Figure 1:

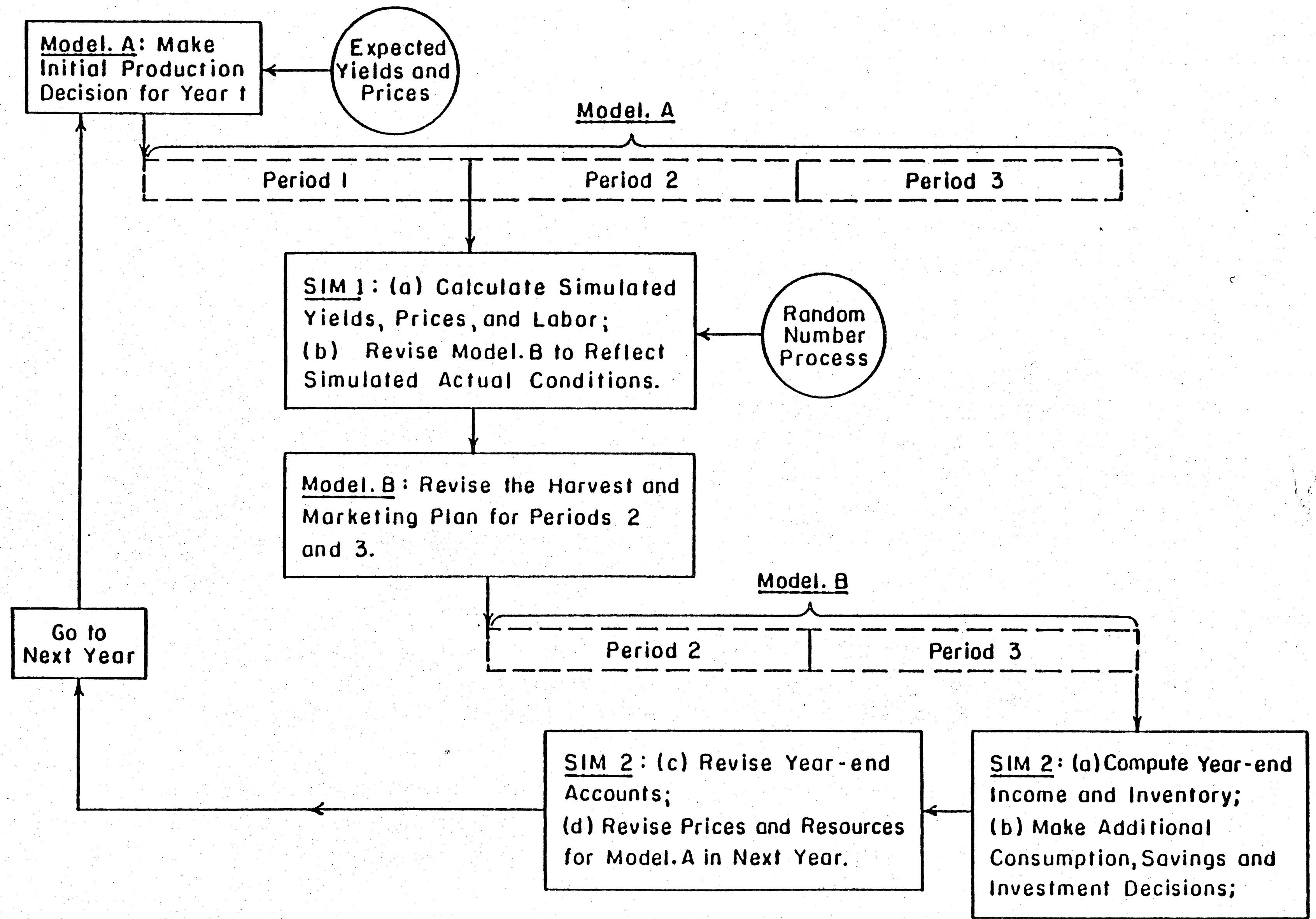
1. A stochastic production/marketing model which maximizes net farm income subject to resource availability and basic consumption needs, solved in two stages each year using multiperiod linear programming (MLP).

2. Two user-written simulation routines: (a) SIM1, which generates stochastic crop yields, investment returns, special consumption expenditures, and derived crop prices and harvest yield requirements; and (b) SIM2, which allocates surplus income among consumption, savings, and investment, and uses the final solution for each year to update the prices, investment activity levels, and resource availabilities incorporated in the production/marketing model for the following year.

As shown in Figure 1, the two stages of the MLP component are referred to as "Model.A" and "Model.B." Model.A is divided into three time periods covering the main phases of the farm operation: land preparation, planting, and weeding (Period 1); initial harvest and marketing (Period 2); and final harvest, marketing, and dry season activities (Period 3). The basic version of Model.B is simply a subset of the rows and columns of Model.A. Following the ex ante farm plan generated by Model.A, the average yield, price, and labor coefficients in Model.B are replaced by randomly determined "actual" values. Given the cropping plan and resources available at the end of Period 1 of Model.A, and the "actual" coefficients, Model.B is then solved to give a revised output and income position. This serves as the input for the year-end consumption, savings, and investment decisions. The results of these decisions are used to revise the prices and resource levels in Model.A for the following year. Model.A is then re-solved, and the process continues.

A major emphasis of the study--the behavior of the farm household over time--provides the principal justification for employing the simulation approach. The

FIGURE 1. FLOW CHART OF MODEL COMPONENTS AND DECISION POINTS.



aim was to go beyond a static, one-year analysis of the farm system and its constraints. In a sense, the nature of the farming system and its environment demanded a systems simulation methodology. Farm and household activities interact with off-farm occupations. Crop yields, investment returns, and major consumption expenditures fluctuate widely from year to year. Under these circumstances, simple linear projections over time, based on alternate initial assumptions, would not provide the depth or accuracy of analysis that a stochastic, recursive model allows.

The flexibility of form which the simulation approach allows makes it possible to incorporate many of the complexities of real farm household systems (Johnson and Rausser), such as a sequential decision process involving multiple goals, as well as the interaction between family size and resource characteristics (Vincent). A theoretical model of this degree of complexity would be impossible to evaluate analytically, especially in a dynamic context (Naylor).

Analysis and Results

The analysis carried out during the study includes: (1) calculation of input-output relationships for the common intercropped mixtures used as production enterprises in Model.A; (2) calculation of one-year farm plans for different household types, using only Model.A; (3) a set of deterministic runs of the full simulation model (Model.A, Model.B, SIM1, and SIM2 linked together), designed to identify key constraints and to investigate the effect of specified experimental factors such as household type, and predetermined sequences of crop yields, investment returns, and major family consumption expenditures on household income and consumption; (4) a set of 20 replications of the full stochastic model for each of two household types, with the values of stochastic variables randomly obtained from their respective probability distributions. Experiments conducted under (3) and (4) are referred to as "deterministic" and "stochastic," respectively.

Several findings of the study have implications for the issue of understanding versus quantification, and the relative merits of detailed surveys and modelling versus more rapid surveys and partial techniques. First, Matlon's survey was very valuable in documenting the great diversity which characterized his area despite its ecological homogeneity and traditional level of technology. It was therefore possible as well as desirable to incorporate several household types and a range of crop mixture types and production techniques in the model, rather than utilizing average categories. The use of average relationships would have given misleading results, a point noted by Palmer-Jones, and Upton and Casey. For example, the average labor profile for fields growing a given mixture will be smoother than the labor profile of a particular field. By underestimating peak labor demands, a model using average coefficients will not represent the labor constraint realistically.

A second, related, result suggests that models based on average yields and prices may overestimate the potential for income growth, at least for the poorer household types. It was found that average levels of accumulated net capital and total consumption per consumer, over the six-year time period of the experiments, were lower in the stochastic runs than in base runs where all stochastic yield and returns variables were fixed at average levels. The gap between stochastic and base run values was statistically significant at the .01 and .05 levels, depending on household type.

Two aspects of the model--both of which reflect observed complexities--explain this finding:

1. There is what might be called an efficiency loss which occurs in Model.B as a result of the sequential decision process. The cropping pattern which is formulated ex ante in Model.A cannot be changed in Model.B, although labor use, marketing, borrowing, and resource transfer plans can be altered. A cropping

plan which is optimal for the average yields and prices of Model.A is unlikely to be optimal given the particular set of simulated "actual" yields and prices incorporated in Model.B. The resulting ex post sub-optimality can reduce net farm revenue substantially.[2]

2. In the model, households can use cash reserves to invest in soil fertility improvements and non-agricultural occupations off the farm, e.g., trading. Threshold levels of working capital must be accumulated before these activities can be undertaken. Studies by Matlon and Hill indicate that the more profitable off-farm activities also have higher working capital requirements. Accordingly, if working capital can be accumulated steadily, the household will be able to engage in activities of increasing profitability, accelerating the growth of income over time. On the other hand, if surplus capital is reduced or wiped out by stochastic crop failures, investment losses, or special consumption obligations, the household must operate in the following year with fewer if any growth-inducing activities. Although crop yields were assumed to be symmetrically distributed, their effect on income growth was not. In a good year, not all additional income is devoted to on-farm or off-farm investment, since larger amounts are consumed or saved before investments are made.

A third result worth noting in this connection is that the importance of the cash constraint--emphasized by Matlon and Hill--was clearly revealed by the full multi-year simulation model, but not when Model.A was used alone. Although there was scope in the MLP model (Model.A) for the cash reserve to influence incomes and cropping patterns, it was not nearly as powerful a constraint as land and labor. Since cash inputs for crop production were low, cash reserves did not

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[2]In reality, farmers may employ a variety of methods for adjusting their farm plans during the season as additional information about growing conditions is gained. Nonetheless, some such losses are inevitable as events happen upon the farmer too quickly for effective adjustment to be made.

constrain the choice of production enterprises. In the full model, however, cash reserves are the crucial factor determining the extent to which the household can undertake on-farm improvements and off-farm investments which boost income over time. This helps illustrate the value of specifying a full range of household activities, and of conducting the analysis within a dynamic framework.

A fourth result was that the household with the poorest resource endowment (i.e., the lowest land/man ratio) not only experienced slower income growth and incurred emergency debts more often, but also experienced greater variability of income and consumption levels over time, by comparison to the better endowed household. This occurred because the poorly endowed household chose labor-intensive crop mixtures emphasizing grain rather than groundnuts, an optimal choice given relative prices and the household's abundant family labor supply and correspondingly large subsistence grain consumption needs. However, grain in the model had a higher yield variance than groundnuts, which predominated in the better endowed household's cropping plan. This adds weight to other findings (Sektheera) that differences in household types, expressed partly in terms of the land/man ratio, should be incorporated in the analysis.

Implications for Survey Methodology

Matlon's survey of three villages covered 35 households with twice-weekly interviews, and another 105 households in monthly interviews. The model described in this paper was constructed almost entirely from the 35-household sample, which provided an excellent picture of the range of farming conditions. The multiperiod linear programming model of Sektheera was based on a sample of 30 households in one village, which was judged adequate in that case. Rapid exploratory surveys can also reveal the diversity in an area, but would be unlikely to provide the detail needed for modelling of this kind. However, it does not appear necessary to mount detailed surveys covering hundreds of households, as done by World Bank projects in northern Nigeria. If the aim is to identify only the principal farm enterprise and the critical resource constraint, the rapid survey approach and partial budgeting can be utilized. On the other hand, a thorough evaluation of the impact of new technology or policies is likely to require some quantification of the full range of household activities. As Collison (p. 11) suggests, the trick is to identify key areas of the farm system where quantification is warranted.

An advantage of devoting survey resources to open-ended interviews by researchers rather than to administration of detailed questionnaires by enumerators, is that interviews can provide information on the pattern of events over time (costly to obtain via large-scale surveys), and on the crucial but hard-to-quantify sociocultural factors and of their impact on the farm system. Such information provides an understanding that is crucial to any analysis, including the design and use of models. For example, are there intangible barriers to investment in profitable off-farm enterprises? The financial ones may be obvious, but social and political status are also probably important. Or, what sociocultural factors affect how farm households allocate surplus income to consumption, savings, and investment? These are important questions when evaluating the survivability or income growth prospects of different household types. However, it is difficult to deduce the answers by relying only on numerical survey results.

In addition to missing important sociocultural information, large-scale surveys do not provide a sufficiently accurate picture of sensitive variables such as income and assets which are important in economic analysis (Palmer-Jones). Moreover, even the most comprehensive farm management surveys may lack information on field-level soil, rainfall, and pest conditions, or on plant density. Physical and agronomic information of this kind is essential for the analysis of production relationships. Such information was not collected by Matlon, largely because of the inherent difficulty of obtaining such measurements without the participation of technical scientists. Accordingly, it proved very difficult to fully analyze the sources of observed variability--in terms of labor inputs and crop output per hectare--among the different fields growing a given crop mixture type.

Conclusions

This paper has attempted to illustrate some of the benefits of quantification and modelling in understanding farm household behavior. Unless the objectives of farming systems research are limited to understanding the principal farming activities and resource constraints--as exemplified by CIMMYT's work in East Africa--it may be desirable to expand the scope of the study to encompass several sub-sectors of the rural household and the range of variables which influence them. The extent to which information gained in rapid exploratory surveys can generate the range of data involved in more complex systems is something which further experience may answer.

It is clear, however, that large-scale farm management surveys cannot be expected to provide sufficient data for complete quantification of the farm system, even if this were desired. Where time and resources are limited, it may be desirable to collect less detailed economic information and broaden the survey to generate information on sociocultural and agroclimatic variables. Some of this information is best collected in open-ended interviews, where multidisciplinary teams employing rapid exploratory survey methods have the comparative advantage. This approach may provide a more complete, profound understanding of the farm household than can be obtained from assembling the myriad pieces of data from a large-scale survey.

There are circumstances in which simulation modelling may be a worthwhile adjunct to experiment station or field-based FSR, despite the recognized data, expertise, and computer requirements of the modelling approach. For example, testing prototype technology via on-farm trials is an essential process, but a slow, sometimes expensive, and expertise-demanding method itself (Collinson, p. 11). Where the manpower and computational resources are available (e.g., at an international research center, or middle-income or developed country institution), simulation studies might usefully proceed side by side with on-farm trials, facilitating a timely assessment of the sensitivity of new technology under different assumptions regarding household type and environmental variability. The analysis can easily be extended over a five to ten year period, guarding against the possibility that the modified farm system might be subject to unacceptable cumulative, seasonal, or bad-year losses. Such losses are unlikely to be picked up in a single-year analysis which relies on average returns to evaluate profitability. The improved evaluation of the dependability of returns which the simulation approach can afford would be particularly helpful where there are many marginal farmers, and/or where weather conditions are highly variable.

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