PN-AAM-624
ISN 27979

Farming Systems Research Group
Michigan State University

The Farming Systems Research Group at Michigan State University, supported by Title XII Strengthening Grant Funds from the U.S. Agency for International Development, and administered by the Institute of International Agriculture, has included Dr. Jay Artis, Department of Sociology; Dr. Robert J. Deans, Department of Animal Science; Dr. Merle Esmay (and Dr. Robert Wilkinson), Department of Agricultural Engineering; Dr. Eric Crawford, Department of Agricultural Economics; Dr. Russell Freed, Department of Crop and Soil Sciences (also representing Horticulture); Dr. Al Pearson, Department of Food Science and Human Nutrition; Dr. Tjaart Schillhorn Van Veen, Department of Veterinary Medicine; with Dr. George Axinn, International Studies and Programs and Agricultural Economics, Chair, and Ms. Beverly Fleisher, graduate research assistant.

FARMING SYSTEMS RESEARCH AND AGRICULTURAL ECONOMICS

by Eric W. Crawford

Working Paper No. 1

June, 1981

THE MICHIGAN STATE UNIVERSITY FARMING SYSTEMS RESEARCH GROUP

WORKING PAPER SERIES

Paper No.	Title	Author
1.	Farming Systems Research and Agricultural Economics	Eric Crawford
2.	Farming Systems Position Paper	Al Pearson
3.	Livestock Systems and Animal Health	Tjaart Schillhorn van Veen
4.	Issues in Farming Systems Research -- an Agronomist's Perspective	Russell Freed
5.	Farming Systems Research As It Relates To The Animal Sciences	Robert J. Deans
6.	Farming Systems Research Position Paper	Jay Artis
7.	The Farming Systems Research Approach in the Agricultural Engineering Field	Merle L. Esmay
8.	Issues in Farming Systems Research -- a Multidisciplinary Behavioral Science Perspective	George H. Axinn
9.	Farming Systems Research and Agricultural Engineering	Robert H. Wilkinson
10.	An M.S.U. Approach to Farming Systems Research	Beverly Fleisher and George H. Axinn
11.	The M.S.U. Farming Systems Research Group Perspective	
12.	A Working Bibliography on Farming Systems Research - August, 1981	
13.	Social Impact, Economic Change, and Development -- with illustrations from Nepal	George H. Axinn and Nancy W. Axinn

June, 1981 WORKING PAPER #1

Farming Systems Research and Agricultural Economics

by Eric W. Crawford*

Background

In its initial form, this paper was intended to [illegible] within the Michigan State University Farming Systems Research Working Group. At the outset, we agreed that it would be desirable to establish a common understanding of what farming systems research (FSR) was all about. We also hoped to learn something about the perspective, concepts, and methodology of the different disciplines represented within our group. As we attempted to define basic terms such as "farming system," not to mention "farming systems research," it quickly became apparent that reaching this common understanding across disciplines would not only be more time-consuming but also more important than originally expected.

In the discussion papers, we therefore attempted to set forth our preliminary understanding of FSR, how it related to other types of research and problem-solving activities in our respective disciplines, and how the involvement of other disciplines would contribute to our own work in FSR. The papers were not an effort to advance the frontier of any particular discipline, but rather to communicate enough of the perspective of each discipline so that henceforth we could operate on the same wavelength. The papers--at least this one--also reflect a personal viewpoint and a necessarily selective picture of the disciplines represented.

*Assistant Professor of Agricultural Economics, Michigan State University.
Many thanks to other members of the FSR Working Group, and to Warren Vincent, for helpful comments on earlier drafts of this paper.

What is Farming Systems Research?

In defining farming systems research (FSR), I feel it is desirable to distinguish between the following two categories:

1. Research on the farming system (RFS), principally characterized by a holistic or systems view, i.e., a focus on some or all major elements and interactions of the farm operation, rather than on individual components such as particular crop or animal production activities. RFS is therefore a broad category of research. It encompasses but is not limited to disciplinary research, i.e., research aimed at improving the theory or analytical methods of a given discipline, provided the work is systems rather than component oriented. Examples include simulation or econometric studies of the farm household. In my view, RFS does not necessarily involve either a multidisciplinary team approach or contact with the farmer.

2. Farming systems research (FSR), described by Hildebrand (1977), CGIAR/TAC 1978), and Gilbert, Norman, and Winch (1980), and carried out largely in the international arena. To me, FSR is a subset of RFS. Its distinctive features are: (a) implementation by a multidisciplinary team of scientists; (b) close contact between researchers and farmers; (c) recognition of farmer goals and the relationship between the human and technical aspects of the farming system; (d) an orientation toward generation of locally suited technology for improving the productivity of the farming system; and (e) an emphasis on field level rather than experiment station research activity.

The term "farming systems research" has been applied to programs which vary significantly along several dimensions: (1) degree of farmer involvement; (2) scope in terms of how many farming systems components and linkages are considered; (3) size of the "recommendation domain" of the research, i.e., the breadth of the region or farm type for which the research is relevant; (4)

extent of experiment station versus farm level activity; and (5) degree of multidisciplinary involvement.[1] Programs labelled as FSR include those which focus only on the cropping system or even more narrowly on particular key crops such as maize, rice, or wheat, and those which are carried out largely by biological scientists on the experiment station. Disciplinary studies which are not oriented to technology generation are not commonly labeled as FSR, yet I think they can be important sources of knowledge about the farming system. This is why I define the broad category of RFS.

At the urging of international donors, FSR has been recently promoted and undertaken largely by researchers concerned with small farm agriculture in the Third World, whether at national or international research centers. However, the FSR methodology is potentially suited to small and large farms alike, and to North American and European farms as well as those in the Third World. Nonetheless, the capacity of FSR to examine complex multi-enterprise farming systems and to "give a voice" to the farmer is probably more beneficial in Third World agriculture than in North America and Europe, where farms tend to be more specialized and where farmers have the resources and education needed for them to represent their own interests to the research and extension estab-

---

[1]For the sake of comparison, the definition of FSR given by Gilbert, Norman, and Winch (1980) may be quoted in part:

> Farming systems research views the farm or production unit and the rural household or consumption unit--which in the case of small farmers are often synonymous--in a comprehensive manner. FSR also recognizes the interdependencies and interrelationships between the natural and human environments. The research process devotes explicit attention to the goals of the whole farm/rural household and the constraints on the achievement of these goals. (GNW, 1980:2-3)

They prefer the term FSR for research which includes the active participation of the farmer. They also state: "Research on a sub-system can be considered part of the FSR process if the connections with other sub-systems are recognized and accounted for." (GNW, 1980: 3)

lishment. For small or part-time farmers in developed countries, FSR may have the same benefits it does in Third World countries.

What Does FSR Have to Offer?

From the standpoint of agricultural economics, FSR potentially contributes to problem-solving by improving understanding of the farming system, and by enabling more effective development of technology for raising farm productivity. Improved understanding results from: (1) description and analysis of interdependencies among components of the farming system, and between the farm household and its environment; (2) the conceptual perspective on goals, constraints, and processes brought from other disciplines represented on the FSR team; and (3) insights gained from including the farmer's viewpoint.

Improved understanding has a disciplinary payoff in terms of more powerful theory and analytical methods for research on the farm household.[2] Improved understanding also leads to better diagnosis of problems and constraints within the farming system, and hence to the development of more productive agricultural technology via new varieties, input combinations, cultivation practices, etc. Thus, there is a close tie between problem identification and prescription of solutions.

A domestic U.S. application of the systems approach to problem-solving is research on integrated pest management. Chemical pest control is replaced by a combination of biological and chemical controls, changes in crop mix and cultivation, and more careful monitoring of pest populations. This approach relies on information from several disciplines, including entomology, soil and plant science, agricultural economics, and agricultural engineering, as well as from the farmer. In West Africa, research on animal traction also

---

[2]By "more powerful" I mean having greater scope and/or predictive accuracy.

represents a systems approach to problem-solving. Low productivity and declining soil fertility under hand hoe bush fallow farming is addressed by a mixed animal/crop farming system in which animal power breaks labor bottlenecks, allows the incorporation of manure and crop residues to improve soil fertility and thus crop yields, and provides a source of non-farm revenue from animal-drawn carting.

The international brand of FSR was developed largely to address the problem of lack of adoption of improved agricultural technology. Low adoption rates were a sign that important factors had been excluded in the technology design process. FSR was intended to account for these missing factors, such as: (1) interactions involving crop and animal enterprises and farm and non-farm activities; (2) the performance of the technology under actual on-farm conditions; and (3) economic and socio-cultural factors affecting acceptability. Whether FSR—so defined—will in fact successfully overcome the "adoption problem" remains to be seen.

Principles and Concepts of Agricultural Economics re: FSR—Background for the Non-Economist

In studying a farming system, what analytical structure would be employed by an agricultural economist? What variables and relationships would be examined? The following is a cursory and personally selective discussion of these questions.

Farm households are considered to engage in several categories of economic activity: production, consumption, marketing (buying and selling of goods and services), and saving and investment. A common "reductionist" approach is to study each of these activity categories in isolation from the others. However, recent theorizing (both for U.S. and Third World farm types) has emphasized the joint nature of these activities and the decisions

involved.[3] For example, what the farm household produces is determined in part by what it needs for consumption. Such interdependencies are particularly salient for semi-subsistence farm households. This implies the need for a more holistic approach, which has led to development of the "theory of the farm household."

A thumbnail sketch of the theory of the farm household includes the following elements:

1. Households are assumed to maximize utility subject to various constraints. Utility is derived from household-produced farm and non-farm goods, goods purchased from the market, and leisure. Goods and leisure generate utility when they are consumed.
2. The constraints on utility maximization include:
   (a) household production functions for farm and non-farm goods;
   (b) a time availability constraint (time is used as an input to household production, as well as for leisure);
   (c) a budget constraint, which states that total expenditures must be no greater than total income (including wage earnings and income from assets).

As one moves from pure theory to applied research and farm management studies, the variables and functional relationships associated with the farm household must be specified in more concrete detail. Information of the following type is commonly sought:

1. Resource inventories. Economics is concerned fundamentally with the allocation of resources to achieve specified goals. Thus, a starting point is the identification of the stocks of resources held by

[3]The next section of the paper contains a more detailed discussion of these points.

the household, including land, buildings and machinery, working capital, family labor, and crop and livestock holdings.

2. Resource utilization. What are the flows of resources through the farm system? Such flows include labor use, cash flow, machinery use, etc. A high proportion of the data collected by large-scale farm management surveys in the Third World results from documenting these resource flows. Since household activities compete for a common set of resources, it is important to determine the flows of goods and services among components within the farm household system.

3. Description of household activities.

   a. Farm production:

      — crop and livestock enterprises (rice, dairying, etc.)

      — production operations (weeding, harvesting, etc.)

   b. Non-agricultural activities, including domestic household tasks, crafts, trading, and other self-employed occupations undertaken by household members.

   c. Other off-farm activities, primarily wage employment.

4. Functional relationships and technical parameters.

   a. Technical input-output coefficients for the production processes.

   b. The parameters of household consumption demand.

   c. Marketing relationships, e.g., the timing and characteristics of items purchased and sold.

   d. Saving and investment behavior.

5. Costs and returns. These are a function of prices, which are a key economic variable.

a. Operating costs associated with production and marketing.

b. Fixed costs, e.g., depreciation, interest, taxes, insurance, etc. These are the costs of owning capital assets.

c. Sale prices for farm output; purchase prices for farm inputs and family consumption items.

d. Wage rates for labor

6. Goals, attitudes and operating procedures.

a. Household goals, i.e., what does the household wish to achieve through the use of its resources? Are its goals primarily profit or growth oriented, or more concerned with security and maintenance of family well-being?

b. Preferences, including preferences for one type of farm activity (e.g., cropping) over another (e.g., livestock raising). Attitudes toward risk are also important.

c. Operating procedures. Does the farmer have standard methods or strategies which he follows in making decisions, e.g., strategies for reducing the impact of uncertainty in the production process?

7. Institutional and environmental variables.

a. How do the markets for resources function: for farm inputs and outputs, for land and labor, and for credit? Does the farmer have access to these markets? How reliable are they?

b. What is the physical environment of the farming system: soils, rainfall, altitude, etc.?

c. Related to (a), are there important rules affecting access to resources, such as rules governing land allocation and land tenure?

Household goals and preferences, and institutional and socio-cultural variables, are a special focus of social scientists, including agricultural economists. Consequently, one of the appropriate contributions of the agricultural economist as an FSR team member is to view the farming system within the larger institutional and policy framework, and to evaluate the impact of market and price factors on the farm household's welfare.

Implementing FSR: Some Disciplinary Challenges

In previous discussions of the problems of organizing and implementing a FSR program, the focus has been on the difficulties of a multidisciplinary team approach, and on procedures for on-farm research (Norman, 1980; Rohrbach 1980; CGIAR/TAC, 1978). Relatively little attention has been paid to ways in which the analytical state of the art in the various disciplines poses obstacles to successful research on farming systems.

In this section of the paper, I will try to sketch a few of the principa theoretical, methodological, and empirical data limitations on the economic analysis of the farm household system. My emphasis here is on the broad stud of existing farming systems and their response to proposed new technology or policies, rather than on FSR for experimental development and field testing o new technology.

As in any systems approach, FSR does not require exhaustive enumeration of system activities, but entails instead a focus on the essential ones. The premise of FSR is that the study of farm households will be strengthened if the scope of analysis is broadened to incorporate formerly neglected activities and interactions which are now recognized as crucial for understanding household behavior.

This implies an increase in analytical complexity along several lines. First, recognition that rural households are diverse rather than homogeneous,

and that variability in agroclimatic environment leads to location-specific constraints and opportunities, calls for analysis of many rather than a few household types. Second, the holistic perspective of FSR calls for an increase in the number of household activities considered in the analysis. Livestock activities are important and should be viewed in conjunction with cropping activities (McDowell and Hildebrand, 1980). It may often be desirable to examine self-employed non-agricultural enterprises in addition to on-farm production and off-farm wage employment. Related to this is a requirement for expansion of the set of variables which enter the analysis. This stems both from the larger number of activities being studied, as well as from the recognition that agroclimatic and socio-cultural factors have economic relevance.

Third, the analysis of farm household decisions must reflect reality more closely. Aspects of importance are: (1) multiple goals and sequential decision-making; (2) intrahousehold patterns of resource allocation; (3) the interdependence between production decisions and those concerning credit, marketing, consumption, savings, and investment; and (4) a dynamic, long-term decision framework incorporating uncertainty.

Fourth, there is a need to recognize the interaction of the household with its surrounding social and institutional environment. The analysis should consider macro factors (market processes, institutions, and policies) which impinge on the farm.

Farming systems studies are therefore threatened with the "curse of dimensionality"—so many factors to analyze that a solution to the research problem may be infeasible (Anderson and Hardaker, 1979). Agricultural economists must not only learn to effectively integrate expertise from specialized fields within their own discipline (e.g., production, consumption, investment,

marketing, decision-making under uncertainty), but also from biological and physical sciences, and other social sciences. This is an intellectually demanding process, even for systems scientists who are at home with a holistic rather than reductionist focus (Dillon, 1976).

Can this be accomplished within current theory and methodology in agricultural economics? This question is clearly beyond the scope of a short paper, but let us briefly examine the current disciplinary capacity to: (a) incorporate household activities and interactions more comprehensively; and (b) incorporate more realistic decision-making processes.

Expanding the scope of analysis is constrained partly by the available theory. Neoclassical microeconomics has traditionally examined the household's producer and consumer behavior separately. Beginning at least with Mellor (1965), efforts have been made to integrate production and consumption decisions in a household framework.[4] Nakajima (1969) developed essentially neoclassical models for subsistence and commercial family farms which incorporated consumption and labor market participation, but not non-agricultural production or (explicitly) leisure. Becker (1965) introduced the concept of the household as a producing not just a consuming unit, with domestic commodities produced with factors including time. Many recent economic models of the agricultural household, e.g., Barnum and Squire (1979), draw on Becker's work. The interdependence of production and consumption decisions within the Barnum and Squire model is accomplished technically by specifying consumption elasticities which contain terms for the effect of exogenous variables on farm profits, and hence on household income and consumption.

---

[4]Chayanov's much earlier model (1966, written in the early 1900's) of the peasant household was holistic, but his definition of the peasant household as relying entirely on family labor has restricted relevance today.

The advantages of such models are: (1) they examine the household in an integrated framework which is consistent with the accepted theory of producer and consumer maximizing behavior; (2) their format and assumptions are by now fairly standard, hence easily interpreted by other researchers; (3) when expressed in mathematical form their properties (e.g., elasticities) can be derived rigorously.

Several offsetting disadvantages should be noted. First, identifying the utility maximizing solution to such models and their corresponding elasticities often requires the imposition of so many simplifying assumptions that only very un-complex household types can be analyzed. For example, although the model of Barnum and Squire includes only one variable input (labor), and two outputs (rice and domestic goods) which are consumed along with leisure and a purchased good, they found it necessary to limit the complexity of the problem even further ". . . by omitting certain decision variables in order to arrive at a solution that has policy content."[5] (Barnum and Squire, 1979: 31).

A second, related disadvantage is the frequent need to restrict the functional form of theoretical models in order to ensure the existence of mathematical solutions. The result may conflict drastically with theoretical axioms or observed reality. Third, although complexities such as multiple goals, sequential decision-making, behavior over time, and stochastic variability have each been explored extensively in the literature (Day, 1977; Day and Sparling, 1977), to this author's knowledge they have not yet been incorporated jointly in theoretical models of the farm household. Fourth, except

---

[5]An extension of this model (Ahn, Singh, and Squire, 1979) incorporated production of several crops using several inputs; farm commodities and profits generated from a linear production system are fed into a linear expenditure system to determine household consumption.

in linear models, the assumption of joint production or multiple inputs and outputs tends to make solutions extremely tedious to obtain, or indeterminate (Pollak and Wachter, 1975; Hart, 1978). Lastly, models of the household are generally employed in the short run comparative statics context in which it is possible to evaluate only small changes under ceteris paribus conditions.

Overall, theoretical models abstract from reality in a way which emphasizes consistency, rigor, and computational convenience. This is more appropriate in the context of disciplinary research than it may be in the context of problem-solving research, which is the prime focus of FSR. Such models are most useful in analyzing relatively simple farming systems (e.g., Asian rice monoculture)[6] where restrictive assumptions and a short run perspective are justifiable.

Ability to expand the scope of farming systems studies is also limited by available quantitative methods used to model the farm household. These methods fall under three headings: econometrics, linear programming, and systems simulation.

Econometric models are attractive in part because comparatively well-accepted procedures are available for estimating and evaluating their structural parameters. Econometric models can potentially incorporate features such as behavior over time and stochastic variability. For example, random coefficients production models have been discussed by Swamy (1974), Mount (1974), and Harville (1977), although apparently they have not yet been applied to an integrated farm household model.

Linear programming (LP) has been a powerful, widely used tool. It is flexible enough to incorporate features such as multiple inputs and outputs,

---

[6]Such farming systems are simple only in the sense that the production process can be approximated in terms of one output and a few inputs.

behavior over time, and the effect of uncertainty. One drawback of LP models is their inherent tendency to give unrealistically one-sided optimal solutions, e.g., over-specialized cropping patterns. Also, very careful scrutiny is needed to establish whether an LP model is sound, or whether apparently plausible results were "forced" by artificial, a-theoretical manipulation of constraints.[7]

Systems simulation models offer even greater flexibility of form. Complex features can be readily accommodated and solutions still obtained (Johnson and Rausser, 1977; Crawford, 1980a). Model specification can be eclectic and behavioral, facilitating use in problem-solving research (Johnson, 1977). The principal drawback is that simulation models often cannot be proven theoretically consistent. A related problem is the inadequacy of standard statistical procedures for evaluating how well a simulation model performs; considerable subjective judgment is also required.

Other difficulties arise in modelling the link between events at the individual farm level and aggregate effects at the macro level. FSR focuses primarily on the farm level, but the literature generally recognizes the importance of national policies and the regional agricultural economy as factors influencing the appropriate direction of new technology development. However, both theoretical and quantitative models are limited in their ability to predict the macro effects of introduced new technology or policy interventions. At the formal level, there are problems of bias in aggregating the results of individual farm models to obtain a picture of regional impact (Day, 1963); in general, it is not legitimate to assume that the whole is equal to the sum of the parts. In addition, evaluating the impact of new technology or

---

[7]This drawback is shared to some extent by econometric and systems simulation models.

policy interventions depends on the ability to analyze regional product and factor markets. This moves the domain of the analysis from a partial to a more general equilibrium framework, unless the situation can safely be simplified. Also, it is clear that the economic impact of a given development intervention is heavily influenced by institutional and socio-cultural variables. However, rigorous prediction of socio-economic effects over time and on a macro level is not yet feasible given available theory and analytical methods in the social sciences.

Empirical Data Limitations

Achieving the holistic FSR approach will require better descriptive and analytical understanding of several sub-systems of farm household activity which hitherto have often been excluded. Perhaps the most important of these is livestock activities, as noted above. Other areas deserving greater attention are: (1) self-employed non-agricultural occupations undertaken by farm household members; (2) intrahousehold resource allocation and decision-making; and (3) production and consumption/savings/investment behavior over time. All four areas (including livestock) have been difficult to research for reasons of required researcher mobility (in studying transhumant herders), access to information (on self-employed and intrahousehold activities, often involving women), and the cost and delay involved (time series data).

Current data collection methodologies are not entirely adequate, even for partial analysis of farming systems. The recognized importance of considering the diversity in farm household types and their agroclimatic environments--rather than assuming homogeneity within broad categories (Crawford, 1980b; Gerhart, 1975; Palmer-Jones, 1978) -- has encouraged reliance on detailed large-scale farm management surveys. However, such surveys do not always allow for the collection of the agronomic and socio-cultural information

needed for accurate identification of farm level constraints, or for the analysis of complex features such as intercropped mixtures. Moreover, certain kinds of information which may be crucial even for narrow economic analysis--income, assets, food reserves--are known to be sensitive and hard to elicit from respondents (Palmer-Jones, 1977).

As an alternative, the rapid survey technique used by some FSR practitioners is less costly and easier to supervise. It brings knowledgeable researchers into direct contact with farmers, using open-ended interviews in place of minutely detailed questionnaires administered by enumerators. By comparison to cost-route farm management surveys, from whose details the essence of the farming system must be deduced, rapid surveys obtain less detail but allow for the application of inductive reasoning and informed intuition. Accordingly, they may ultimately give rise to a more profound understanding of the farming system. A variant of this approach has been developed by CIMMYT in East Africa (Collinson, 1979).

The Role of the Agricultural Economist in FSR

Although there is room for improvement in the systems research capacity of the disciplinary tools of agricultural economics, agricultural economists have a practical role to play in FSR programs at international and national research centers, and as members of development project teams. As part of the general goal of FSR, work by agricultural economists leads to improved understanding of existing farming systems. The particular contribution of agricultural economists stems in part from the level at which they study the farming system, namely the level of the whole farm or household rather than the level of the plant/soil/water complex. Moreover, while assessing costs and returns and resource constraints at the farm level is useful in solving some farmer problems, economic analysis can and should define the farming system's

boundary more broadly, so that linkages with market institutions and the effects of input/output price relationships are also examined. Because these factors are critically important in determining the appropriate characteristics of new technology, the FSR team has the opportunity to obtain an indispensable contribution from the agricultural economist.

In turn, a wide range of disciplines can potentially assist in the solution of economic problems by elucidating critical variables, functional relationships, and constraints. For example, in studying investment behavior (or the disposition of unspent income), it is desirable to know how social and cultural factors determine the availability of investment opportunities and who is allowed to take advantage of them. Or, in formulating a set of improved cropping plans for farmer adoption, it is desirable to know which crops are suited to local soils and rainfall, what their growing period is, how yields respond to different cultivation practices, etc. More generally, the economic feasibility of new technology or policy interventions is inextricably tied to questions of technical, institutional, and socio-cultural feasibility.

From a methodological standpoint, several disciplines are helpful in facilitating economic research. As a mundane example, in mounting a farm survey, geographers can suggest which agroclimatic zones are relevant in stratifying the sample, statisticians can advise on sampling technique and data analysis, biological scientists can advise on soil and water variables which affect crop and livestock yields, and anthropologists can advise on important cultural factors and techniques for informal interviewing.

REFERENCES

Ahn, C. Y., Inderjit Singh, and Lyn Squire. 1979. "A Model of an Agricultural Household in a Multi-Crop Economy: The Case of Korea." Invited paper presented at the XVII Conference of The International Association of Agricultural Economics, Banff, Canada, September 3-12.

Anderson, Jock R., and J. Brian Hardaker. 1979. "Economic Analysis in Design of New Technologies for Small Farmers." Economics and the Design of Small-Farmer Technology, Alberto Valdes, Grant M. Scobie, and John L. Dillon (eds), pp. 11-26. Ames: Iowa State University Press.

Barnum, Howard N., and Lyn Squire. 1979. A Model of an Agricultural Household: Theory and Evidence. World Bank Staff Occasional Papers No. 27. Baltimore: John Hopkins University Press.

Becker, Gary S. 1965. "A Theory of the Allocation of Time." Economic Journal. 75: 493-517.

Chayanov, A. V. 1966. The Theory of the Peasant Economy. Homewood: Richard D. Irwin.

Collinson, Michael. 1979. "Micro-Level Accomplishment and Challenges for the Less Developed World." Paper presented at the XVII Conference of the International Association of Agricultural Economics, Banff, Canada, September 3-12.

Consultative Group on International Agricultural Research, Technical Advisory Committee (CGIAR/TAC). 1978. "Farming Systems Research at the International Agricultural Research Centers." Mimeo. September.

Crawford, Eric W. 1980a. "A Stochastic Farm System Simulation Model, with Emphasis on Experimentation." Department of Agricultural Economics Staff Paper No. 80-81, Michigan State University, East Lansing, Michigan.

_____. 1980b. "Understanding, Quantification, and Modelling in Farming Systems Research: Results of a Simulation Study in Northern Nigeria." Department of Agricultural Economics Staff Paper No. 80-19, Michigan State University, East Lansing, Michigan.

Day, Richard H. 1977. "On Economic Optimization: A Nontechnical Survey." A Survey of Agricultural Economics Literature, Vol. 2: Quantitative Methods in Agricultural Economics, 1940 to 1970s, George G. Judge et al. (eds), pp. 57-92. Minneapolis: University of Minnesota Press.

_____. 1963. "On Aggregating Linear Programming Models of Production." Journal of Farm Economics. 45:797-813

Day, Richard H., and Edward Sparling. 1977. "Optimization Models in Agricultural and Resource Economics." A Survey of Agricultural Economics Literature, Vol. 2, Judge et al. (eds), pp. 93-127. Minneapolis: University of Minnesota Press, 1977.

Dillon, John, L. 1976. "The Economics of Systems Research." Agricultural Systems. 1: 5-22.

Gerhart, John. 1975. "The Diffusion of Hybrid Maize in Western Kenya--Abridged by CIMMYT." Mexico City: CIMMYT.

Gilbert, E. H., D. W. Norman, and F. E. Winch. 1980. Farming Systems Research: A Critical Appraisal. Rural Development Paper No. 6. East Lansing, Department of Agricultural Economics, Michigan State University.

Hart, Gillian P. 1978. "Labor Allocation Strategies in Rural Javanese Households." Ph.D. thesis, Cornell University.

Harville, D. A. 1977. "Maximum Likelihood Approaches to Variance Component Estimation and to Related Problems." Journal of the American Statistical Association. 72:320-338.

Hildebrand, P. E. 1977. "Generating Small Farm Technology: An Integrated Multi-Disciplinary System." Paper presented at 12th West Indian Agricultural Economics Conference, 24-30 April 1977, Antigua.

Johnson, Glenn L. 1977. "Contributions of Economists to a Rational Decision-Making Process in the Field of Agricultural Policy." Decision-Making and Agriculture, Theodore Dams and Kenneth E. Hunt (eds), pp. 25-46. Oxford: Alden Press.

Johnson, S. R., and Gordon C. Rausser. 1977. "Systems Analysis and Simulation: A Survey of Applications in Agricultural and Resource Economics." A Survey of Agricultural Economics Literature, Vol. 2, Judge et al. (eds), pp. 157-304. Minneapolis: University of Minnesota Press.

McDowell, R. E., and P. E. Hildebrand. 1980. "Integrated Crop and Animal Production: Making the Most of Resources Available to Small Farms in Developing Countries." New York: The Rockefeller Foundation, January, 1980.

Mellor, John W. 1965. "The Subsistence Farmer in Traditional Economies." Paper presented at the ADC Seminar on Subsistence and Peasant Economies, East-West Center, Honolulu, Hawaii, February-March.

Mount, T. D. 1974. "Applications of Variance Components in Economics." Cornell University, Department of Agricultural Economics Staff Paper 74/7.

Nakajima, Chihiro. 1969. "Subsistence and Commercial Family Farms: Some Theoretical Models of Subjective Equilibrium." Subsistence Agriculture and Economic Development, Clifton R. Wharton, Jr. (ed), pp. 165-185. Chicago: Aldine Publishing.

Norman, David W. 1980. "The Farming Systems Approach: Relevancy for the Small Farmer." Rural Development Paper No. 5, Department of Agricultural Economics, Michigan State University.

Palmer-Jones, R. W. 1978. "Peasant Differentiation in Rural Hausaland." Mimeo. Department of Agricultural Economics and Rural Sociology, Institute for Agricultural Research, Zaria, Nigeria.

_____. 1977. "Field Research Methods Used in Farm Management Studies." Mimeo. Department of Agricultural Economics and Rural Sociology, Institute for Agricultural Research, Zaria, Nigeria.

Pollak, R. A., and M. L. Wachter. 1975. "The Relevance of the Household Production Function and Its Implications for the Allocation of Time." Journal of Political Economy. 83:255-278.

Rohrbach, David D. 1980. "A Discussion of Issues Relevant to the Development and Implementation of a Farming Systems Research Program." Mimeo. Washington, D.C.: USDA/OICD.

Swamy, P.A.V.B. 1974. "Linear Models with Random Coefficients." Frontiers of Econometrics, P. Zarembka (ed). New York: Academic Press.