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THE EVOLUTION OF FARMING SYSTEMS RESEARCH: TOWARDS WHERE?

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The Evolution of Farming Systems Research: Towards Where?

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What is Farming Systems Research (FSR) and where does it come from? (See Davidson and Martin, 1965, for a forerunner of FSR concerns.) In the sixties and early seventies three agricultural economists were working with national institutions in developing countries -- Peter Hildebrand with ICTA in Guatemala, David Norman with Ahmedu-Bello University in Zaria, Nigeria, and Michael Collinson in East Africa. They were concerned with the production of new agricultural technologies. At that time many believed that the international centers for agricultural research[1] were not sufficiently concerned with the specific objectives and constraints faced by small farmers, hence it was necessary to go out to the field to describe the conditions and identify the constraints of small farmers. At the same time scientists from Colorado State were attempting to define alternatives to large scale irrigation projects by systematically evaluating the farm level demand for water. From these efforts supplemented later by the CIMMYT Economics Program and the Farming Systems Units developed at different International Centers,

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[1] There are now thirteen of these international centers with an approximate budget of 200 million dollars supported by international donors coordinated by the Consultative Group on International Agricultural Research (CGIAR)

especially IRRI and ICRISAT,[2] has come the present FSR approach (see Gilbert, et al., 1980; CIMMYT Economics Staff, 1981 and 1984; Collinson, 1982; Shaner, et al., 1981; Zandstra, 1979; Gomez, et al., 1979; and Norman, 1978).

The FSR approach reported in the literature is a resurgence of traditional pre-Heady farm management with some concern for research resource allocation. The basic tenets are the need for multi-disciplinary involvement in research design and evaluation and on doing simple applied analysis of real farm level problems with an avoidance of the sophisticated modeling presently practiced in much of the agricultural economics profession.

Before asking where FSR is going it is worthwhile to define FSR, look at some of its basic tenets or propositions, consider some specific problems of collaboration between biological and social scientists, and briefly evaluate the application of FSR in three different programs and two countries. The sections of this paper correspond to the above divisions.

An Overview of FSR

There are customarily three stages:

A. Base-line Surveys

B. On-Farm Trials

C. Evaluation and Processing

A. Base-line Survey. In this stage the farmers' conditions, objectives, and constraints to improving his well-being are described. This

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[2] The success of IRRI and ICRISAT in FSR can probably be attributed to the narrow focus or definition of their program. IRRI's FSR program, has been principally concerned with double-cropping after irrigated rice and ICRISAT's program has concentrated on the technical factors associated with low cost methods of providing supplemental irrigation.

process may be informal, such as the Hidebrand "sondeo"[3] technique, or through formal surveys. On the basis of this survey(s) on-farm trials will be designed. One recent objective of this surveying technique has been to define Recommendation Domains. These domains would delimit the area for consideration of a particular technology. For example, in defining the on-farm testing of new technology in Niger, a regional division by rainfall might indicate a concentration on millet where the rainfall is between 350 to 500 mm., sorghum in regions with annual rainfall of 500 to 750 mm, and corn at above 750 mm. Clearly, the distribution of rainfall within the crop season and the soil characteristics, including water retention capacity and soil fertility, would be additional, important factors. Other agronomic and farm characteristics may also be significant in defining the region within which given new technology(ies) would be considered.

B. On-Farm Trials. The basis of FSR is that farmers' incomes can be increased by adapting new technologies to their conditions. Most proponents argue that this new technology comes from the experiment station and that one of the principal clients for information on the performance of new technology in farmers' fields should be the personnel at the experiment station (Figure 1).

There is a wide range of techniques utilized in on-farm testing. Generally, on-farm trials put together various input combinations, which have been analyzed separately on the experiment station. The reductionist approach on the experiment station considers the impact of one factor at a time with the other factors held at high levels. On-farm trials combine

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[3] This is a step further than the windshield survey where the agricultural scientists drive through a region(s). It involves informal interviews with farmers and field visits by a multi-disciplinary team.

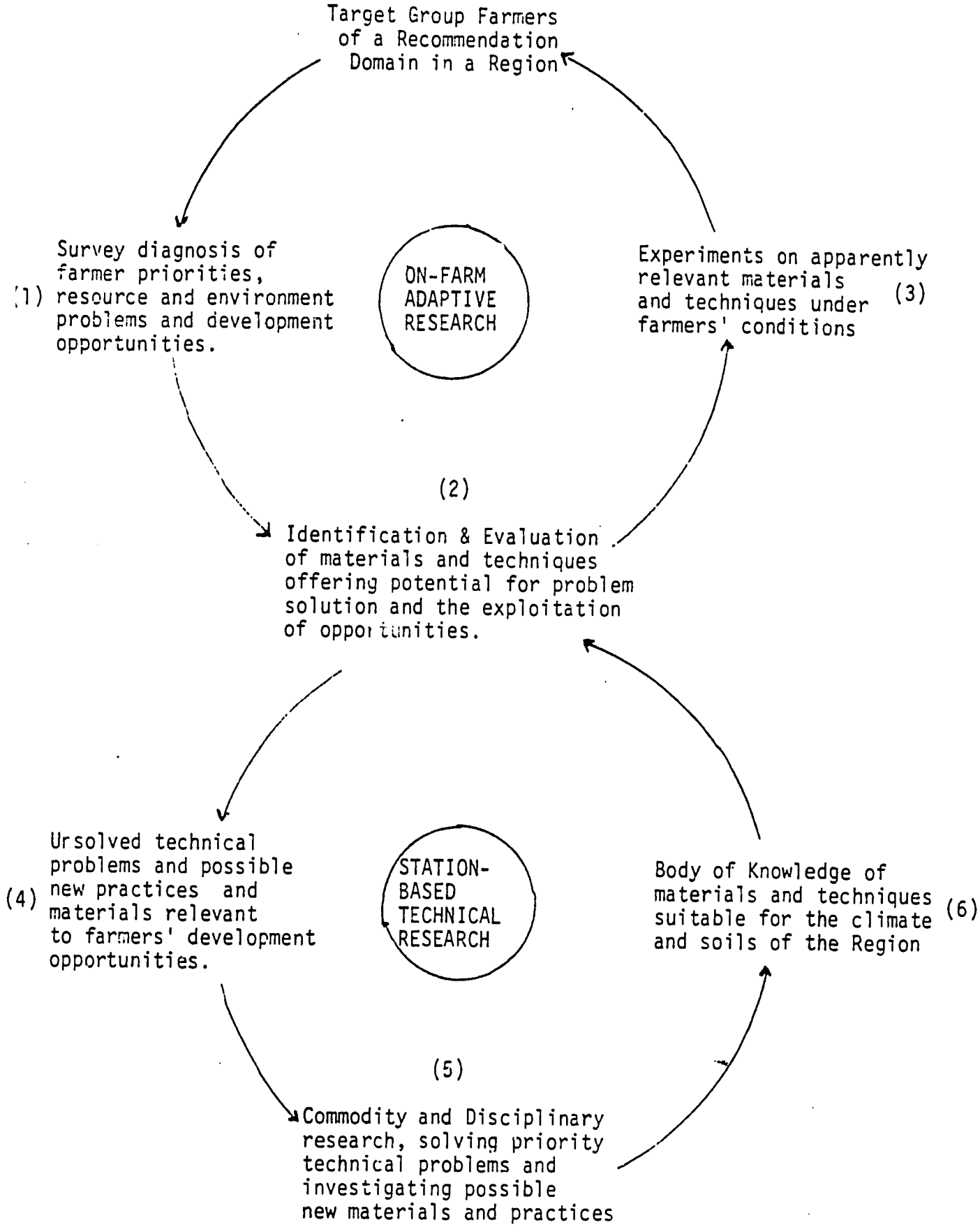

Figure 1. Interactions between Station-based Technical Research and On-Farm Adaptive research.

Source: M.P. Collinson, 1982, p.5

these component parts and evaluate whether some combination of components functions under the farmers' conditions.

On-farm trials have been divided into researcher and farmer-managed trials although there are also gradations between the two. The coefficients of variation[4] (CVs - $\frac{\text{standard deviation}}{\text{mean}}$) tend to be substantially higher in the farmer-managed than in the researcher managed trials, hence they would be less credible to the Experiment Station personnel. However, farmer-managed trials may influence more the Extension Service and other farmers. Farmer-managed trials may also provide information on the diffusion process through observation of the modifications made by the farmers to the component combinations.[5] However, the argument for utilizing farmer modifications to evaluate diffusion potential assumes that it is possible to identify the innovators. Adoption of a new technology generally takes place with an S-shaped or learning curve. Rural sociologists have invested substantial intellectual effort to identify early adopters. However, there has

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[4] These CVs are an arbitrary indicator of the quality of experimental data and are given almost religious significance by agronomists and some other but not all biological scientists. The real issue to economists and policy makers is the relative cost of Type I and Type II errors. Type I error is the rejection of the null hypothesis when it is true. Type II error is the acceptance of the null hypothesis when it is false. Translating this from statistical theory, an excessive concern with rejecting the new technology as not being any better than the farmers' practices will increase the probability that a new technology will be erroneously rejected. The cost of an error in making a recommendation of a particular technology to the extension service (or farmers) needs to be compared with the costs to the continued survival of an On-Farm Research Program when there is a long time delay before any recommendations are made. Many funders are not prepared to wait five to ten years for recommendations on new technology. They fund on-farm research because they believe that they will get a response in two to three years or even sooner.

[5] These component combinations of new technology used to be referred to in the fifties and sixties as technology packages.

apparently been no integration of this investigation into the FSR framework. If it were possible to clearly identify those farmers most likely to innovate, then the adoption and/or adaptation of new technology combinations by these farmers would be very useful information for those in the experiment station and those concerned with agricultural policy. Since little is known about innovators, the meaning of farmer adaptation and adoption or failure to adopt is uncertain. Hence, the Researcher-Managed On-Farm Trials with their lower CVs probably give more important information.

In the earlier stages of on-farm testing the principal clientele is expected to be those on the experiment station, and the principal product is feedback. In the later stages of on-farm testing the principal client is often the Extension Service, hence a sacrifice of statistical rigor may be appropriate to evaluate farmer behavior, in response to those technological options. More involvement of Extension in both types of on-farm trials would undoubtedly facilitate better linkages between farmers and the researchers at the experiment station.

C. Evaluation, Modeling. Once the data are in from the on-farm testing, they are often handled mechanically and the FSR researchers go charging off to other activities. Why? The on-farm trials are usually set up very simply, often there are no repetitions on the farm, and there is frequently confusion as to who the client is.

However,it is critical that the analysis and interpretation of the data be sufficient to provide feedback to the researchers at the Experiment Station and ultimately "feed-forward" to the Extension Service. Since farmers' objectives and constraints are complex, yield comparisons and simple budgeting are necessary but often not sufficient information. Mathematical modeling of the farms including the new prospective technologies may be necessary

to consider the interactions and the constraints, to evaluate the income increasing effects of new technologies, and the potential of various agricultural policies to release these constraints.

With this brief overview of the FSR process it is useful to summarize some basic propositions about FSR.

Some Basic Propositions About FSR

1. Farmer-oriented. The research focus will be defined by the present or anticipated constraints to raising farmer incomes. Since constraint identification tends to be biased by the discipline of the scientist, a multi-disciplinary approach to the definition of these constraints is necessary.

2. New agricultural technology comes from the Experiment Station. In the initial enthusiasm about FSR the impression is sometimes given that technology can be independently developed or adapted on farmers' fields. There are distinct comparative advantages to the concentration of scientists, laboratories, research fields, and other supporting services in the experiment station. Technology adaptation from other regions or countries and even technology creation in a response to specific regional problems, still not resolved elsewhere, is most efficiently done on the experiment station. Once improved technology components have been identified at the experiment station, their performance under farm level conditions needs to be evaluated.

3. Holistic vs. reductionist approach. In the farm trials component parts of new technology, tested at the experiment station, are combined. On the experiment station one factor tends to be intensively studied while other factors are held constant usually at high levels. Generally, large

increases in yields are only expected with the combination of a series of component parts. Inputs are expected to interact in a multiplicative rather than additive manner. These interactions are well-known phenomena among agronomists, who often find highly significant interaction terms in their experiments. In on-farm trials changes of only one input such as density can even make things worse; i.e., increased disease incidence (Sanders and Lynam, 1982). It is expected that substantial (above 30%) yield and income increase will depend upon the combination and interaction of changes in the levels of various inputs.

4. Differences in statistical approach and research design between the Experiment Station and the on-farm trials. Instead of minimizing the non-treatment variance as is done on the experiment station, the farm trials can be used to identify under which farm level conditions the technology does and does not perform. Hence, the sources of the non-treatment variance need to be systematically analyzed. Rather than repeating treatments on each farm this research problem implies the need for an increased number of farm trials.

5. Need for analysis and interpretation. FSR should not just produce methodology and data. The data should provide information to researchers as an input into the future research design on the experiment station and to the extension service on the potential utility of new technology for further testing or promotion by them. FSR critically needs more analysis and interpretation.

Collaboration Between Biological and Social Scientists in FSR

Each discipline has its body of literature, its journals, the statistical methods customarily dominated by its practitioners, and even its

philosophical attitudes about research and the process of agricultural development. Moreover, universities and many agricultural research institutions are organized by discipline. Promotions in universities are linked to publications in the high prestige journals of their discipline. Hence, to overcome these barriers strong institutional support and continued personal relationships are both required. There is a tendency to give control of the on-farm trials to either the biological or the social scientists or to compartmentalize their efforts. For example, the agronomists might take the researcher-managed on-farm trials giving the economists the farmer-managed trials or the agronomists might ask the economist's help in interpreting data without collaborating with him on research planning and research design.

The most basic differences between agronomists and economists are in their treatment of data (See Collinson, 1981, p. 442). Agronomists are trained to be extremely careful in data generation, to wait a number of years to verify results, and to utilize a series of statistical techniques, variations of analysis of variance, whose principal objective is to control the quality of the data. Policymakers need new technology suggestions in short time periods and farmers are more interested in the profitability and fit into their operations of one or two new systems of production rather than identifying the level of significance of the treatments and their interactions. Economists with simple modeling and synthetic estimates can help fill the gap between the public policymakers' and the farmers' demands for new technology information and the output from agronomic researchers. Some knowledge of agronomy and some simple modeling are the necessary components of the economist's contribution. Effective interdisciplinary collaboration means that the agronomists and the economists have to continually

interact not only in the analysis of the data but also on experimental design and even number of repetitions. For effective interaction a thorough understanding of each discipline is necessary. Another necessary component for successful interaction is the desire to respond rapidly to real world problems of technology evaluation and generation even if the data utilized are preliminary and synthetic. Preliminary results can always be refined and improved with further experiments and/or data collection and analysis.

Evaluation of FSR Concepts in CIAT Crop Programs and in the Bourkina Fasso-SAFGRAD-Purdue FSR Program

Ideally, benefit-cost analysis could be applied to FSR to compare it with other techniques. Here the analysis will be more qualitative on the value of the information gained from FSR. The criterion of evaluation will be the response to the following question: What was learned from FSR, that was not known at the experiment station or by policymakers, and was important either for feedback or "feedforward"? The performance of FSR will be briefly examined in three cases, the CIAT Field Bean and Cassava Programs and the Farming Systems Program in Bourkina Fasso of SAFGRAD-Purdue.

The CIAT (Centro Internaccional de Agricultura Tropical) Bean Program did a baseline study to estimate the economic importance of the various factors reducing yields of field beans on farmers' fields. Table 1 summarizes estimates of the economic significance of the different diseases and insects observed in farmers' fields. The elimination of rust in the Cauca Valley of Colombia in one production season would have increased the value of the field bean harvest by almost 1.2 million dollars. This type of study helped justify the Bean Program research strategy concentrating on resistance breeding. However, the results are time and region specific; hence,

Table 1 Bean production losses caused by plant diseases and insect pests in three Colombian bean zones during 1974-1975

Production Problem	Estimated Value of Production Loss During One Crop Cycle	
	Cauca Valley[a]	Huila and Nariño[a]
Plant Diseases		
Rust	U.S.$ 1,171,000	-
Common Bacterial Blight	933,000	-
Angular Leaf Spot	552,000	-
Viruses[b]	-	400,000
Anthracnose	-	282,000
Powdery Mildew	-	250,000
Root Rot[c]	-	207,000
Insects		
Leafhoppers	749,000	537,000
Thrips	-	510,000

a The average elevation above sea level was 1120 m in the Cauca Valley and 1320 m in Huila and Nariño.

b The interviewing agronomists were unable to always differentiate between virus symptoms caused by bean common mosaic virus, bean rugose mosaic virus or other viruses.

c No attempt was made to identify the specific root rot pathogen responsible.

Source: Sanders and Schwartz, 1979, p. 12

they supplemented other information but did not give a definitive economic ranking of priorities for disease and pest resistance.

After undertaking the Baseline Survey the CIAT Bean Program turned to Researcher-Managed On-Farm Trials. In Figure 2 and Table 2 a synthesis is made of the Colombian farm trials in the Field Bean and Cassava Programs. Figure 2 emphasizes the techniques of evaluation of the data from on-farm trials. Reading down from the left yield differences, simple profitability, and then the fit into the farmers' systems of production are successively evaluated. The analysis techniques are analysis of variance, simple budgeting, and some type of mathematical programming, often linear programming, for the three stages respectively. Enough repetitions on farms are necessary to stratify the farms between those on which the technology does and does not function. For example, fertilizer response will depend upon the initial soil fertility. The response to a disease resistant variety will vary with the incidence and the severity of the disease attack. Since these factors of soil fertility and disease incidence will differ substantially between farms, a large sample is necessary. As an approximate rule of thumb, CIAT and IRRI researchers have been recommending 15 to 20 farm sites per recommendation domain (Sanders and Lynam, 1982).

Table 2 summarizes the utilization of these evaluation criteria for the 3 and 1/2 years of farm trials. As important feedback to the Experiment Station neither improved quality seed nor fertilization in the Huila area increased field bean yields on farmers' fields in contrast with the experiment station results showing substantial yield increases. Another important case of feedback was on a new cassava variety. This new variety outyielded the farmers' varieties, both at higher input levels and at the farmers' input levels. Field interviews indicated that starch maintenance is an

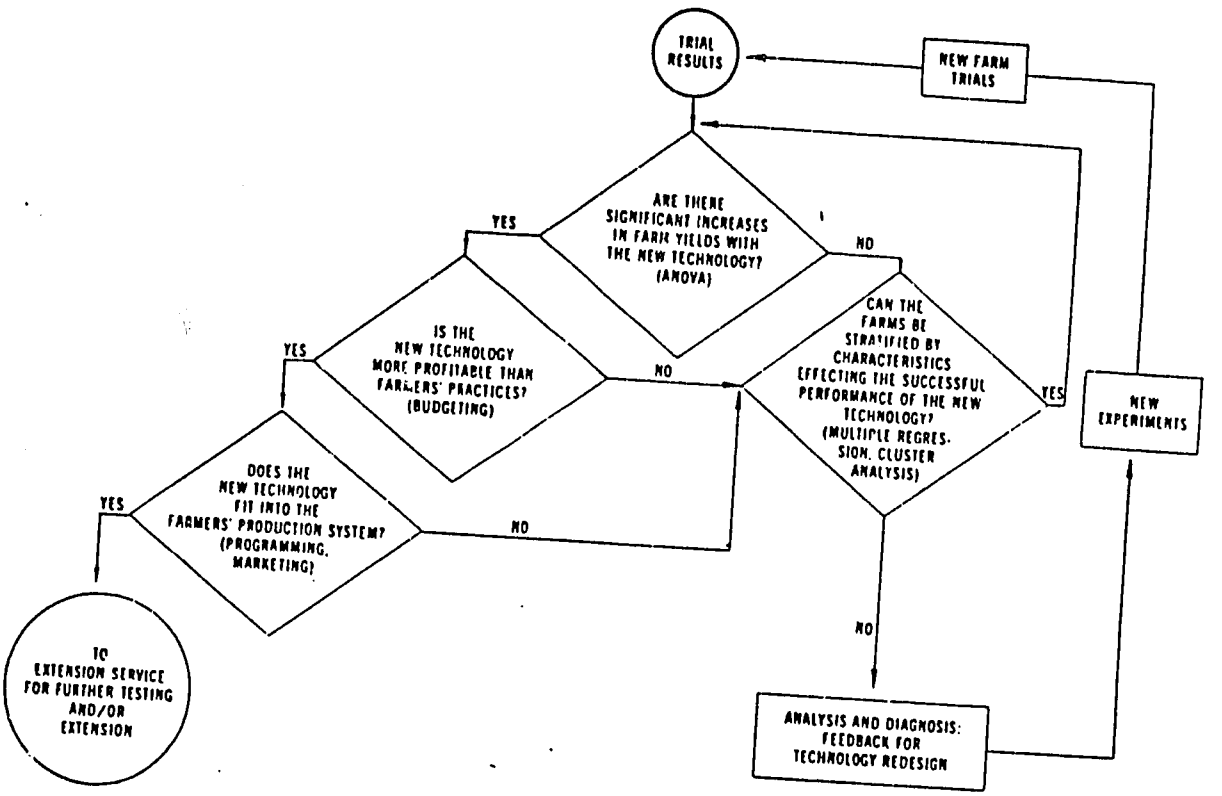

Fig. 2. Flow chart for new technology evaluation in farm trials.

Source: Sanders and Lynam, 1982, p. 100

TABLE 2

EVALUATION OF NEW TECHNOLOGY IN THE COLOMBIAN FARM TRIALS OF THE BEAN AND CASSAVA PROGRAMMES, 1978-1980

Crop programme	*New technologies*	*On-farm evaluation criteria*			
		Significant yield increase?	*Profitable?*	*Fit into farmers' production system?*	*Farmer adoption?*
Beans:	Fertilisation	Sample stratified by initial soil fertility	In sub-sample	Substantially increased capital requirements	*Restrepo:* Utilising fertilisation
	'Clean' or improved seed	No	–	–	
	Improved agronomy: Higher density; Chemical control of diseases and insects	Yes	Yes	*Huila:* Low rate of return due to price collapse at harvest *Antioquia:* High density makes cultural operations more difficult *Restrepo:* High capital requirements as soil fertility is the most limiting constraint	*Huila:* Higher density, some spraying *Antioquia:* Change of chemical controls but not density increase *Restrepo:* Higher density and spraying and fertilisation with organic and inorganic fertilisers
	Inoculation	No		–	
	New varieties	For most varieties—no For one variety—yes	Price discount makes it unprofitable compared with farmers' varieties. Taste requirements are fairly rigid for colour and seed size	–	
Cassava:	Fertilisation	Sometimes	No	–	
	Improved agronomy: Higher density; Stake treatment; Weed control	Yes	Highly profitable; small cash outlay	Large management requirements	
	New varieties	Yes	No, due to a substantial price discount. Importance of starch content and starch maintenance with a longer time in the ground as breeding criteria	–	

Source: Sanders and Lynam, 1982, p. 104

important varietal characteristic. Cassava harvest dates are staggered according to the marketing conditions and fresh cassava spoils rapidly after harvest. The on-farm trials showed that the starch level of the new variety declined rapidly after the optimum harvest date whereas starch levels of the traditional varieties were not only higher but also more stable after the optimum harvest date. Due to the lower starch levels the new variety was not acceptable to urban consumers.

In both the field bean and the cassava programs improved agronomic technologies could be passed on to the Extension Service. With field beans better agronomy included higher density, some disease and insect control, and in the low soil fertility regions fertilizer. These combinations of improved agronomy passed all three of the evaluation criteria of Figure 2. Nevertheless, the ultimate validation of the utility of the above evaluation criteria is farmer adoption. Over the time of the on-farm trials even with minimal extension involvement there was diffusion among Colombian farmers of the improved agronomic practices.

In the Colombian commodity programs the Researcher Managed On-Farm trials indicated some important differences between experiment station and farm yields for both improved seed and fertilization and helped identify some important plant characteristics for future cassava breeding work. There was also technology passed on to the Extension Service and farmers. So there was apparently a high value for the FSR.

In a poorer country, Bourkina Fasso, almost without an agricultural research base the FSR concepts were incorporated into the Researcher Managed On-Farm trials. How were the constraints identified in order to set up these on-farm trials? First, it was necessary to challenge the conventional wisdom of much of the literature on sub-Saharan agriculture that the

principal constraint is seasonal labor availability (see, for example, Norman, et al., 1981). Clearly, the most pressing constraint in a semi-arid region without irrigation is water. If some technology for water retention or conservation can be made available, then the riskiness of fertilizer use will be reduced. These changes in the environment increasing the water availability and improving soil fertility are expected to eliminate the need for the extreme risk avoidance strategies presently practiced by many farmers such as low or no purchased inputs and a dependence upon production of the basic cereal grains for family consumption. The subsistence first objectives of African farmers have been shown to change as new technology alternatives and better marketing conditions become available (Norman, 1982, pp. 641, 642).

The combination of tied ridges and fertilization almost tripled sorghum yields and was highly profitable (Table 3). Moreover, with more water and increased soil fertility the potential for introducing new varieties with higher yield potential will be substantially improved. Traditional varieties are selected for yield stability under adverse moisture and soil fertility conditions and would not be expected to respond well to improved environmental conditions. Animal traction will also undoubtedly need to be utilized to prepare the tied ridges. So once again it is the combination of inputs that results in the large gain in yields (also see Dillon and Anderson, 1982).

Conclusions

Baseline studies have been expensive and generally have not resolved the problems of research priority ranking (for an opposing view see Collinson, 1981). Informal surveying and identification of some components

Table 3. Yield Effects of Tied Ridges with Two Different Fertilization Levels on Sorghum in the Researcher Managed Farm Trials in Four Sites of Bourkina Fasso in 1982 (kg/ha).

	Water Conservation	
Fertilization	No Tied Ridges	Tied Ridges 30 Days After Planting
Without Inorganic Fertilizer	385a	561
With Inorganic Fertilizer	759	1130

[a] This treatment should be considered as a proxy for farmers' practices in the three sites.

[b] 100 kg/ha of (14-25-15 NPK) plus 50 kg/ha of Urea.

Note: The l.s.d. at the 95 percent probability level was 79 kg/ha.

Source: Lang, et al., 1984, p. 8

from the experiment station for Researcher Managed On-Farm Trials are the high payoff activities of FSR. Biological scientists almost always believe that they have a series of things ready for farm level conditions. In the Colombian and Bourkina Fasso cases discussed here many of the new technologies proven on the experiment station either did not outyield the proxy for farmers' practices on farmers' fields or were not profitable.

Substantial yield and profit increases apparently depend upon obtaining the synergistic effect of combined input use. Given the reductionist approach of the experiment station estimating the farm level impact of the combinations of component parts is an important result of the Researcher Managed On-Farm Trials. More efficient and rapid interaction between experiment station and on-farm testing will require an increased understanding and collaboration between biological and social scientists. If biological scientists can be involved in on-farm testing and the social scientists in the research planning on the experiment station, the farm testing and technology production system should function more efficiently. Given disciplinary barriers presently existing in universities and elsewhere, those modifications in practices and mentalities will not be easy.

Once new technology combinations have been shown to outyield and to be more profitable than farmers' practices in the on-farm trials, then more systematic modeling activity is needed to evaluate the fit of these technologies into the whole farm system. Figure 3 illustrates various issues that may need to be systematically considered in the whole farm modeling. Baseline studies can be usefully employed at <u>this</u> point to provide more information for the models.

Analysis and interpretation of results has been the weak point of FSR. Substantial investment and knowledge about the first two stages of FSR, i.e.

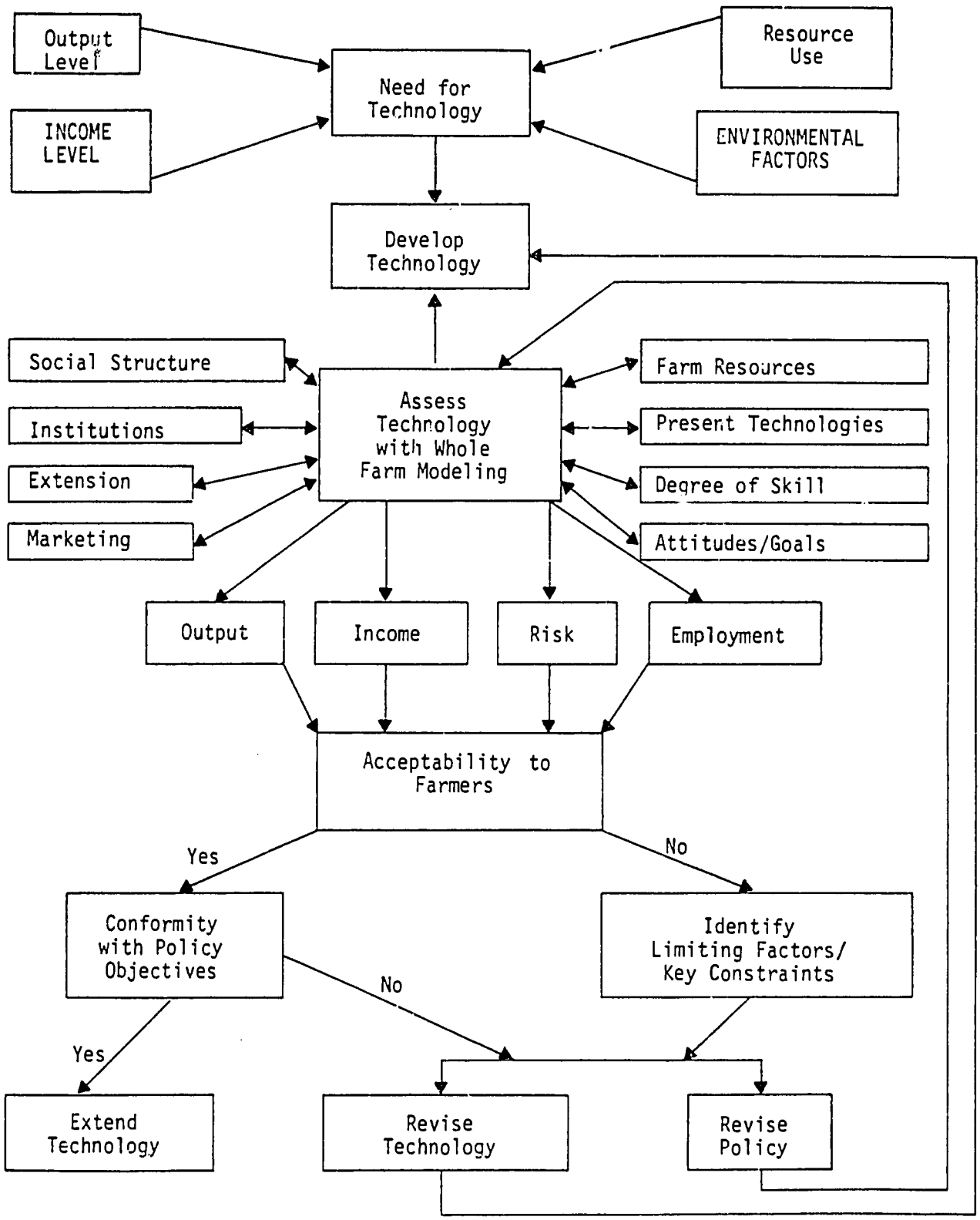

Figure 3 Technology assesment with whole-farm modeling

Source: Ghodaker and Hardaker, 1981, p.9

baseline studies and on-farm testing, have been acquired. Clearly, FSR now needs to reintegrate the mainstream of agricultural economics production theory and quantitative modeling back into its third stage of Evaluation and Processing once the Researcher Managed On-Farm Trials have identified new technologies, which are more profitable than farmers' practices. Mathematical programming of various types[6] appears to be the appropriate tools for studying the potential effects of new technology and identifying the constraints in a whole farm context (see Collinson, 1980, pp. 388-89; Ghodake and Hardaker, 1981; and Valdes, et al., 1979). Different farmer goals and risk can also be incorporated into this modeling. The degree of complexity of the models will depend upon the problems evaluated and the access to computer facilities.

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[6] Ghodake and Hardaker (1981, p. 9) suggest whole-farm budgeting, simplified programming, linear programming, linear risk programming, quadratic risk programming, linear stochastic programming, nonlinear stochastic programming, goal programming, Monte Carlo programming, and systems simulation. The methods are listed from the most simple to the most complex. The first two do not require a computer but approximate the decision criteria of linear programming.

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