Diagnosing Research Priorities for Small Farmers: Experiences from On-Farm Research in Pakistan

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1. Introduction

During the past five years a number of national and international research institutions have collaborated in establishing on-farm research (OFR) programs using a farming sytems approach to address the major problems of the various farming systems of Pakistan. This paper briefly reviews experience gained from the on-farm research programs, with emphasis on the major types of farming system interactions encountered, the methods developed for the diagnostic stage of on-farm research, and the lessons learned from applying those methods.[1] We particularly highlight the different approaches needed for the irrigated lowlands of Pakistan, which have undergone rapid technological change since the initiation of the Green Revolution in the 1960s, and the more marginal rainfed and mountain areas of northern Pakistan, which have largely been overlooked by past research and extension efforts.[2]

2. Major Types of Farming System Interactions: Irrigated and Marginal Areas

The focus of all the on-farm research programs was to increase the productivity of major food grain crops – principally wheat and rice in the irrigated lowlands, and wheat and maize in the marginal rainfed and mountain areas. The basic characteristics of the farming systems studied in these different environments are summarized in Table 1. Clearly the resource base of the rainfed and mountain areas was much poorer. Farm size was generally smaller and farmers were not self-sufficient in their subsistence food grain. Single cropping was common in the rainfed and mountain areas, with the major crop being a food crop, usually wheat or maize.[3] Cropping intensity was considerably higher in the irrigated plains where double cropping of food and cash crops was common. In the irrigated lowlands, farmers depended on cash crops such as rice, sugarcane, and cotton to generate cash income; in the rainfed and mountain areas, farmers depended on livestock and off-farm work for cash, part of which was used to purchase food grain.

Although the OFR programs usually focused on only one major food crop in the system, the diagnosis of production-limiting factors and the design of technological interventions for this crop was done in the context of the major interactions with other crop and livestock enterprises in the system. The choice of methodology for the diagnostic stage

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Table 1: Some differences between farming systems in the irrigated lowlands and rainfed and mountain areas, Pakistan on-farm research surveys, 1984-87

Characteristic	Irrigated lowlands, Punjab and NWFP	Rainfed lowlands, Punjab	Mountain areas, NWFP
Average farm size	8 ha[a]	3 ha	1.0–1.5 ha
Main source of draft power	Hired tractor	Hired tractor	Draft animal
Food self-sufficiency	Yes	No	No
Main source of cash	Cash crops	Off-farm work, livestock	Off-farm work
Main cropping patterns	Rice-wheat, Cotton-wheat, Maize/sugar-cane-wheat	Fallow-fallow-wheat-fodder, Maize-wheat	Maize-fallow, Maize-wheat, Maize-fodder
Cropping intensity (%)	135–160	118	120[b] 160[c]
Coefficient of variation of maize/wheat yields between fields	25–45%	50–65%	40–55%

[a] Average farm size in NWFP was much smaller at 3.6 ha.
[b] Rainfed mountain land.
[c] Irrigated mountain land.

of OFR was dictated in large part by the types of interactions in each farming system – especially the interactions between food crops and cash crops and between crops and livestock. Byerlee and Tripp (1988) have classified these interactions into four main types: 1) direct interactions between crops, especially interactions over time in crop rotations; 2) interactions between crops and livestock; 3) interactions arising from resource competition and complementarity; and 4) interactions arising from efforts to meet the multiple objectives of farm households.

In the irrigated lowlands, the dominant farming system interaction in all cases was the interaction over time in the crop rotation. Such interactions occurred when evolving cropping patterns in the more intensive systems (made possible by increased irrigation water supplies, adoption of chemical fertilizer and the use of earlier maturing varieties) provoked conflicts in the timing of operations. As a result, land preparation and timely planting of wheat (the dominant food crop in these irrigated lowland systems) were compromised by the late harvest of the preceding crop – rice, cotton, or sugarcane. Carry-over or residual effects of crop residues, fertility, and weed and pest populations also considerably influenced management of the wheat crop. Since wheat typically accounted for nearly 80% of the cropped area in the *rabi* (winter) season, competition for resources between crops grown in the *rabi* season *and* tradeoffs in meeting multiple objectives were relatively unimportant. Also, since most farmers in the irrigated lowlands planted a separate fodder plot for animals, have adopted chemical fertilizers to partially replace organic manure, and have hired tractors to replace draft animals, crop-livestock interactions have become less important in recent years.

In contrast, in the rainfed and mountain areas livestock tended to be relatively more important and crop-livestock interactions have a major influence on crop management.[4] The wheat and maize crops supply the fodder needs of domestic animals through intercropping green fodder in wheat and maize[5] and through crop residues. Organic manure is important both as a source of fertility maintenance and, especially in rainfed areas, as a means of improving soil structure and the capacity to retain moisture. In mountain areas, farmers still rely exclusively on animals for draft power (Table 1).

In addition to crop-livestock interactions, a major issue in the rainfed and mountain areas is that cropping intensity is low relative to its potential. Hence an important focus of the diagnostic surveys was to identify ways for increasing the intensification of agriculture. The diagnostic surveys in these more marginal areas were also influenced by the greater variability in yields in rainfed and mountain land. In the lowland irrigated areas, the coefficient of variation of yields between fields was typically 25-30% compared to 50% or more in rainfed and mountain areas (Table 1).

3. Diagnostic Methods

The sharp distinctions between irrigated and marginal areas led to the use of somewhat different methods in the diagnostic surveys. Three types of survey methods were employed: 1) the informal survey, 2) crop production surveys integrating agronomic and socioeconomic variables, and 3) system surveys covering broad aspects of the farming system and system interactions. All three methods were used in both irrigated and marginal areas, but crop production surveys were emphasized more in the irrigated areas and systems surveys were relatively more important in the marginal areas.

3.1. Informal Surveys

Informal surveys were an essential part of the diagnostic stage of OFR in all study areas. The informal surveys provided researchers with a first hand understanding of the farming system and its management that guided the delineation of recommendation domains and the selection of promising research opportunities. The methodology for the informal survey followed that initially developed by Hildebrand (1981) and Collinson (1981). A multidisciplinary team consisting of 5-10 persons spent approximately one week in the selected project area. Although the diagnostic surveys focused on the major food crop in the system, usually maize or wheat, it was found useful to also include members of research programs for other major commodities in the system. Each day, groups of two to three researchers from different disciplines or commodity research programs traversed the area, informally talking to farmers and observing their fields. No questionnaire was used and the use of notebooks was minimized, although interviews were guided by a checklist of major topics to be discussed. The informal survey was always conducted in the main crop season prior to harvest so that researchers could observe crop growth and management and pest problems in the field. The full team met daily for intensive discussions of major findings in order to develop an understanding of the system and to begin to focus on major constraints and opportunities in the system. As the survey proceeded, it focussed on fewer issues in greater depth.

The informal survey was judged to be a powerful tool for bringing researchers from different disciplines and commodity research programs together and for establishing direct contact with farmers and their problems. The shared experiences of crop scientists and social scientists in the field, and the intensive group meetings, were an excellent forum for improving cross-disciplinary communication.

We would argue that this type of multidisciplinary and multicommodity survey should be a regular part of all research planning, including the establishment of research priorities for commodity and disciplinary research programs on the experimental station. The informal diagnostic survey is a way to increase communication between research programs for commodities that interact closely in the farming system. It is also a way to explicitly consider farming system interactions and the reality of the farmers who are the clients of the research system.

Although we judged the informal diagnostic surveys to be extremely successful, we may have improved the surveys even more by including senior crop researchers from the experiment stations, livestock scientists, and more female researchers to provide better coverage of womens' activities and household decisions. The surveys would also have been improved if we had interacted more closely with extension. Nonetheless, the selection of team members cannot cover all areas of desired expertise since there are probably decreasing returns in terms of logistics and team interaction for teams larger than 8-10 persons.

3.2 The Integrated Crop Production Surveys

The diagnostic stage relied heavily on integrated crop production surveys, especially in irrigated areas. The crop production surveys had several important characteristics:

1) The data collected focused on a specific field, although some general farm-level data, such as source of draft power and cropping pattern, were also collected (Table 2).
2) The field-specific data included detailed information on the management of the target crop as well as crop rotation and selected management variables on previous crops in the field which, on the basis of the informal survey, were thought to have an important influence on management of the target crop.
3) The types of variables collected included agronomic variables such as plant density, weed population, soil type, and timing of critical operations.
4) In most surveys, yields and other harvest data were estimated by crop cutting.
5) The survey instrument was restricted to one or two pages that could be completed in 15-20 minutes.

Clearly, the methods for the diagnostic crop production surveys departed substantially from those of traditional crop production surveys usually conducted by economists. We placed more emphasis on detailing management practices in specific fields – timing, method, and level – than on resource use at the farm level (e.g., total amount of labor used for production of a given crop over all fields). Also, because of the importance of interactions over time in crop rotations in multiple-cropping systems, many of the variables emphasized crop rotation and crop management in *previous* crops (Table 2).

Although the crop-cut estimate of yield at harvest was not essential to the method and we recognize its limitations (Poate 1988), the crop cutting had two major advantages. First, it ensured that the interview was conducted with the farmer in the selected field and hence greatly helped to obtain reliable management data specific to that field. Second, the crop cutting facilitated collection of other data such as grain moisture, plant density, weed scores for grassy weeds in wheat, and lodging.

The design of the formal survey was guided by the understanding of the farming system and crop management gained during the informal survey. The sampling method varied

Table 2. Categories of information collected in the crop production survey

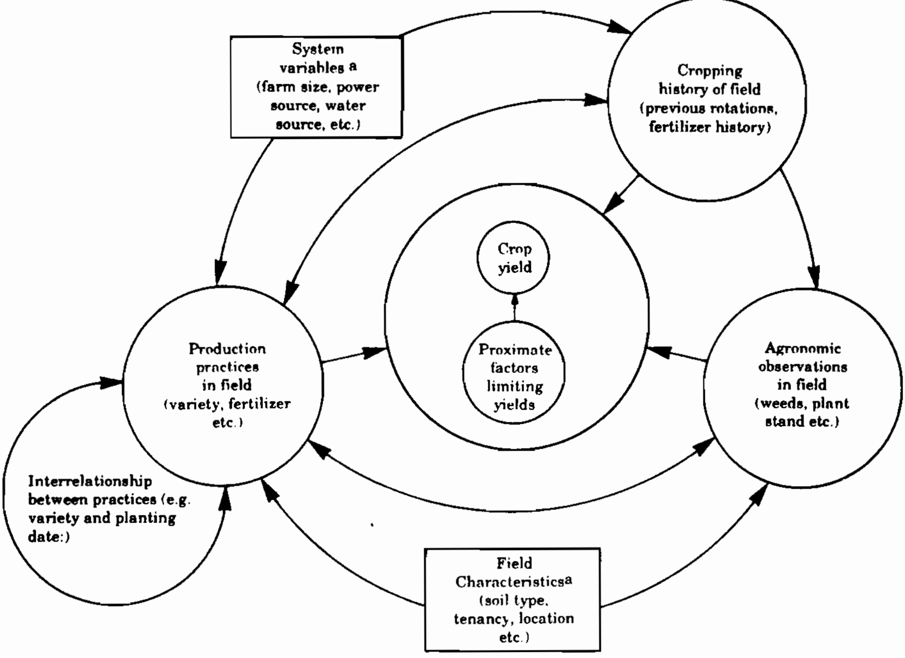
Field-specific information	
1. Production practices for crop	– Operations performed – Timing of operation – Inputs applied – Method of application
2. Cropping history	– Cropping rotation for previous two years – Practices in previous crop affecting target crop (e.g., variety, planting date) – Fertilizer history
3. Agronomic observations	– Plant stand – Weeds – Salinity – Lodging
4. Field characteristics	– Soil type – Tenancy – Proximity to village
5. Harvest data	– Grain yield – Straw yield – Grain moisture
Farm-level information	
1. Resource base	– Power source – Irrigation system – Farm size
2. Cropping pattern	– Crops grown in each season
3. Livestock	– Number – Composition

but was based in most cases on selection from among farmers met harvesting the crop in the field. The survey required considerable skill for taking field observations and researchers themselves usually conducted the interviews.

All questionnaires were precoded to facilitate the immediate entry of data onto microcomputers. The analysis focused on testing the hypothesized relationships (Figure 1) using two-way and three-way frequency tables, simple correlation analysis, analysis of variance, and multiple regression analysis. The analysis typically examined the following relationships:

1) The relationship between cropping history and such system variables as farm size, access to irrigation, soil type, etc.
2) Variation in production practices in the selected field as a function of a) system variables, b) cropping history of the field, c) soil and other characteristics of the field, and d) other production practices employed in that field.
3) Agronomic variables for the selected field as a function of cropping history, field characteristics, and production practices in the field.
4) Yield in the selected field as a function of cropping history, agronomic variables, field characteristics, and production practices.

Figure 1: Schematic representation of interrelationships analysed using data collected in the formal survey



[a] Considered as exogenous variables.

Data analysis and preliminary reports were completed a few weeks after conducting the survey to be available for planning experiments for the following cycle. In a few areas, the crop production surveys were conducted over two or more seasons for different crops in the same field or were repeated for the same crop in consecutive years to record year-to-year variation in management practices and yields.

The integrated crop production surveys were useful in providing a lot of information quickly and at a relatively low cost. Many of the relationships identified through the crop production surveys were later verified in on-farm experiments. For example, in two areas the surveys indicated a strong response to nitrogen, but not to phosphorus. These results were verified in on-farm experiments over three years in the same area (Byerlee et al. 1984, Aslam et al. 1988, Byerlee et al. 1987, Khan et al. 1986). In another area, the relationships between yield, plant density, and fodder production in maize, established in the production survey, were later confirmed experimentally (Byerlee, Iqbal and Fischer 1989, Byerlee et al. 1987, Khan et al. 1986). Further support was given to the validity of the survey approach by the consistency of results obtained over several years in the same study area (Byerlee et al. 1987, Hobbs et al. 1989). However, despite these encouraging results, we view the integrated crop production survey as a way of generating useful hypotheses rather than a substitute for experimentation. Although multiple regression of yields identified many statistically significant and agronomically plausible variables responsible for the yield differences between fields, the explanatory power of the regressions was often low (R^2 less than 0.35), suggesting that important variables were not measured in the surveys (e.g., soil chemical properties and soil moisture content at critical growth stages).

Undoubtedly these survey methods can be improved further. Because the data are increasingly used for purposes other than research planning (e.g., for policy analysis and project design), the sampling method should be more structured and based on a random sampling approach. Also, crop cut estimates of yield should probably include a larger number of samples per field to reflect intra-field variability.[6] Furthermore, greater efforts should be made to characterize soil type and properties, possibly by recording soil test data as well as field observations. Finally, with more resources there would be clear advantages in conducting multiple visits during the crop season to obtain better estimates of agronomic variables.

3.3 System Surveys

In a number of cases, especially in the rainfed and mountain areas, we also conducted a farming systems survey, in addition to the crop production survey. As in the irrigated lowland areas, integrated crop production surveys provided a useful focus to all subsequent work. However the informal surveys, the integrated crop production surveys, and subsequent on-farm experimentation all pointed to three features of the more marginal areas that suggested a deeper understanding of the system would provide better guidance for designing technological interventions.

First, system interactions were more complex in the rainfed and mountain areas. In particular, since crop-livestock interactions were often dominant there, a major focus of the system surveys was on livestock composition and productivity, fodder management and seasonal fodder calendars, ownership and use of draft power, and use and allocation of farm yard manure.

Second, in the rainfed and mountain areas, crop yields were more variable, farm sizes were smaller, and, as the system surveys later confirmed, many farm families were not self-sufficient in their staple food or fodder. This suggested that costs of experimentation in these areas would be much higher relative to the likely benefits than in the irrigated lowland areas. Nonetheless equity considerations directed research resources to these areas. In the more marginal areas, improving total system productivity through broader interventions (i.e., new crops or early maturing varieties, or a new input) was an alternative to a program of research focused solely on management interventions in the target crop. System surveys helped to clarify the likely points of intervention.

Third, one area in which total system productivity could be improved in irrigated lowland areas as well as in rainfed or mountain areas was through interventions designed to increase cropping intensity. Therefore, a major focus of the system surveys was to analyze factors affecting cropping intensity. In the irrigated lowlands, the variables affecting cropping intensity were related to cropping pattern, farm size, access to irrigation water, and draft power. Some of these variables (e.g., farm size and draft power) remained important determinants of intensity in rainfed and mountain areas, but a wider range of variables was included, such as rainfall or altitude, number and composition of livestock, land type, and location of fields relative to the village.

Given the nature of the system surveys, the questionnaire was generally longer than for the crop production surveys and analysis and reporting of results was correspondingly slower. However, the objective was not to collect all information on the farming system and special care was needed to ensure that the survey focused on the major system interactions that were hypothesized to be important in understanding system management and designing interventions. In the rainfed and mountain areas, the system surveys were an essential part of the diagnostic exercise, especially the verification of hypotheses on important system interactions formulated during the informal survey.

4. Design of Technological Interventions: Irrigated and Marginal Areas

In all areas there was scope to improve productivity by introducing new varieties of the principal food crop. In many cases, earlier maturing varieties were needed to provide greater flexibility in cropping patterns and planting times.[7] This was particularly true in irrigated areas where time conflicts in the cropping patterns were common and a major constraint on productivity. In mountain areas, earlier maturing varieties could also often provide greater flexibility in management. Other characteristics such as tolerance to drought and other stresses, and fodder value are also important factors influencing farmers' acceptance of new varieties in the more marginal farming systems.

The design of technological components other than varieties, however, may differ greatly between rainfed and mountain areas, and irrigated areas. This difference arises in part due to variation in major interactions in the farming systems of these areas. In addition, an important difference between the irrigated areas and the rainfed and mountain areas is the level of variability between fields in crop management and productivity. In rainfed areas there was also substantially more variability between years and hence in input response, which can be highly dependent on seasonal rainfall distribution.

The system surveys also showed that small farm-households in rainfed and mountain areas were not self-sufficient in their staple food or fodder, in contrast to small farm-households in the irrigated lowlands which were mostly self-sufficient in these products. This difference, together with the relatively poor infrastructural and market development in the rainfed and mountain areas, implies that in the marginal areas, more emphasis should be placed on increasing staple food and fodder production before offering farmers alternative cash crops.

The nature of system interactions and high level of variability in rainfed and mountain areas also imply a somewhat different strategy for designing research and extension interventions. In the irrigated lowlands it is possible to delineate relatively large homogeneous recommendation domains on the basis of such factors as crop rotation, soil type, and access to irrigation water. Each domain is large enough to justify a well-focused research effort to refine recommendations on management practices such as fertilizer doses, weed control, and irrigation water applied, as well as the timing and method of application of each practice. In the rainfed and mountain areas, it is often very difficult to identify homogeneous strata because of the extreme variability. Even if they can be identified, they are often too small to justify an adaptive research program to refine recommendations. Hence, the best strategy is to look for widely appropriate system interventions such as deep tillage methods to conserve moisture in rainfed areas, a new fodder crop to relieve fodder constraints, a new cash crop suited to local conditions, or a new early-maturing variety of a staple food crop to promote increased cropping intensity. In most cases these interventions will have to be evaluated for their impacts on the total farming system, since their effects are not crop specific.

5. Conclusions

The experiences of conducting diagnostic surveys over a wide range of farming systems in Pakistan has shown the importance of the diagnostic stage of research. The diagnostic surveys described here have identified new problems, helped quantify and evaluate the importance of practices such as intercropping, and provided information for refining or, in some cases, drastically changing recommendations and recommendation domains. The diagnostic surveys have served not only to design adaptive experiments but also to provide information to plant breeders on varietal requirements (e.g., Byerlee, Akhtar, and Hobbs 1987).

The diagnostic survey is an important part of the research process. It should not be equated with the common practice of requesting social scientists to provide a benchmark description of the area, as often happens in many farming systems projects. Rather the diagnostic survey should be seen as an integral part of research planning and priority setting involving several disciplines and commodity groups. The widespread use of microcomputers now allows more quantitative and rigorous statistical testing of hypotheses in the diagnostic stage. Agronomic variables are also an important part of the diagnostic survey and become even more so as the emphasis in the diagnostic surveys is broadened to include issues related to the long term sustainability of the system.

Nonetheless, the methods used for diagnosis must be adapted to the system under study. In all systems the informal survey approach involving different disciplines and commodity research groups should be an important part of the diagnosis. We have also found that field-specific crop production surveys of key management and agronomic variables are an effective and low-cost method for obtaining information in multiple-cropping systems. More general farming systems surveys may also play an important part in designing system-wide interventions in environments where management of crop enterprises is closely related to livestock management and yield variability is high.

Summary

Recent experiences in on-farm research programs in Pakistan are reviewed with special reference to the importance of farming system interactions in diagnosing technological interventions for the major food grain crops in various systems. A sharp distinction is drawn between the irrigated lowlands, where crop rotation effects were the dominant type of system interaction, and the more marginal rainfed and mountain systems, where crop-livestock interactions had a major influence on food crop management. Three methods used in the diagnostic stage are briefly described: 1) informal surveys by a multidisciplinary team formed from research programs representing the major commodities in the system; 2) crop production surveys emphasizing data on crop management, cropping history, agronomic observations, and yields and other harvest data for specific fields; and 3) system surveys that explored key system interactions in more depth. The implications of the diagnostic surveys for designing appropriate technologies for these systems are briefly reviewed.

Zusammenfassung

Erfahrungen in „on-farm research“ Programmen in Pakistan werden besprochen mit spezieller Berücksichtigung der Wechselbeziehungen im Betriebssystem für die Diagnose technologischer Eingriffe in die Pflanzenproduktion.

Eine Unterteilung in bewässertes Tiefland, marginal regenabhängige Gebiete und Berggebiete wurde vorgenommen. Im ersteren stellten die Auswirkungen des Fruchtfolgewechsels die wichtigsten Wechselbeziehungen im System dar. In den zwei letzteren übten die Wechselbeziehungen zwischen Getreide- und Tierhaltung den stärksten Einfluss auf die Pflanzenproduktion aus.

Die Methoden, die in der diagnostischen Phase benutzt wurden, werden kurz beschrieben:

1. Informelle Umfrage durch ein multidisziplinares Team bestehend aus Vertretern der Hauptforschungsprogramme.
2. Umfragen bezüglich Pflanzenproduktion mit spezieller Berücksichtigung gegenwärtiger und vergangener Produktionsverläufe, agronomischer Beobachtungen, sowie Ertragsdaten und anderer Erntedaten in spezifischen Feldern.

3. Systembezogene Umfragen, welche die wichtigsten Wechselbeziehungen in vertiefter Weise untersuchten.

Die Schlußfolgerung aus der Umfragediagnose für die Entwicklung systemangepaßter Technologien werden kurz besprochen.

Footnotes

1 Full details of the on-farm research projects and methodology can be found in Byerlee and Hussain (1989).

2 Despite this neglect, high yielding varieties of wheat have steadily diffused in the marginal rainfed and mountain areas of Pakistan during the past decade and are now sown on the bulk of the wheat area in these marginal zones.

3 In the rainfed lowlands, the common practice is to double crop wheat-maize or wheat-sorghum in one year and then leave land fallow for a whole year.

4 The number of animals per cultivated hectare in the mountain areas was approximately double that in the lowlands.

5 In the rainfed lowlands, mustard is commonly intercropped in the wheat crop (Hobbs et al. 1986). In the mountain areas, maize for green fodder is "intercropped" in maize grain crops (Byerlee, Iqbal and Fischer 1989).

6 In most cases we took three yield cuts per field (1 m^2 each for wheat and 8 m^2 for maize). In the rainfed and mountain areas, we increased this to five cuts per field.

7 In the case of wheat, varieties that perform well at late planting are required. These may be earlier maturing varieties but some longer season varieties also do well at late planting. In the rainfed lowlands, longer maturing varieties with early heat tolerance, would allow earlier planting and better utilization of residual monsoon moisture.

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