Contributions of Farmer Knowledge to Agricultural Technology Development

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Abstract

Recognition that conventional research processes and the quantum leaps in food grain yields generated by the "Green Revolution" in the 1970s were not reaching the majority of the world's small farmers gave rise to an interest in the potential contributions of farmer knowledge to agricultural development. A growing understanding of small farmers and the circumstances under which they operate led to the emergence of an evolving farmer-oriented approach to technology development. In an effort to reduce the increasing gap between on-station and on-farm performance, researchers began to look for ways to identify key aspects of farmer wisdom and experience and to incorporate this body of knowledge into the agricultural technology development process. This paper provides a brief overview of the various processes and methods that have been used to achieve this integration and their relative success. Scientific and local knowledge systems are compared and contrasted in terms of their defining characteristics. An assessment is made of the varying impacts of farmer knowledge within the agricultural research and extension process and comments are offered concerning the need for continued change in the roles of researchers and farmers to achieve a more integrated and balanced role for farmers in agricultural technology development.

Introduction

The Green Revolution of the 1960s and 1970s generated two main outcomes. First, it produced high-yielding crop varieties that resulted in quantum jumps in food grain yields in Asia and Latin America. And second, it led to a series of evolutionary changes in the research process that have placed increasing importance on the role of farmer knowledge in agricultural technology development. It became increasingly apparent that the goals of crop researchers, with their focus on improved yields, differed from those of small farmers who were driven by a broader range of concerns related to food security (Norman, 2000).

A growing need among agriculture researchers to better understand small farmers and the circumstances under which they operate led to the emergence of a farmer-oriented approach to technology development which is still evolving today. Researchers and development practitioners began to realize that the inter-relationship between technologies and the environment, economy, culture, beliefs, attitudes and politics of rural societies are to a large extent determined by decisions made by smallholder farmers (Anandajayasekeram, 1997).

In an effort to reduce the increasing gap between on-station and on-farm performance, several of the international agricultural research centers began to look for ways to identify those aspects of farmer knowledge that could be used by researchers to make their technologies more relevant to the needs of small farm families operating under marginal conditions. Such efforts were hampered by the growing realization of

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the fundamental differences between farmer empirical experience and formal agricultural science.

Scientific and farmer knowledge

As can be seen in Table 1, the knowledge of agricultural researchers is largely based upon reductionist research utilizing controlled trials and objective analysis of experimental data. The results of such experiments are validated through scientific testing and communicated in written reports and published articles. Farmer knowledge, on the other hand, is based on indigenous wisdom generated from trial and error experimentation and the subjective integration of first and second hand information and observation. This knowledge is validated through experience. It is housed in the minds of multiple generations of farmers and is transferred largely by oral communication rather than written documents.

Scientific knowledge seeks to further universal understanding by isolating cause and effect relationships. Farmer knowledge (including soil and plant classifications, cultivar characteristics, and local agroclimatic history) seeks to solve problems and support desired production objectives. Both researchers and farmers conduct experiments but there is a difference, and possible confusion, between farmer experimentation as a process and researcher "experiments" as identifiable activities, (Martin and Sherington, 1987).

Table 1 Attributes of scientific and farmer knowledge systems

Scientific knowledge	Farmer (indigenous) knowledge
Reductionist	Integrative
Based on controlled experimentation	Based on trial and error
Objective	Subjective
Written documentation	Oral documentation
Data-intensive	Experience-intensive
Seeks to isolate cause/effect	Seeks to achieve or support desired objectives
Validated by the scientific method	Validated by experience, observation, intuition
Contributes to universal knowledge/understanding	Contributes to site-specific farmer problems
Supported by the scientific method	Supported by experience & cultural world view

These generalized attributes apply particularly to basic (upstream) scientific knowledge and are used to highlight differential thrusts in scientific and farmer knowledge. This is not to say that the only goal of scientific knowledge is to isolate cause and effect relationships or that it does not contribute to solving farmer problems. Indeed, applied agricultural research has always had a problem-solving orientation. However, over the last several decades, increased specialization has pulled many applied researchers away from this focus.

Prior to the 1970s, researchers and development theorists considered farmer indigenous knowledge to be inferior and an obstacle to development (Stroud and Kirkby, 2000). The emphasis in agricultural research and extension was on bringing modern technological packages to farmers, rather than utilizing their own experience and knowledge in the technology development process.

Participatory research

Early efforts by cropping systems researchers to increase interaction with farmers set the ground work for the emergence during the 1980s of a range of processes broadly defined as farming systems research (FSR) to identify the needs, constraints, and priorities of small farmers. Within the general FSR framework, processes such as Farming Systems Research and Development (FSR&D) (Shanner *et al.*, 1982), Farming

Systems Research/Extension (FSR/E) (FSSP, 1987), Farmer Participatory Research (FPR) (Farrington and Martin, 1987), Farmer-First-and-Last (Chambers and Ghildyal, 1985), Farmer-Back-to-Farmer (Rhoades and Booth, 1982), Farming Systems Development (FSD), (FAO, 1989), On-Farm Client-Oriented Research (OFCOR) (Merril-Sands, 1986) and Participatory Plant Breeding (PPB) (Ashby, 1987) have all sought to incorporate farmer knowledge and concerns into the design, testing and transfer of appropriate agro-production technologies.

In addition, some of these approaches have gone beyond research to address issues related to extension, policy and institutional support. In most cases, the FSR approach has been applied to downstream or applied research. A key tool associated with many of these approaches was rapid rural appraisal (RRA) which helped researchers to communicate with farmers and to understand the circumstances under which they operated.

While these approaches were being refined within the international and national agricultural research centers, a number of alternative paradigms were developed in the 1990s by university faculty and a growing community of non-governmental organizations involved in local-level development programs around the world. Three distinct but complementary thrusts emerged, Participatory Action Research (PAR), Agroecosystem Analysis (AEA), and Indigenous Knowledge Systems (IKS).

Participatory Action Research and its related off-shoots including Participatory Learning Approach (PLA) and Linked Local Learning (LLL) seek to use local knowledge and skills as a means to empower local residents to identify and resolve their own problems. Within PAR there is less emphasis on combining farmer and scientific knowledge and more focus on empowerment of local groups to identify and resolve their problems with minimal reliance on external resources. In PAR, research is focused not on alleviating biophysical constraints but on the social processes that contribute to or limit people's ability to access and manage information and resources to solve problems. Action research presumes that there is no single solution for a problem. It involves researchers and farmers in identifying and assessing alternatives where, unlike a demonstration, the outcome is not presumed or predetermined.

Agroecosystem Analysis (AEA) (Conway, 1985) was developed and refined by a group of ecologists and social scientists who focused their research efforts on the ecological dimensions of farming systems and their sustainability. By working with farmers and villagers to better understand how they manage their natural resources and impacts of these processes on the larger environment in which they live, AEA researchers work to identify options for more environmentally sound farming systems (Dalsgaard *et al.*, 1994; Lightfoot *et al.*, 1988). They also seek to better inform planners and donors on the potential natural and social impacts of different development strategies (Cuc *et al.*, 1990).

In indigenous knowledge systems research (IKS), the emphasis is on the content and processes of communication within local level communities. All societies have a large body of technical knowledge that has been amassed from generations of careful observation and experimentation in the use and management of natural resources. IKS researchers argue that a familiarity with indigenous knowledge can help agricultural researchers to understand and communicate with farmers in ways that will enhance possibilities for sustainable development (Warren, 1991).

Because of their fundamental differences in disciplinary orientation and objectives, there has been little communication across these different paradigms. However, in spite of this situation, each of these frameworks shares many of the same participatory tools (including Participatory Rural Appraisal (PRA) and has made significant contributions to the process of incorporating farmer knowledge and resources in agricultural research and development programs.

Many practitioners consider PRA to be a more advanced, and more participatory, version of RRA. This perception is largely accurate except for two important distinctions. First RRA, as generally practiced, is a researcher-managed process to increase understanding and knowledge of farmer problems. Emphasis is on the use of focused interviews and observation. PRA, in its idealized form, is a process facilitated by outside researchers or development workers, to help farmers identify issues for their own experimentation and problems that they can solve with their own resources. The major tools used in PRA are visual in nature, and generally involve villagers in the generation of resources maps, transects and other graphic visualizations of their community and farming systems (McArthur, 2000).

Second, in PRA, there has been a key effort to broaden the focus from individual farmers, that predominated in RRA, to a wider range of participants including women, and other key stakeholders such as traders, processors and even consumers. The level of analysis also was expanded from single farm families to groups of farmers, whole villages and even entire watersheds. These changes in scope and level have important implications for how farmers and rural residents are involved in research and development programs.

Impacts of participatory research

At this point, rather than discuss the particular characteristics of each of these approaches and the kinds of farmer participation they generate at different levels, I prefer to look at a range of cases where the incorporation of farmer knowledge has resulted in positive outcomes for both farmers and researchers. From the case examples, it will then be possible to trace the particular process that led to the successful use of farmer knowledge and determine under what circumstances and in what environments such processes are most likely to be replicated.

Areas where farmers have been successfully involved in research and technology development include crop storage, plant breeding and varietal selection, soil fertility improvement, natural resources management, integrated pest management and integrated crop-tree and crop-aquaculture systems. I will briefly look at selected cases in several of these areas before proceeding to the analysis of the attributes of successful involvement of farmers and their inherent wisdom and experience in technology development.

1 **Diffused light storage** — The importance of farmer knowledge in the development and dissemination of diffused light technology for improved potato storage has been well documented by Rhoades and Booth. This classic example of the Farmer-Back-to-Farmer approach had its origins in indigenous technical knowledge (ITK). The basic concept of diffused light storage systems was a farmer invention. It was observed and refined by a group of researchers and then passed back to farmers who had not used it before. The most interesting aspect of this case is not that the original idea came from farmers but that when the improved version of the technology was reintroduced it was not widely "adopted" in the presented form. What did happen was that many farmers "adapted" the idea of diffused light into their own on-farm storage systems (Rhoades and Booth, 1982).

The important lesson here that set the base for future participatory research is that farmers do not readily adopt complex technology packages in their entirety but do select aspects of the technology for incorporation into their existing farming systems. The idea of creating options (rather than packages) from which farmers can choose and adapt, has become an underlying operating principle of most farmer participatory research.

2 **Participatory plant breeding** — Proponents of participatory plant breeding (PPB) argue that the systematic inclusion of farmers' knowledge, skills and preferences in plant breeding programs provides a cost-effective way to produce crop varieties that respond well to very specific growing conditions. In one cassava breeding program in Colombia, a cost comparison between the farmer participatory approach and traditional variety evaluation indicated that data points from the farmer participatory trials cost about US$ 0.50 compared to $0.80 for researcher-managed trials. It was also noted that the improved understanding of

farmers' varietal choices led to the incorporation of farmer criteria into breeding programs and stimulated researchers to provide earlier-generation breeding materials to farmers for evaluation (Weltzien *et al.*, 2000). Another example from Colombia also suggests that farmer-led research can be efficient and less costly that traditional on-station testing (Ashby and Sperling, 1994).

PPB programs are relatively new, most having been initiated within the last ten years. The emphasis has been on major staple food crops with a focus on the verification and testing of specific selection criteria. Participatory breeding is being used today in a wide range of crops and countries, such as pearl millet in India, barley in Syria, common beans in Brazil, rice in Nepal an cassava in Colombia (Sperling and Ashby, 2000). Farmers commonly provide two kinds of input to PPB: knowledge and information and genetic material.

There are many case studies illustrating the positive impacts of PPB. In Latin America, participatory variety selection (PVS) work has focused on selection and testing of improved bean and potato varieties (Thiele *et al.*, 1996). In India and Nepal, there are numerous examples of farmer participation in the selection and testing of improved varieties of such crops as rice (*Oryza sativa*), chickpea (*Cicer arietinum*), and black gram (Witcombe *et al.*, 1996). In a PPB program in Rajasthan, India, one of the pearl millet (*Pennisetum glaucum* [L.] R.Br.) test cultivars proved so popular that villagers were willing to pay twice the price for its locally produced seed and quickly learned new techniques to maintain their own pure seed of this open-pollinated variety (Dhamotharan *et al.*, 1967). Participatory plant breeding methods developed by CIAT (Centro Internacional de Agricultura Tropical) (Ashby *et al.*, 1987) have been shown to substantially increase the adoption of a new bean variety (*Phaseolus vulgaris*) in Colombia and Rwanda (Sperling, 1992).

While many PPB projects have sought ways to improve researcher-led breeding programs, their results suggest two key factors related to the success of participatory breeding and variety selection. First, "farmers are keen to test new varieties and to learn techniques for improving their own varieties" and second, programs with the most immediate impact are those that have a build-in seed production and distribution component (Weltzien *et al.*, 2000).

3 Soil fertility and natural resources management — Farmers and high-yielding, disease-resistant crops are only two parts of the formula for improved agriculture. Two other key ingredients are soil and water. Over the last half century, much attention has been given to regional level soil variations. Considerably less effort has been focused on local level soil variation within a single village or field. At this level, farmers are usually the best source of information about soil and often have amassed considerable knowledge about different soil types and their associated growing characteristics.

In the same way that no plant variety is equally well-suited to all environments and growing conditions, no single set of soil management recommendations will be appropriate to all situations, even within the same general soil type. Like plant breeders, soil scientists have begun to work with small farmers to develop land management options appropriate to their particular location, resources and cropping systems..

One program that brought farmers and scientists together to address the challenges of integrated soil management was supported by the Centre for Research and Information Exchange in Ecologically Sound Agriculture (ILEIA) in the Netherlands. This program, begun in 1995, established working groups of farmers and scientists in three different parts of the world (Ghana, Peru and the Philippines). The objective of this multinational effort was not only to refine methods for involving farmers in soil management research but also to test the hypothesis that such processes and their findings can be transferred across different cultural and environmental zones.

In parallel processes, both farmer and scientist knowledge was inventoried. National soil institutions were contracted to work closely with the farmers and non-governmental organizations (NGOs) at each site. Participatory appraisals were conducted with farmers in each location. The soil scientists surveyed and classified the soil and land at each site following standard international procedures. Soil samples were taken and analyzed to complement farmer assessments.

The next step involved correlating the researcher information with local farmer knowledge. Joint field observations were conducted. Farmers and researchers compared and discussed their different perceptions of their soils and land management practices.

In Ghana, the soil types distinguished by the farmers correlated well with those identified by the soil scientists. The soil names used by farmers also correlated rather well with the national soil series system. The farmers and scientists generally agreed on the most important soil-related constraints. Possible solutions to the major constraints were prioritized by the farmers. The researchers then made recommendations and the farmers provided their own ideas for innovative management procedures that could be implemented in the field and evaluated (Kauffman, 1996).

In the Philippines, farmers were concerned about soil acidity induced by the intensive use of fertilizer. They were provided with simple soil testing kits, plant nutrients and techniques for improving the use of rice straw as compost. In Peru, the major issue concerned erosion and the relative merits of placing furrows perpendicular or parallel to the contours. The results of research by scientists, not previously known to the farmers, were suggested as the base for testing of new conservation practices.

A similar multinational program focused on the control of soil erosion was sponsored by the Sasakawa Foundation. In 1994, collaborative research was initiated in Thailand, Vietnam, China and Indonesia. Rapid rural appraisals were conducted at potential pilot sites. Farmers were shown demonstrations plots and were able to physically observe and discuss the amount of soil run-off from each treatment.

The use of vetiver grass hedgerows was the first choice of farmers in Thailand and Vietnam. Support teams consisting of research and extension agents helped farmers select the most suitable sites for their on-farm trials. At harvest, these teams assisted in the measurement of soil loss and crop yield. In Vietnam, a treatment of vetiver grass barriers and cassava/peanut inter-cropping produced the highest yields and lowest soil loss. It also resulted in the highest gross and net income (Reinhardt *et al.*, 1996).

4 Integrated agriculture-aquaculture — The potential role of farmers in the development of new farming systems is demonstrated by an example of an integrated agriculture - aquaculture system in Africa. Traditionally, agriculture and aquaculture have been largely seen as distinct, rather than integrated systems, even when they have occurred on the same farm. The goal of the pond has been fish production and that of the field crop production. In the 1990s, the International Center for Living Aquatic Resources Management (ICLARM) launched an effort to look at the potential of aquaculture and agriculture as means to rehabilitate degraded farmlands and their surrounding environment.

A collaborative project was undertaken in Ghana involving ICLARM scientists, government researchers, an NGO, and farmer cooperators. Following an initial village resource appraisal using standard PRA and AEA techniques, workshops were conducted among groups of farmers who had expressed interest in adopting aquaculture as a new enterprise in their farming systems. Planning efforts centered entirely on using available on-farm resources. Once the farmers dug their own ponds, the only inputs provided by the project were fingerlings of Nile tilapia (*Oreochromis nilocticus*) and catfish (*Clarias gariepinus*) for initial stocking. In addition to a fishpond, many farmers also added a vegetable garden to their farming. Local farmers understood the value of vegetables but had been previously unable to undertake their cultivation because of lack of a year-round source of water.

After the first growing cycle, some of the harvested fish were sold to interested neighbors and the others were consumed in-house or given away. During the growing period, farmers used water from the pond to irrigate adjacent vegetable gardens and some applied the nutrient-rich pond mud to nearby staple crop fields (Pullin and Prein, 1994). The economic analysis indicated that gross income, net income and net cash income all increased significantly with only a slight increase in total cost through the integration of a fishpond and vegetable garden.

Similar integrated agriculture-aquaculture projects have been carried out in the Philippines in both lowland and upland environments. In one case, after the introduction of a fishpond, the surrounding lowland area became the primary source of on-farm inputs including azolla, rice bran and golden snails. Additional resource flows into the pond include duck and pig manure and water spinach. Both rice and fish yields increased through the more intensive use and reuse of on-farm wastes and by-production. Net income increased by nearly 50% compared to only a modest increase in total cost (Lopez *et al.*, 2000).

Although there are some examples of participatory technology development with farmers in prime growing environments, most of the work has been focused on meeting the site-specific needs of farmers operating in harsh and marginal environments. These are also the areas where researcher knowledge of growing conditions is least reliable. In such areas, farmers have had to rely heavily on their own indigenous experimentation to identify those cultivars and management practices best suited to their growing conditions and resource base. It is in such circumstances that farmer involvement in incremental research to build upon and improve existing management practices is likely to be most successful. The case from Ghana and others like it suggest that some prior exposure or knowledge of alternative options may be a key factor in farmer participation in and acceptance of introduced systems.

Future opportunities and challenges

Although considerable progress has been made in involving farmers and their unique knowledge in agricultural technology development and dissemination, many obstacles still remain. Researcher/farmer interaction has faced numerous challenges. Given the differences in perceptual and operational orientations, it has often been difficult to develop effective relationships between agricultural scientists and farmers.

Stephen Biggs (1989) has categorized such relationships into four general types: "contractual", where the researcher contracts for the use of the farmer's resources, "consultative" where the farmer is consulted about his or her farming system; "collaborative" where farmers work cooperatively with researchers to achieve specific research objectives; and "collegial" where farmers involve researchers in a more development-driven research process. The vast majority of interaction between agricultural researchers and farmers has been at the contractual and consultative levels which has meant that the farmer has been in a clearly subordinate relationship. For farmers to become true partners and "owners" in technology development, more effort needs to be placed on moving the relationship dynamics towards the collaborative and collegial modes.

Directly related to the nature of the working relationship are the fundamental roles played by both the researcher and the farmer. Traditionally, researchers have seen themselves in the role of educated teacher and the farmer as a learner. Researchers designed and tested technologies for farmers. Robert Chambers (1995) has called for a fundamental role reversal whereby researchers become facilitators and learners and farmers become teachers. In order for true collaboration to emerge in participatory research, he argues that researchers need to become facilitators rather than leaders.

Critics of this position have argued that when researchers facilitate PRA type learning exercises it is they who learn and benefit, rather than the farmers. It is true that in such situations the learning is largely one-way, from farmer to researcher, but the farmer also gains. Any time that researchers come away from such an interaction knowing more about the local agricultural conditions than they did before, the farmers have gained. They have been treated as someone worth listening to and through interaction with researchers, the farmers have increased the possibility of eventually receiving technologies and management options that are more relevant to their particular needs and constraints. This is not to say that participatory approaches are appropriate for all situations. Neither the researcher nor the farmer has all the answers. What we need to strive for is a process that results in more balanced interaction, one in which farmers and researchers learn from each other, not so much in a teacher - student mode but more along the lines of how professional colleagues share information and knowledge amongst one another.

In addition to making the relationship between farmers and researchers more equal, we must also look for ways to scale up the level at which such relationships occur. Intensive interaction with a few farmers can produce significant results but the costs in researcher time and effort can be high. Greater efficiencies and broader impact can be achieved by working with groups of farmers and with a broader range of stakeholders, often including traders and processors. Many researchers do not have the tools or the attitude to effectively deal with the increased complexity that working at multiple scale levels requires (Rhoades, 1997).

Robert Rhoades has noted that "the main obstacle to participatory research is the research workers themselves - the vast majority of research workers prefer to do research about a problem rather than research to solve a problem." (cited in Stroud and Kirkby, 2000). And "there has been a faster evolution of tools to generate information on local knowledge than collective willingness among researchers to change their perspectives" (Schoomaker and Freudenberger, 1994, cited in Martin and Sherington, 1997). For many researchers, sustained collaboration with farmers can interfere with career development. Participatory research is often considered less rigorous than conventional research and the results of such collaboration tend to be published in other than the premier discipline journals.

Researchers are also often concerned with how to fit farmer knowledge and the data generated from participatory research into their scientific process. Qualitative data generated through farmer participation are seen by some as being subjective and too fragmentary for generalized conclusions. Proponents of participatory research, on the other hand, have argued that statistical validation is less important than farmer adoption (Sumberg and Okali, 1988). Currently menu-driven statistical packages specifically designed to deal with hierarchical and ranked data that frequently occur in on-farm research are addressing this issue (Martin and Sherington, 1997).

Institutional structure and commitment are also a crucial factor in the success of participatory processes. Most national and international research centers tend to be organized along traditional disciplinary divisions. Such structures do not easily accommodate the sustained interdisciplinary team efforts involving both biological and social scientists, much less farmers.

Even within the international agricultural research centers (IARCs) that have given considerable attention to multidisciplinary research to address the constraints of marginal farmers, economists and other social scientists have had an uphill battle to hold their own in the face of the dominance of the biological scientists. Although clear strides are being made to include farmers more actively in agricultural technology development, the efforts of researchers involved in these programs have yet to be fully institutionalized within the centers in which they work.

In addition to issues related to modes of interaction and institutional support, more research is needed on issues relating to the costs and benefits of incorporating farmer's needs and viewpoints in technology development and dissemination. Because much of the research involving farmer participation and knowledge is context-sensitive, it is often difficult to assess the degree to which such work can be transferred to other areas. Currently, the CGIAR Systemwide Participatory Research and Gender Analysis (PRGA) program is attempting to document the costs and impacts of projects that involve farmers and women in technology development and natural resources management research.

A role for JIRCAS

I cannot presume to suggest how JIRCAS might contribute to and benefit from processes that embrace farmer knowledge as a key component of technology development. I simply do not know enough about your organization and its goals, structure and culture.

However, as an outside observer, I would ask several questions:

1) Are there are ways in which JIRCAS, as a center involved in international research collaboration, can increase our understanding of the processes by which farmers evaluate, adapt and reject new options?

2) Can JIRCAS create closer links between its basic upstream "comprehensive" research programs and the more downstream adaptive programs that it pursues in developing countries?

3) Is it possible to use outreach programs in places like Indonesia, Thailand and Vietnam to generate new insights on how farmers are making incremental changes in their farming systems? And,

4) Are there ways that such knowledge can then be incorporated into the design of basic and adaptive research programs at JIRCAS?

While the development of "new" farming systems can identify possibilities for expanding productive capabilities beyond existing limits, it must be remembered that farmers do not build new systems. Rather, they make improvements to the system they have. Ultimately, with the incorporation of new ideas and technologies, they evolve systems changes in ways that minimize risk and best fit their own objectives and conditions.

References

1) Anandajayasekeram, P. (1997): Farming systems research: concepts, procedures and challenges. J. Farm. Syst. Res. -Ext. 7(1).
2) Ashby, J. A. (1987): The effects of different types of farmer participation on the mangement of on-farm trials. Agric. Admin. Ext. 25.
3) Ashby, J. A., Quiros C. and Rivera, Y. (1987): Farmer participation in on-farm trials. Discussion Paper 22: Overseas Development Institute Agricultural Administration (Research and Extension) Network.
4) Ashby, J. A. and Sperling, L. (1994): Institutionalizing participatory client driven research and technology development in agriculture. Agricultural Administration (Research and Extension) Network, Paper 49, July: Overseas Development Institute, London.
5) Biggs, S. (1989): Resource-poor farmer participation in research: a synthesis of experiences from nine national agricultural research systems. International Service for National Agricultural Research (ISNAR), The Hague, The Netherlands.
6) Chambers, R. (1995): Paradigm shifts and the practice of participatory research and development. In Power and Participatory Development, N. Nelson and S. Wright (eds.): Intermediate Technology Publications, London.
7) Chambers, R. and Ghildyal, B. P. (1985): Agricultural research for resource-poor farmers: the farmer-first-and last model. Agric. Admin. Ext. 20, 1-30.
8) CIAT (1999): CGIAR systemwide program on participatory research and gender analysis for technology development and institutional innovation annual report, April 1998-March 1999: CIAT, Cali, Colombia.
9) Collinson, M. (2000): My FSR origins (early Tanzania experience). In A History of Farming Systems Research: FAO and CABI Publishing, Wallingford, Oxon, UK and New York, pp. 34-39.
10) Conway, G. (1985): Agroecosystem Analysis. Agric. Admin. 20, 31-55.
11) Cuc, Le T., Gillogly, K. and Rambo, A. T. (eds.) (1993): Agroecosystems of the Midlands of Northern

Vietnam. Occasional Paper No 12: East-West Center Environment and Policy Institute, Honolulu, Hawaii.
12) Dalsgaard, J. P. T., Lightfoot, C. and Christensen, V. (1994): Towards quantification of ecological sustainability in farming systems analysis. Ecol. Eng. 4, 181-189.
13) Dhamotharan, M., Weltzien, R. E., Whitaker, M. L, Rattunde, H. F. W, Anders, M. M., Tiagi, L. C., Manga, V. K. and Vyas, K. L. (1997): Seed management strategies of farmers in western Rajasthan in their social and environmental contexts: results from a workshop using new communication techniques for a dialogue between farmers and scientist. 5-8 Feb, 1996, Digadi village, Rajasthan, India: Integrated Systems Project Progress Report No. 9: International Crops Research Institute for Semi-Arid Tropics (ICRISAT), India.
14) FAO Agricultural Services Division (1989): Farming Systems Development: Concepts, Methods, Applications. Food and Agriculture Organization of the United Nations, Rome.
15) Farrington, J. and Martin, A. (1987): Farmer participatory research: a review of concepts and Practices. ODI Agricultural Administration (Research and Extension) Network, Discussion Paper 19.
16) FSSP (Farming Systems Support Project) (1987): Diagnosis, Design and Analysis in Farming Systems Research and Extension. Vols. I, II, and III, and Trainer's Manual, Farming Systems Support Project: Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida, USA.
17) Kauffman, S. (1996): Integrated Soil Management - a challenge for farmers and scientists. ILEIA Newsletter for Ecological Sound Agriculture 12(3) (December 1996).
18) Lightfoot, C., De Guia Jr., O. and Ocado, F. (1988): A participatory method for systems-problem research: rehabilitating marginal uplands in the Philippines. Exp. Agric. 24, 301-309.
19) Lopez, T. J., Dalsgaard, P. T. and Bimbao, M. -A. (2000): Application of PRA tools for integration of aquaculture into rice-based farming systems in Cavite, Philippines: a case study. In Report of the Workshop on Participatory Approaches in Aquaculture. BAO, Bangkok, Thailand, 28 February - 1 March 2000.
20) McArthur, H. J. (2000): Application, Development and Impact of Participatory Research Methods within ICLARM and the CGIAR. ICLARM Studies and Review Series (In press).
21) Martin, A. and Sherington, J. (1997): Participatory research methods - implementation, effectivness and institutional context. Agric. Syst. 55(2), 195-216.
22) Merril-Sands, D. (1986): Framing systems research: clarification of terms and concepts. Exp. Agric. 22, 87-104.
23) Norman, D. (2000): FSR: a personal evolution (early Nigeria experience). In A History of Farming Systems Research. M. Collinson (ed.): FAO and CABI Publishing, Wallingford, Oxon, UK and New York, pp. 30-33.
24) Norman, D. (2000): FSR: a personal evolution. In A History of Farming Systems Research. FAO and CABI Publishing, Wallingford, Oxon, UK and New York, pp. 30-34.
25) PRGA (1999): Crossing Perspectives: Farmers and Scientists in Participatory Plant Breeding. CGIAR Program on Participatory Research and Gender Analysis: CIAT, Cali, Colombia.
26) Pullin, R. and Prein, M. (1995): Fishponds facilitate natural resources management on small-scale farms in tropical developing countries. In Proceedings of Seminar "The Management of Integrated Freshwater Agro-piscicultural Ecosystems in Tropical Areas," J. -J. Symoens and J. -C. Micha (eds.): Technical Centre for Agricultural and Rural Co-operation (CTA) and Royal Academy of Overseas Sciences, Brussels.
27) Reinhardt, H., Howeler, N., Dang, T. and Vongkasem, W. (1996): Farmer participatory selection of vetiver grass as the most effective way to control erosion in cassava-based cropping systems in Vietnam and Thailand. Paper presented at the International Conference on Vetiver, Chiang Rai, Thailand, 4-8 February, 1996.
28) Rhoades, R. and Booth, R. H. (1982): Farmer-back-to farmer: a model for generating acceptable agricultural technology. Agric. Admin. 11, 127-137.

29) Shanner, W. W., Phillip, P. F. and Schmehl, W. R. (1982): Farming Systems Research in Development: Guidelines for Developing Countries. Boulder, Colorado, West View Press.
30) Sperling, L. (1992): Farmer participation and the development of bean varieties in Rwanda. In Diversity, Farmer Knowledge and Sustainability, J. Moock and R. Rhoades (eds.): Cornel University Press, Ithaca, New York, USA, pp. 96-112.
31) Sperling, L. and Ashby, J. (2000): Moving participatory plant breeding forward: the next steps. In A History of Farming Systems Research: FAO and CABI Publishing, Wallingford, Oxon, UK and New York, pp. 354-363.
32) Stroud, A. and Kirkby, R. (2000): The application of FSR to technology development. In A History of Farming Systems Research, M. Collinson (ed.): FAO and CABI Publishing, Wallingford, Oxon, UK and New York, pp. 95-129.
33) Thiel, G., Watson, G, Torrez, R and Gabriel, J. (1996): Evalluacion de clones resistentes al tizon: experiencia con agricultores. Instituto Boliviano de Tecnologia Agropecuaria (IBTA) Programa de Investigacion de la Papa (PROPINA), Cochabamba, Peru.
34) Warren, Mi. D. (1991): Using indigenous knowledge in agricultural development. World Bank Discussion Paper, No. 127: Washington, D. C.
35) Weltzein, E., Smith, M. E., Meitzner L. S. and Sperling, L. (2000): Technical and institutional issues in participatory plant breeding - from the perspective of formal plant breeding. A Global Analysis of Issues, Results, and Current Experience. Working Document, No. 3, CGIAR Systemwide Program on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation: CIAT, Frankenstraat, The Hague, The Netherlands.
36) Witcombe, J. and Joshi, A. (1996): The impact of farmer participatory reseach on biodiversity of crops. In Using Diversity-Enhancing and Maintaining Genetic Resources On-Farm, L. Sperling and M. Loevinsohn (eds.): International Development Research Centre (IDRC), New Delhi, India.