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FARMING SYSTEMS RESEARCH, A RETROSPECTIVE CONSIDERATION OF THE IMPORTANCE OF ECOLOGICAL SCALE AND STAKEHOLDER PARTICIPATION.[1]

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Marginal and impoverished ecologies are complex in their landscape diversity and the livelihood strategies of their population. In developing countries these regions have long been a challenge to development agencies. The diversity of ecologies, land use systems, water management and marginality of infrastructure and markets contribute to this challenge. Scientists' ability to analyze livelihood systems and their relation to land qualities has been limited, so that there often was a weak scientific underpinning to developmental interventions. Farming systems research (FSR) and its participatory application has evolved to an approach that is uniquely suited to address the technical and institutional challenges associated with the research for development of important regions. This note seeks to summarize the evolution from on-farm research directed at single commodities or factors of production, to cropping and farming systems research and eventually to approaches that lend themselves uniquely to address watershed management and ecoregional research. The authors hope that this retrospective will be of use to those dedicated to research for the development of marginal and impoverished regions.

This commentary relates the farming systems research (FSR) experience and our impressions of FSR's evolution over the last 35 years. Much of this retrospective panorama will be based on the observations of a small expert panel of willing colleagues, who have contributed greatly to farming systems research[4]. This account will no doubt be biased and the authors are aware that with a few words it is impossible to give credit where it is due: to all those who contributed in one way or another to this story along the years. The objective of this commentary - and of the expert panel - is to emphasize how changes in the research methods for farming systems were achieved, and to define where FSR approaches now stand. The authors hope to highlight a set of methodological questions they formulated, as well as to provide answers to others that arose during the research for this paper. These answers will be strongly based on the responses provided to these questions by the expert panel, even though they do not necessarily represent the opinion of any one contributor.

In this review of research approaches and analysis of responses to the questions we raised, we focus on several key changes in the practice of FSR, such as the effect of broadening research boundaries and the inclusion of environmental and health concerns in the research agenda. We also view how new approaches to stakeholder and institutional participation and the encouragement of local communities to take control over the research agenda has increased the utility of research results. The perspectives and voices that appear from this analysis are presented through a chronological overview of changes, which are reinforced and illustrated with the panel's responses to a questionnaire we devised. We conclude with observations

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about future opportunities for approaches that include FSR to contribute to an adaptive research agenda tailored to the twin goals of poverty reduction and ecological protection.

The beginning

Some of the earliest on-farm research had the explicit objective of supporting rural development. These projects included one in Borgo a Manzano, Italy, conducted in the 1950's and sponsored by Shell Ltd.. Another was the Comilla Project carried out in East Pakistan (now Bangladesh) and founded in the early 60's by Akhtar Hameed Khan. Also in the early 60's was the on-farm research of the Indian Intensive Agricultural District Program (IADP) . A few years later, the "Plan Puebla" was launched in Mexico. Throughout the early 70's, these pioneer initiatives, whose work followed the standards of farmer field trials and a continuous presence of researchers in the farm community, led to a greater recognition of the role of agricultural research and technological change in the rural development process[5].

During the early 70's, researchers from the Colombian Farming Institute (ICA), including the senior author of this paper, were busy investigating the management of inter-planted crops of maize, potatoes and beans in Cáqueza (Cundimarca) and Río Negro (Antioquia). At that time, the research process of Puebla Plan in Mexico was well underway and likewise focused on groups of corn and bean farmers for their studies. The gaze of agricultural investigation in Latin America had settled on the realities of small-scale farmers.

Many miles away, Richard Bradfield, an acclaimed agronomist from Cornell University, United States, had recently returned to Los Baños, in the Philippines. He demonstrated that with tropical soils and environments, crop yields (measured as annual cereal grain equivalent) could exceed 20 t/ha—an unbelievable amount if superimposed on the context of European or North American land. It was then that David Hopper, then President of the recently created International Development Research Center (IDRC), Canada, decided to support these initiatives. Hopper had developed his PhD thesis in India, which gave him a unique sensitivity to common third world agricultural challenges. Recognizing Bradfield's discovery as remarkable, Hopper sent agricultural economist Gordon Banta from IDRC to the Philippines to work with IRRI's Agronomist Richard Harwood and present Bradfield's results to farmers of Batangas province for their approval. The diagnostic studies and field trials that began in the International Rice Research Institute (IRRI) and in Batangas farmers' fields were taken by Richard Hardwood and transformed into IRRI's Department of Multiple Crops. Thelma Paris, social scientist who later led IRRI's Women in Rice Farming Systems' Program, was also one of the team members working in Batangas, and brought to the team a unique capability to look at the whole farm family and consider the role of women

David Hopper and Joseph Hulse, then the founding Director of IDRC's Agriculture Food and Nutrition Division (AFNS), had decided to support Colombia's ICA an institution that planned to re-focus research towards the needs of small-scale farmers. That was the beginning of the Cáqueza Project, mainly dedicated to investigating the Eastern Cundinamarca methods of production and the way these methods could be improved. These studies formed the basis for the establishment of the Integral Regional Development projects that would be implemented in Colombia during the late 70's and early 80's.

[5] Zandstra, H.; Swanberg, K.; Zulberti, C.; Nestel, B., ed. 1979. Caqueza: living rural development. International Development Research Centre, Ottawa, ON, Canada. 321 pp.

In 1973, Gordon Banta visited the Cáqueza project to become familiar with intensive multiple cropping practiced there and exchange experiences in on-farm research with the Cacqueza team. A year later, in 1974, Richard Harwood and Gordon Banta arranged a meeting at IRRI to organize what would become probably the first international program in farming systems. It was at this meeting that Asian and Latin American researchers shared and synthesized their respective experiences over the past 5-10 years. The topics of discussion centered on multiple cropping studies and participatory research in agricultural fields learnt in Asia and Latin America. This reunion also marked the beginning of the Asian Cropping Systems Network. The significance of this programmatic decision lies in the fact that, at the time, many national institutions did not allow their researchers to conduct their work in farmers´ fields. The statement of one imminent Director General reflects the attitude underlying this tendency: "It would be irresponsible to introduce technological innovations to the farming community without first trying and checking them out in experimental stations made solely for that purpose. Only after such testing can we pass on our conclusions to the extensionists, so that they, in turn, can teach the farmers how to change their farming methods". It was not easy to convince the research mangers/leaders leaders of the need to involve farmers and other groups affected by new technologies from the beginning. Nor was it accepted that the environmental conditions in experimental farms--particularly soil conditions-- were not at all representative of conditions that small-scale farmers had to deal with.

In brief, the seventies were the starting point of widespread on-farm research that involved a certain degree of participation and control by farmers, with or without specially devised methodologies for this purpose. An exemplary application of new methodologies was Peter Hildebrand's[6] fieldwork, which began in Guatemala during the late seventies. His work combined the well-known diagnostic technique of the "sondeo," or survey, with experimentation. The Uaxactún community farmers in the Petén actively participated in this combined approach, as was the case within the CATIE farming systems group in Turrialba, Costa Rica[7] - although in the latter case there was a much greater emphasis in the inclusion of new technological components. Even though there was remarkable progress in researchers' acknowledgement of the complexity of farming systems—a trend that has been pointed out by Hans Ruthenberg in the historical third edition of his book "Farming Systems in the Tropics" [8]—most farming systems research remained in this period limited to the descriptive. Moreover, even in experimental work, farming systems were perceived as fixed external factors.

Some of the questions, along with a synopsis based heavily on practitioners' answers, raised by the early days of participatory on-farm research are:

- *Why was agricultural research initially predominantly conducted on research stations?*
  By the turn of the century, science-based agricultural research was conducted primarily in research stations and by the 1960s this was the predominant practice. The classical research model did not need input from local communities. Key reasons for this omission

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6 Hildebrand, P.E. 1979. Generating technology for traditional farmers—The Guatemalan experience. Presented in the symposium on socio-economic constraints to crop protection. IX International Congress of Plant Protection, Washington, D.C., August 5-11. ICTA, Guatemala. Hildebrand, P.E. 1981. "Motivating small farmers, scientists and technicians to accept change". Agricultural Administration 8: 375-383.

7 Moreno, R. and Saunders, J., 1978. ***A Farming Systems Research Approach for Small Farms of Central America***. Turrialba, Costa Rica: Tropical Agronomic Center for Teaching and Research.

8 Ruthenberg, Hans. 1980. ***Farming Systems in the Tropics***. Oxford University Press.

included: to make the process easier by controlling fixed variables; to make the process more precise and efficient, and the goal to retain the choice of adding resources as it was deemed necessary to do so. Researchers were more interested in measuring treatment-to-treatment differences, rather than in learning about treatment performances in a broader, more variable domain.

- *When did researcher-managed on-farm research become common practice in developing countries?*
  This new practice started in the 1960s and became common by the end of the 70s or beginning of the 80s.

- *How did the farming community become a participant in research and why?*
  Initially scientists conducted on-farm research. Conflict was a significant aspect of the impetus to involve farmers, because there was originally, a lack of trust between farmers and researchers, which was a significant obstacle to effective research. Observation of the irrelevance of laboratory and station-based research, combined with low adoption rates of certain crop management technologies, forced researchers to develop a bottom-up approach. This was the advent of an on-farm, multi-systems- and stakeholder analysis-based farming systems approach in which farmers and researchers learned how to talk to each other as peers. But this trend, and the presence of the aforementioned elements varied greatly from case to case. An early example of this development is Harwood and Carangal's Asian Cropping Systems Network of the mid-1970s.

- *What influence did smallholders have on agricultural research approaches in the 1960s and 70s?*
  In the 1960s and 70s, farmers had only a faint influence on agricultural research approaches and until about the mid-80s, smallholders were mainly "helpers" for the researchers, insofar as they provided access to farms, labour, and answers to questions and surveys. There are a few uncertain but significant aspects of the farmers' influence, including how much experimenting farmers did on the side, what impact did it had, and how receptive were the farming communities actually to researchers at this time. Farmers, and farmer organizations have also expressed support for OFFSR to policy makers. It is undeniable that farmers themselves have proven through action that when they adopt a research program as their own they can be very proactive in influencing decision-making even at the national level. This underlines the importance of facilitating the adoption by farmers of a research program.

- *What were the roles of farmers, researchers and other agents in the shift toward greater recognition of community based knowledge?*
  Farmer's knowledge was originally mostly ignored and/or undervalued, reinforcing a relatively passive role for farmers, while researchers were comparably active agents who were involved in directing and implementing research activities. This tendency changed as funding agencies and local institutions challenged researchers, as social scientists were included in the research teams, and as leading studies in the 1960s and 70s pointed to the value of farmers' knowledge. Researchers began to take on roles that allowed for more equal relations—one major example of this trend being the groundbreaking recognition by Bradfield that the underpinnings of indigenous multiple cropping were congruent with Western science. Soon after this shift, the on-farm research movement was born, and today, farmers' knowledge is more respected and utilized. Although the shift in balance of

power and activity level between the roles of farmers and researchers is not complete, there has been a marked change in this relationship.

- *What are the advantages of changing the research framework of analysis from a science-based one, in which farmers help define research issues and assess qualities of proposed solutions, to one based on farmers' knowledge or indigenous culture, in which scientists learn a local knowledge-based perception of reality and apply that knowledge and the underlying scientific principles to new solutions?*
  It is important to note, in considering this question, that science and farmers' local knowledge are not necessarily juxtaposed, and that the value of local knowledge is immense. However, when the roles of science and of indigenous cultures are viewed, the authors and the panel acknowledge a definite shift from a framework of analysis based on the former to one based more on the latter. There appears to be a preference for a framework that is rooted in farmers' knowledge or indigenous culture, in which scientists learn a local knowledge-based perception of reality and apply that knowledge and the underlying scientific principles to the formulation of new solutions and their extrapolation to other conditions. We see the ability of both parties to adapt, in different ways, as crucial.

The eighties

During this decade the greatest development and experimenting with methods of system research was achieved. Land use systems began to be considered as variables in research, and therefore suitable for optimization. Experimental designs changed. The concept of extrapolation domain or recommendation domain as a sampling space changed treatment designs and the placement of replications in ways that reflected farmers' limitations and landscape realities. The spreading of farming systems towards Africa (Mike Collinson and team members[9]) was an important step, since the main objective ceased to be the comparison of management alternatives in a field, and grew into the goal of an estimating their performance in a domain of potential extrapolation. Latin America's contribution to farming system programs has been particularly important in relation to livestock systems research. For instance, the study of dual purpose, mixed (crop-livestock), and sylvi-pastoral systems, as well as new approaches to participatory research has been a major contribution. These studies, performed by the Tropical Agriculture Research and Training Center (CATIE) in Central America, but also conducted by national institutions in Colombia, Panama, Guyana and Peru (Pucallpa and Puno), served as centers for methodological development and the training of scientists. Many of them later contributed to farming systems research in Africa and Asia.

During the eighties, farming system programs multiplied, and Canadian IDRC, IFAD and US-AID supported many of them. These programs often combined the systems concepts differently and therefore translated into a variation in types or levels of farmer participation, importance placed on diagnostic methods, economic and market-based analyses, results extrapolation, and some use of process simulation and gender analysis. There were also differences in the scope of program objectives, many limiting themselves to certain main crops as determining factors of the program focus. Thus, most research was limited to corn-based production systems (Mike Collinson and the CIMMYT), rice-based programs of IRRI, and the still existing "rice-wheat"

[9] Collinson, Michael. 1981. "A low cost approach to understanding small farmers". ***Agricultural Administration*** 8 (6): 433-50. Collinson, M. 1983. ***Farm management in peasant agriculture***. Westview Press, Boulder, Colorado.

systems program in Asia. Others concentrated on farm level sub-systems, such as livestock or cropping systems.

It was also during the eighties that a great deal of research was done on methodologies such as diagnostic approaches, analytical methods to better grasp the interaction between components, sub-systems and external factors of the farm (Gordon Conway, Clive Lightfoot, the FFSP and AID program, among others), and methods for the extrapolation of results to other environments. The dynamics of rural families played an important part in these diagnoses, and many researchers, among them Thelma Paris (Coordinator for the IRRI's Women in Rice Farming Systems), contributed to the inclusion of gender aspects among them. Contributions made by Jaqueline Ashby[10], Hillary Feldstein, Cornelia Flora and Susan Poats[11] went further than the methodological aspect and helped to establish a group of female professionals known worldwide for their contribution to farming systems research and to its gender aspects These methodological studies with the purpose of improving users' participation in research, would lead to important results in the nineties, such as Farmer Field Schools, Local Agricultural Research Committees (CIALs), and programs for the participation of contributors to the food and market chain, among others.

It is evident that during this period, the support of donor institutions for the research networks and for the regional and international conferences on farming research caused important impact. The creation by IRRI of the Asian Cropping/Farming Systems Network and support for national programs (initially crops and later crops and livestock) were important steps, strongly stimulated by IDRC and IFAD. US-AID developed the expansive Farming Systems Support Program and brought in the considerable capabilities represented by the Universities of Florida, Kansas, and Colorado State. These institutions established an important series of Farming Systems Research conferences. Around this time, the work of Peter Hildebrand,[12] W.W. Shaner, and P.F. Phillips[13] contributed to the integration of concepts and the preparation of teaching materials. These were later used widely, at the regional symposiums in Asia, Africa and Latin America, and at the Global Conferences supported by FAO and the aforementioned donors. In the process of systematizing achievements and methodologies, the variability in approaches and the differences in configuration and focus of the networks and conferences contributed much to the evolution of FSR; diversity spelled enrichment. The financing of these networks and meetings by IDRC, US-AID, IFAD and ACIAR (Australian Center for International Agricultural Research) has been essential to the development of these methodologies.

During this decade we also witnessed the important impacts made by the research in farming systems. These include the success of the Plan Puebla in increasing small holder corn and

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[10] Ashby, J.A. 1985. Women and Agricultural Technology in Latin America and the Caribbean. Background document prepared for the CGTAR Intercentre Seminar on Women and Agricultural Technology, Bellagio, Italy, 25-29 March.

[11] Feldstein, H., Flora, C.B., and Poats, S.V., 1989. Gender Variables in Agricultural Research. Manuscript report 225c, prepared for the Women In Development Unit, International Development Research Centre, Ottawa, Canada, pp. 13-18, June. Feldstein, H.S. and S.V. Poats, eds., 1990. ***Working Together: Gender Analysis in Agriculture***. West Hartford, Conn.: Kumarian Press.

[12] Hildebrand, P., 1984. "Modified Stability Analysis of Farmer Managed, On-Farm Trials". ***Agronomy Journal*** 76: 271-274. Hildebrand, P.E. 1986. ***Perspectives on farming systems research and extension***. Lynne Rienner Publishers, Inc. Boulder, Colorado. Hildebrand, P., and F. Poey', 1985. ***On-Farm Agronomic Trials in Farming Systems Research and Extension***. Boulder, USA: Lynne Rienner.

[13] Shaner, W.W., Philipp, P.F. and Schmehl, W.R., 1982. ***Farming Systems Research and Development: A guideline for developing countries***. Westview Press. Boulder

bean production; the expansion of vegetable farming made possible by the substantial increase in corn and potato productivity in the Cáqueza region; the double-rice cropping and the increased planting of legume with rice crops in Asia; and, the improvement of the dual-purpose cattle enterprises in Latin America, to name only a few. All these developments would not have been as successful (or possible) if they were pursued through single crop studies or individual cattle farming enterprises. Another great impact was on methods for varietal improvement and integrated crop management, which changed as researchers in this period began to adopt, farming systems research methods. Indeed, word of these achievements has not been sufficiently spread.

By the end of the decade, farming systems research methodology had reached such widespread acceptance that the great majority of international and regional agricultural research centers had adopted FSR as an official part of their programs. The World Agro Forestry Center (ICRAF), the International Livestock Research Institute (ILRI), and the World Fish Center (ICLARM), embraced FSR in the most outstanding way of at the institutional level as the basis for their programs. In doing so, they followed the pioneering steps of the International Rice Research Institute (IRRI), the International Maize and Wheat Improvement Center (CYMMIT), the Tropical Agriculture Research and Training Center (CATIE) in Central America, and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

Although a great deal of the initial controversy arising from the existence of divergent methodologies had been solved by the late 1980's, as shown in Mike Collinson's impressive compilation, "History of Farming Systems Research" [14], and in the Turner and Bush edited study of "Comparative Farming Systems"[15], there remained some areas that could be improved. One of these was the interrelation of surveys and ex-ante and experimental evaluation of alternative systems and their technological components. There also remained important challenges in the methods for the extrapolation of results, both in the biophysical sense and in the participation of the communities. A great many of these subjects were dealt with in the following decade, with advances made in methods of community and institutional participation, a greater capacity for modeling systems, and the integration of economical evaluation and sustainability of the research.

Some of the questions and responses raised by developments in FSR during the 80's are:

- *What drove natural sciences researchers to move beyond the crop boundary and to engage in multiple (sequential-, rotation-, inter-, associated-, and relay-) cropping techniques?* This change of attention by the natural sciences researchers was in part a curiosity about time-honoured intercropping and relay systems and what motivated farmers in those practices. It was in part a greater attention to actual farming systems, and, to a certain extent, a greater desire for sustainable agriculture. The assertions of specific researchers also contributed to this shift—namely Bradfield's and Harwood's demonstration of the appropriateness of multiple cropping in the tropics, Willey's development of the Land Equivalency Ratio (LER), and the work of Integrated Pest Management pioneers. All of these contributed to the realization that crop technological change was strongly premised on cropping system and even farming system-wide conditions.

[14] Collinson, Mike. 2000. ***A History of Farming Systems Research***. Oxford University Press.

[15] Turner, B.L. and Bush, S.B., 1987, Editors, ***Comparative Farming Systems.*** The Guilford Press.

- *Why did scientists stop at cropping systems or selected livestock systems before they considered the whole-farm enterprise, and what (if any) are the merits of cropping systems, livestock production systems, and other subsystems as boundaries of research?*
  Scientists stayed with cropping or livestock sub-systems because they lacked capacity, theories, and tools necessary to handle the next level of complexity. In addition, the clear differentiation between the responsibilities and roles of farmers and researchers was conducive to continuing research at this level. Farmers were rightly considered more adept at incorporating sub-system elements into their overall farm enterprise. However, another reason for restricting agricultural research to the cropping system or livestock system level was an avoidance of the risk of skipping essential details before moving to grasp the whole picture.
  Systems and sub-systems analysis allows for a more in-depth analysis, while broadening the scope allows researchers to see a greater number of component interrelations (i.e. synergies and competition) and to build knowledge that is more poignant to land users, funding agencies, and policy makers. A focus on the subsystem also has the advantage of lending itself to the framework of academic disciplines, which makes for in-depth analysis. However, most researchers reach their disciplinary limits quite quickly when applying their knowledge to a real, working farm. In contrast, when the sub-systems level is transcended, researchers work in teams and farmers' contributions are integrated, making the work more complex. When researchers progressed to the whole-farm enterprise, it was also in realization that this was the overall decision-making unit for the agricultural enterprise.

- *What were the most salient scientific disciplines participating in the early onset of researcher-managed, on-farm research (OFR)?*
  The most salient domains were agronomy , soil science, crop and animal science, statistics, watershed forestry, participatory plant breeding, agricultural economy, sociology, and anthropology. There is ample evidence in project documents that team composition responded to the type of production system being addressed and to the nature of the research institution.

- *What influence did the social sciences have on OFR? How did they complement research on biological or physical factors?*
  Although the integration of social science perspectives in OFR has not been without conflict, these disciplines have influenced OFR in a number of ways: by increasing profitability, gaining a clearer picture of marginal returns (economists worked with cost-returns and returns to labour analysis from the 1970s on), and –perhaps most importantly— asserting the need to include stakeholders. More specifically, they assisted natural scientists in identifying and understanding the socio-economic factors that determined the technologies farmers would end up selecting from those produced by research. Social scientists also added gender role analysis, and a deeper sensitivity to household and community dynamics, although the impact of this novel awareness was not felt until community-based approaches were instituted throughout the1980s and 1990s. The benefits of the social science lens were particularly powerful when seeking to improve the management of common resources, perhaps because of a deeper understanding of the challenges to participation, conflicts of interests and perspectives.

- *When did farmer-managed OFR become an accepted approach in on-farm farming systems research (OFFSR) and what marked the acceptance of farmer-managed OFR?*

Although farmer-managed OFR had not reached full acceptance or institutionalization, it was promoted in the 1980s when community-managed research became more apparent. Examples of early farmer-managed OFR include on-farm trials (Poey & Hildebrandt), Farmer Field Schools (first in Indonesia), CIALS (Jacqueline Ashby), and The Asian Cropping Systems Network (Harwood and Carangal) projects.
There has been more talk about participatory FS research than enactment of the concept. Despite it being an invaluable mechanism for change, its presence in research literature has been underwhelming (perhaps due to a perception that it is an inefficient research tool). Furthermore, acceptance by NARIs and CGIAR centers for participatory FS research was for a long time wanting. Through their on-farm presence, FS researchers realized that farmers could contribute to research ideas. The Asian network detailed farmer-managed OFR in their design for site research and IRRI taught courses including the principles of OFR in the late '70's. Some journal papers described success stories and scientists increasingly pursued opportunities to learn participatory techniques.
An indication of the extent of this acceptance happened when commodity improvement and pest and disease management programs adopted farmer-managed on-farm research, since these programs in particular were reticent to shift their methodology and involve more stakeholders. Due to the combined value and continued under-use of farmer-managed OFR, this approach still holds huge potential for progress in agricultural research.

- *When, and for what reason, did the objective structure of OFR shift from a productivity- or income-based one to a set that was at least conditioned by sustainability or environmental concerns?*
  The agenda has always had some environmental consideration, but not until the 1990s did a growing, generalized environmentalism blossom into existence as a central tendril of OFR. (That being said, however, Altieri and Harwood are two researchers who had already begun to write about agro ecology by the mid-1980s). The reasons for the development of environmentalism in FSR were a more generalized growth in awareness of environmental and social externalities of current production systems. This awareness was precipitated by the Brundtland Report and the associated growing concern in wealthy Northern countries about how food was produced, as well as researchers' abilities to demonstrate win-win cases of the balance between environmental and productivity payoffs with FSR.

- *How did the relationship between survey techniques and experimental research evolve? What role did survey play in OFR? What was the evolution in survey approaches?*
  There was an evolution in OFR toward participatory methods—or at least toward further involvement of farmers—and the survey occupied a key place in this shift. Beginning in the late 70s, when the misuse of survey techniques reflected a lack of intellectual, and other, capacity to process complex data or to combine variables with different metrics, surveys were mainly used by social scientists, and not by biophysical scientists. Formal rural surveys conducted by agricultural economists like Gilbert, Matlon and Gordon Banta *et. al.* (IRRI) initiated this process, which was streamlined with the rapid rural reconnaissance survey by Robert Waugh, Peter Hildebrandt, and others. This was an approach that permitted a team to learn how to collaborate well and to quickly develop a research program.
  Initially, experimenters valued survey results for the resultant information about farming communities' environmental and market conditions, which in turn helped researchers to acquaint themselves with those communities and better select sites, partners etc. This experience made it attractive to include surveys in the OFR methodology, "especially to complement existing base line information, mainly on the natural environment." Then came

Clive Edwards' resource mapping, as well as a plethora of "how to learn from farmer" techniques, such as participatory appraisals by Robert Chambers and Janice Jiggins in the late 1980s and early 90s. As the experience level among OFR teams grew, and as other social scientists joined the teams, researchers began to integrate economic and social science analysis into their methodologies. The results of participatory surveys began to clearly determine the research agenda, the location of trials, the definition of extrapolation domains, and intervention points in the policy arena and in the product marketing chain. Notably, the advance of information and communication technology and process modeling has been very important, since surveys help determine how representative sites are selected, which only comes to light when there is an extensive database and access to statistical tests, so that drivers of land-use can be defined. Today, a combination of surveys, modeling, experimentation and other (more and less participatory) techniques are used. Despite this encouraging evolution, the outcomes of the diagnosis and the derived process models are still inadequately reflected at the level of research, experimental, and treatment designs.

- *What elements of participation are now considered essential in FSR?*

These elements today include, on the institutional/social side; education, support of knowkedge access, shared indicators and an agreed balance between sustainability, efficiency and equity; shared expectations of efficiency, equity and sustainability goals. On the ecological side they include; landscape use intensification; and on the economic side, support by the market. The panel and authors feel that participation should be extended to all stakeholders should, from the farm family, to farmers groups, local government, input and product related institutions, as well as national systems and policy makers.

- *What do you consider is the relationship between productivity and sustainable natural resource use ?*

The panel and commentators found the relationship between productivity and sustainable natural resource management is considered to be neutral or positive, even if it is often presented as negative in public fora. This points to the need to change this misperception among policy makers and others. There is additionally the factor of time; the relationship between productivity and natural resource use can be positive in the intermediate to long term (10 years +) for individual farmers, but is often negative if considered for under five years.

- *Which additional benefits does participatory research yield, as compared with researcher-managed OFR?*

It was generally agreed that though a transforming of the notion of "them" into "us," true participatory research greatly increases adoption of changes (particularly in low-producing areas). Participation helps to create a more effective feedback loop between research, research result uptake and dissemination, learning, and scaling up. Participatory research also contributes directly to building capacity of decision-makers and scientists, who learn to make research and results more directly applicable.

A question stemming from this topic is how to partner in research to best harness participatory benefits. Here we note a strong evolution towards farm family level and institutional capacity building for sustainable development, with a focus on local leadership, indigenous capacity development, conflict analysis, prevention and resolution, and the link between local governance and national policies. These elements become ever more critical as research embraces environmental concerns and services.

The nineties

The nineties brought an important change in the field of farming systems research. The Brundtland Report, and the Agenda 21 a few years later, boosted a series of analyses and methodological studies to answer the need for efficient incorporation of environmental aspects and the sustainable natural resource use/management into a system's programs. With these added requirements, the system under study became so complex and multifaceted, that new methodologies and instruments were required to measure and optimize existing and alternative resource uses. Initially, there was a danger of dividing the issues of rural development into two competing streams, one being efficiency and productivity; the other being respect for the environment and/or natural resources. Fortunately, nowadays it is essentially seen as a truism that all these aspects form an integral part of responsible economic development, and so they must be treated as comprising a single, whole question/approach.

In addition, the Technical Advisory Committee of the Consultative Group on International Agricultural Research (CGIAR) and the International Centers formulated the eco-regional concept[16], which concluded that the best focus of international research on the use of natural resources was that of predominant ecologies associated with a geographical region, such as the Sahel region in Africa, the Highlands of Eastern Africa, or the Andean Mid-altitude Tropical Forest Region (Ceja de Selva) or "Altiplano" in Latin America. In effect, with this position, OFSR finally moved into the CGIAR supported Centers' mainstream as an instrument for conducting ecoregional research. The ecoregional approach resolved what had been a major stumbling block to the acceptance of OFFSR by the TAC—that of site specificity. What had been a dooming indictment against FSR activities for international agricultural research now became accepted as a reality that had to be treated by effective diagnostic, design and extrapolation methods that FSR and ecoregional research approaches now provided. The eco-regional concept, and the emphasis it placed on natural resources, also encouraged the study of environmental impacts and of the ways external factors could be monetized and internalized for potential solutions to land and water management and sustainability challenges. The subject of the 2005 IESA-AL symposium "Valuing environmental goods and services and their role in poverty reduction"[17] is evidence of the progress made in these highly complex matters.

The Ecoregional Fund, established by the Netherlands' DGIS under the initiative of Rudy Rabbinge, Johan Bouma and the senior author, resulted in conceptual stimulus and financial support for the creation of research tools such as "Trade-off Analysis", the multiple goal optimization and the use of remote sensing, process modeling and field trials as part of the diagnosis of resource use systems and the testing of alternatives. This was a significant advance as these tools allowed improvements in the extrapolation of results at different scale levels. Many of the recent studies have been on the forms of community participation, decision-making processes and formulation of policies related to management of biodiversity, and soil and water resources. It is no longer only the farmer's family enterprise that must take part in the

[16] TAC/CGIAR. 1994. Review of Proposals for System-wide and Ecoregional Initiatives. ICW 1994. AGR/TAC:IAR/94/11

[17] VI Simposio de la Asociación Latinoamericana Sobre Investigación y Extensión en Sistemas Agropecuarios, (IESA-AL VI) "La Valoración de Bienes y Servicios Ambientales y su Papel en la Reducción de la Pobreza". Universidad de Caldas, Manizales Colombia 20-22 de Julio de 2005

initiatives of participative research; the community with its unique organization structures, at a local and regional scale, must also be included.

As far as the level of community participation is concerned, there have been outstanding methodological study results: Farmer Field Schools, Committees for Local Agricultural Investigation (CIAL), participation of contributors to the Food and Market Chain, among others. There has been an impressive evolution in these participative methodologies towards the inclusion of environmental subjects (for example: the Randi Randi Group Association work done on water resources in Ecuador), and of the incorporation of food and market chains by the INCOPA project of the International Potato Center (CIP). These aspects deserve more attention in the years to come, and there is a clear need to strengthen methodologies for enterprise development and the study of market chains for the identification of research intervention points.

In this context, CIP has stood out in its response to the challenges presented by the research systems and the participation of the community in the improvement of management of natural resources (as in the case of integrated pest management - IPM). CIP first used the "Farmer Back to Farmer" model for integrated crop management research, and later it stressed the importance of user participation and women in research (UPWARD). UPWARD strengthened women's roles in research by selecting promising female scientists, then mentoring and supporting them to run/work on/take part in participatory research projects. The IPM activities used the Farmer Field Schools as method of participation. Research teams on natural resources management and associated policies applied various models, such as the "agreement round tables" or "harmonizing meetings", at local government or community or watershed level as well as the participatory Outcome Mapping for research design and monitoring (Randi-Randi, Ecuador) .

It's evident from presentations at recent FSR meetings that these subjects still make up much of the methodological research and the study of implementation of research results and it remains in the institutional arena that methodological challenges demand attention. As will become clear in the section on "Year 2000 onwards" and in the "Conclusion", the institutional constructs for research that allows the combination of multiple institutional capabilities needed to address a wide range of constraints – and later, of Millennium Development Goals (MDGs) -- , require much attention and experimentation. There is still an inefficient use of existing capacity of regional academic institutions, and a failure to combine these resources with NGO and private business ventures. The initiative taken by the Consortium for the Sustainable Development in the Andean Ecoregion (CONDESAN) is an example of advanced experimentation to improve this institutional reality/approach. Progress in postgraduate farming system programs – evident at an increasing number of universities in Latin America and Asia[18], is an example of the important contributions made by academic members of this consortium.

CONDESAN is still an incomplete institutional experiment with very positive initial results. Most FSR and NRM researchers from Andean countries have in some way been involved in CONDESAN's activities. However, as far as its effective integration of the International Centers' capacities is concerned, there is still much to be done. Fortunately, though, there is a sharing of work methods among the national members, and this contributes greatly to CONDESAN's efficacy. It is encouraging to see how, from Pueblo Llano in Venezuela down to Jujuy in

[18] Examples are the University of Caldas in Manizales; Colombia; the Universidad de Los Andes, (ULA) Mirada, Venezuela; Universidad Nacional de Cajamarca, Peru; Universidad Major, San Simon, Bolivia Universidad Nacional de Jujuy. Argentina; University of Temuco, Chile

Argentina, there has been an effective institutional participation in drawing up a new CONDESAN Navigation Chart, and a subsequent sharing of information and results. Consortium members agree on two regional thematic main subjects that shall be enriched by its members' studies and experiences. The themes are "Integrated management of water resources" and "Innovations in farming methods that obtain value from the riches contained in the Andean bio-diversity". This Navigation Chart will help to gather the contributions made by CONDESAN's numerous gifted members, and to strengthen a multi-institutional consortium of ample participation.

Some of the questions raised by developments in FSR during the 90's, and the expert panel's responses are:

- *When did the Ecoregional Approach come into existence and how was it useful?*
  The ecoregional approach came into existence during the early 90s. It was useful as it allowed incorporation of spatial heterogeneity and scale dependency, strong biophysical concepts, expanded recommendation domains, and capacity to reconcile production and sustainability objectives. The reasons for its utility therefore center on the ecoregional scale and its relationship to productivity and/or sustainability. The ecoregional approach has provided an opportunity to develop a "big tent" concept, thereby expanding the research community that collaborates with the CG centres, such as was the case with CONDENSAN and evidenced by the history of the Ecoregional Fund since 1996.

- *What are the most important objectives in terms of institutional linkages and participation associated with ecoregional research?*
  To "really connect with policy makers and planners," to create policy and institutional levers that support the use of efficient and sustainable technologies, is one aspect. Another is to allow for a focus on the role of sustainable agriculture in society (in addition to that of commodities) and for decision-making and support mechanisms that provide for good technical management of production and economics at the farming level. This broader focus implies participation of institutions that bring new skill sets to the mix. It also demands effective research partnership approaches. Finally, ecoregional research encourages structural integration of systems approaches into research institutions, although this is an ongoing struggle. Ecoregional research shows a greater use of participatory diagnostic techniques, greater linkages between diagnosis and the design and ex-ante analysis of policy or technology interventions, and their testing within a methodological framework with the stakeholders' community. More specifically, the goals of integration of research tools and the networking among providers of different skill are key, becomes evident in recent work (see year 2000 and onwards).

- *Ecoregional research pursues multiples goals. What methods exist to reconcile, optimize, or determine achievement of alternative goals?*
  The goals of ecoregional research occur in the full array of resource domains—political, social, economic, infrastructural, and the bio-geophysical—and are determined by various stakeholders and groups. Furthermore, these goals change often, in response to emerging concerns and innovations.
  The methods used to reconcile, optimize, or determine alternatives and their achievement include: multiple goal linear programming, trade-off analysis (as well as other simulation techniques), GIS with analysis of key drivers; ecosystems science and ecology, with agronomy, soil ecology, ecosystems economics, social science etc. "being brought to

bear." In a few instances, interdisciplinary research work with a system perspective has been used to facilitate various participatory approaches and partnerships. "The trend seems to be to integrate more and more research as part of decision-making contexts, and decision-makers as part of the research, shortening the processes of research, application of research results in specific research instances, and how to use of these instances to learn more about ways to scale up the application of different lessons and results." There is no doubt more work is required to find ways to accommodate and resolve the challenges from of improvements in resource use that have greatly different benefits for different stakeholder groups.

- *By which means does FSR bring about more efficient and sustainable crop production and livestock production systems.*

  The factors of increased efficiency and better sustainability should be combined to achieve more sustainable agriculture. Crucial general conditions include: strengthened identity of participants (empowerment that facilitates collective action), differentiation between elements vulnerable to external dynamics and those that are robust, and maximization of return per the most limiting factor. "New scientific tools including advanced genetics, reduced tillage methods, appropriate use of IPM, satellite imagery, climatological models for risk analysis, soil erosion and siltation models and a host of other tools can provide community stakeholders with decision-support tools for technology selection and adaptation."

  Specifically regarding efficiency, what is required is the proper selection and management of the biodiversity, complementary inputs, and harvest and post-harvest processes that are part of the production system in order to effectively use and sustain nutrients and water in the soil profile in the site, given the temperature and rain profile of the production season. These must all fit the market openings and price opportunities for the producer. To better achieve efficiency and sustainability goals we need to emphasize the study of "nutrient balances for crops; crop calendars and options for action at different dates; risk assessment relating to factors that are important to production; simple models that translate agronomic actions into environmental side-effects in terms of water-, soil- and air quality; models that allow quantitative tradeoffs between conflicting demands", and that lead to quantification across gradients.

- *What impact can be achieved with the Ecoregional Approach, which is unlikely to be obtained from FRS?*

  The application of FSR in an ecoregional context allows simultaneous consideration of FSR's yield and income increases in participating communities with reduced value of products or negative impacts on the natural resource base. The ecoregional approach makes for wider spatial, social, and time scale considerations toward the objective of developing and evaluating technologies, and institutional and policy options through agricultural research. The ecoregional approach's incorporation of geospatial analyses provides scientists and decision-makers with the tools to discover niches and comparative advantages according to the given resource base, associated vulnerabilities, and market accessibility. The ecoregional approach also emphasizes sustainability more "explicitly and forcefully then FSR" and thereby more effectively impacts the policy arena.

- *What is the role of process simulation in FSR?*

The role of process simulation[19] in FSR is to: develop sound theories of systems' functioning; fill in data gaps; develop ex-ante assessment of technological responses in different agro ecologies or ideotyping of technologies, increase meaning of experimental observations, save time and other costs in the context of the research objectives and generation and evaluation of results; make for better selection of research sites; aid in the extrapolation of research results across gradients, and; show which production process leads to certain economic and environmental outputs.

- *List the factors that influence recommendation domains. What are the drawbacks of the concept of recommendation domains?*

  The factors that influence recommendation domains include: soil characteristics (eg. fertility), climate (water availability, temperature and rain profiles), accessibility, environmental vulnerability (relevant pest and disease incidence/risk), livelihood strategies and farmers' managerial sophistication (proactive and controlled use of inputs, equipment, information), and market access and conditions (inputs and outputs).

  The drawbacks of the concept of recommendation domains are seen to be in general that the recommendation domain can be an insufficiently refined, overly rigid, "one size fits all" approach that can thus yield misleading results, particularly in terms of socio-economics. A recommendation domain often erroneously defines a geopolitically- or institutionally-imposed boundary, rather than one based on the ecosystem.

  Also, they are seen as unstable, in that they become "obsolete" once the research is completed and its recommendations, indicating their domain, are released. Recommendation domains, when imperfectly defined, lead to recommendations that, once applied even within their domain, can result in unexpected performance given the existence of uncontrollable and extraordinary changes in factors that were excluded from their definition.

  The term "extrapolation domain" is one helpful alternative, because it allows for a clustering of domains based principally on gradients of biophysical variables. And from there, it is possible to study the livelihood strategies in target regions or communities prior to recommending technologies. With the usage of recommendation domains, it is also important, to always question which institution(s), communities or persons is/are targeted by the research.

- *What are the most common weaknesses or errors in participatory production systems research?*

  Weaknesses in participatory production systems research boil down to incomplete knowledge or faulty employment of participatory methodologies. For instance, it is common to see the eclipsing of science and measurement by individual's perception and hard science trained practitioners acting as "pseudo social scientists" with insufficient training. Misused participatory methodologies are lost opportunities for high quality results and the ability to address a greater number of development objectives at once. Therefore, there is a need to address the misunderstandings and poor employment of participatory research by:

[19] Here, process simulation is the imaging of mechanisms and conditions (including stochastic ones) of a system based on insights into its biological, physical and socioeconomic and other processes and that allows estimation of the way these processes influence (through associated technological coefficients) the status of the system's components and its overall outcomes.

- Raising awareness about the benefits of participatory research in order to clear up what is perceived as a conflict between the added complexity of participatory research and the goals of farming systems research;
- Including the right partners, defining their strengths and roles, and facilitating balanced participation;
- Carrying out good measurement and diagnosis, monitoring and evaluation, and charting out impact pathways;
- Properly integrating both advanced science and introduced technology with local technology and community-based knowledge;
- Sufficiently relate participatory research activities to the appropriate socio-political and economic context(s) and drivers;
- Ensuring practitioners are well trained.

Year 2000 onwards

We come to the present, the first decade of the 21st century and find other challenges that no doubt will imply further changes in FSR-like methodologies and forms of participation. One of these challenges is to recognize human health and that of the environment as main components of the system and the structure of objectives This attention to human health and to the health of the environment is a logical part of the evolution, integration and maturity in the community that conducts research for development in general, including those coming from what was the FSR front. It is part of becoming more aware of the bigger picture and complexity of the context in which we work and of the complexity of our objectives even when we define them simply. We now include improving people's well being, which is not only greater income, but includes at least secure food, and health. Besides making research more complex, this also gives us opportunity to value results from different perspectives and to learn to deal with trade offs between objectives, and the people's interaction among themselves and with the natural environment (economy, governance, politics). This evolution should also capture the influence of environmental health on human health (ecosystem health), and as such, on the farming capacity of the rural community and its ability to manage natural resources. This research demands an intervention in the area of local and national policies. It may also require changes in attitudes of funding agencies and the private sector. Examples of this are the debate about the appropriate roles of micro-nutrient supplementation and biofortification of major food crops, or the benefits to health and productivity of shifting to less toxic and more targeted pesticides. The means to achieve the necessary changes in these policies should be based on the knowledge acquired through participative research and through a wide range of institutional alliances.

Other issues that merit future attention are the need to study and negotiate the forms of structuring and managing institutional interaction and participation. The experience from models such as the Latin American Center for Rural Development (RIMISP) and CONDESAN, demonstrate special needs of participants. Institutions need to understand and differentiate unique institutional objectives from areas that are in common; the importance of having a clear understanding of the rights and obligations of cooperation and the accountability to stakeholders. In these institutional agreements, the types of contribution by the public sector, by commercial interests and by the user organizations, must be fully recognized. The experience of the Asian Rice-Wheat Program conducted by several National Institutions and International Centers together with local interest groups, present a worthy example of such clear transactional relationships. Because of the multi-sector characteristics of natural resources management research, the rules of the game need a great deal of attention and we lack a compilation of experiences. These institutional studies of eco-regional research programs have received inadequate attention in the past, which is now causing a bottleneck in the successful

implementation of those programs and of new initiatives that seek the attainment of MDGs in defined regions.

Over the years, a number of valuable research tools have been developed and research teams typically access several of these in their projects. The relationship between these tools needs to be better understood. For example, the use of participatory interviews of producers or other stakeholders, (e.g. cattle farmers and tourist service managers around a cattle induced uetrophying lake) and the modeling of mechanisms of phosphate flows will be different depending on the phase of the research or on the state of knowledge availability. Similarly, we must clarify how the use of indigenous knowledge can be better incorporated into FSR—specifically, for instance, by linking such knowledge systems to modeling based ex-ante analyses of management alternatives and on-farm experimentation. Johan Bouma and colleagues[20] have recently explored these connections between different research procedures, such as local experiential knowledge, qualitative description or quantitative modeling, and field experimentation, large scale (e.g. landscape), or small scale (e.g. root zone) studies. Their concept of "Research Chains" in which different research approaches (or tools) are applied in different situations, as well as the going to and fro between these tools for measurement, hypothesis building and testing, is worthy of further work and systemizing. It is evident that the choice of tools at any time or in any situation of the research and implementation process is not accidental, and underlying rules can be further clarified.

Finally, as land use intensifies and environmental and health problems worsen, there are bountiful opportunities for the farming systems methodologies to support the study of urban and peri-urban agriculture. This is where we find a concentration of multi-sectorial factors, such as agricultural production, business development, waste management, and human and environmental health. An appropriate institutional mix, therefore, must cut across various government agencies, NGOs, commerce and producer organizations (to name a few), which creates an urgent need for regionally-organized participation of affected groups in the formulation of research, as well as in the evaluation of outcomes such as policies.

Some of the questions raised by developments in FSR during the last five years, and the expert panel's responses are:

- *What type of new technologies can be integrated in OFFSR? How should FS researchers access the sources of these technologies?*
  If referring exclusively to production technologies, the following can be integrated into OFFSR: GMOs, market chain approaches, ICT, GIS, process models, partnership approaches, and use of qualitative models for research management. FS researchers should access these technologies by participating in larger communities who have access to CGIAR centers and ARIs. They should increase and improve the use of the Internet and tele-centers in a manner that closes the gap between researchers in the South and those in the North. This move can fertilize "a symbiosis greatly needed to succeed." On the specific

[20] Bouma J.; Droogers P. Comparing different methods for estimating the soil moisture supply capacity of a soil series subjected to different types of management : Geoderma, Volume 92, Number 3, 1 October 1999, pp. 185-197(13)
J. J. Stoorvogel, J. Bouma, and R. A. Orlich. Participatory Research for Systems Analysis: Prototyping for a Costa Rican Banana Plantation. Agron. J., March 1, 2004; 96(2): 323 - 336.

topic of ICT, more work is needed to synthesize, showcase and visualize the possible related economic, environmental, and social outcomes. It is imperative that researchers ensure technologies such as biotechnology, GIS, process models, partnership approaches, use of qualitative models for research management are accessible and affordable to researchers and where applicable, targeted producers and policy makers.

- *How can the Ecoregional Approach make a greater contribution and how can ecoregional research be more effective?*

  The ecoregional approach can make a greater contribution primarily by building collaboration and practical knowledge. The ecoregional approaches currently in existence can be enhanced through networking that establishes better communication, participation, and knowledge building. Specifically, better interchange, stakeholder engagement, and knowledge sharing will make for stronger interaction and collaboration with practitioners, decision-makers and policy makers at all levels and in different relevant sectors, which in turn will lead to changes in behaviour, and greater expectation and demands for research results. Researchers in particular should accrue knowledge so as to assist in appropriately defining ecoregional research. They should make the approach less diffuse by focussing on principal "drivers in each resources domain". One particular possibility is to establish a collective of comparative case studies in different continents, designed to prove the usefulness of the approach and the tools developed, and to use the studies as training sites for practitioners worldwide.

  To become more effective, ecoregional research must consider the following areas:

  - Networking – Ecoregional research must bridge gaps between various sectors, from researchers (who have been/ are pioneers of the topic), practitioners, land users, national research institutions, and policy makers. This interchange from the research to policy spheres and back must be continuous.
  - Refining and rebuilding the paradigm – In order to work more effectively together, participants need to reach clear and shared understandings of the concepts and framework on which the ecoregional approach rests. This means defining system drivers, emphasizing quantification and risk assessment, and pursuing the right blend of sustainability, equity, and efficiency aims through stakeholder engagement.
  - Creating knowledge and institutional training –There are two aspects: accruing knowledge and imparting it to those involved in instituting the ecoregional approach. On the former, building detailed and useful stories that reflect local thinking and other state-of-the-art knowledge, quantifying data and risk, and demonstrating the associated tradeoffs are important. With respect to education, extensive hands-on training—particularly with local universities—is crucial. This training must make complex tools into user-friendly interfaces.

- *Which of the multiple goals pursued by Ecoregional Research have been particularly useful?*

  Participation, collaboration, and inciting communities to become more conscious of their constraints and opportunities as well as willing take charge, are

the especially useful goals of ecoregional research. Of special importance has been the involvement of decision-makers in the selection of paradigms to be addressed and spatial scales to be incorporated into systems' analyses. People's visualization of common problems and opportunities has been aided by way of the participatory elements of an ecoregional effort. Along this line, ecoregional research has effectively formulated story lines by using a combination of models. Moreover, the organizing by stakeholders to act collectively and proactively to solve problems and pursue existing opportunities has been particularly useful.

Combining production and environmental goals has been another particularly useful goal of ecoregional research; specifically, pest management research (IPM being the best example), watershed management, and soil quality, fertility management and ecology.

- *In which ways could research participants more effectively serve the institutional aspects of the Ecoregional Approach?*

  Research participants could more effectively serve the institutional aspects of ecoregional approach in a variety of ways, depending on their positions.

  - Researchers can collaborate more openly with local scientists, engage in more course development and teaching at universities, and mentor younger researchers and newcomers.
  - Community dwellers can improve their ability to "organize and reorganize themselves for collaborative work of different sorts."
  - NGOs, institutional decision-makers, and policy-maker participants can become more proactive in adjusting their organizational policies and practices. And to do this, what is needed is sensitive and thorough collaborative communication among participants for a shared vision of ecoregional concepts, objectives, expected contributions, benefits and their distribution.

Conclusions

The evolution of participatory on-farm research has included several expansion paths. First and foremost is the now full recognition of the farm family -- gender roles being considered --, and the farm community with its indigenous knowledge, as those who must drive the research agenda and engage in the implementation and interpretation of research. Second is the embrace of ever wider system boundaries, to include sustainability, environmental objectives, human and environmental health, environmental services and rights of access, origin and use of technologies and resources. Third is the increased number of research tools for the study of complex systems, the optimization of and trade-off's between multiple objectives associated with different stakeholders, the capacity to carry information forward across different scales, the expanded use of models, satellite imagery, geographic information systems and other methodologies.

The authors and panelist contributors showed a great deal of coincidence in views about this evolution. Where responses showed strong differences, this was mostly because different time or geographic scales, such as developed versus developing country, were considered. The coincidence of views greatly facilitated the synthesis of the Panel's responses to the questions posed throughout this paper.

From the perspective of scientists and institutions that focus on research for development, the continuous expansion of system boundaries and the increasing inclusion of new resource domains embodies a serious institutional challenge and requires accessing new knowledge sets, as well as growing more familiar with the institutions and issues concerned with them. Developing country scientists deserve admiration for the courage and dedication with which they have sought to contribute to this rapid sequence of new approaches, and frequently, to build them into their institutions. It may be useful, however, to spend the time and effort required to make these approaches more systematic and manageable and to develop guidelines for their application and linkages, such as exemplified in the recent concept of Research Chains.

It is evident and encouraging that on-farm farming systems research has evolved from researcher led on-farm testing to a set of effective participatory research approaches. These approaches cited throughout this paper, when judiciously applied, allow researchers to address complex production, human well-being and environmental problems at farm, land type, watershed or ecoregional level. The authors are convinced that there will be a continued improvement of these instruments as an integral part of agricultural and environmental research, and do not doubt that this progression of methodologies and approaches will benefit sustainable development and the reduction of poverty.