2 Systems research for agricultural development

Past, present and future

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Introduction

In the mid-1960s the Green Revolution (GR), based on fertiliser-responsive, high-yielding varieties of rice, wheat and maize, began having a major impact in favourable (including both biophysical (technical) and socioeconomic (human) elements) production environments (Norman et al., 1982), particularly in Asia, and parts of Latin America and North Africa. Since the GR technologies were scale-neutral, 'revolutionary' and robust, their adoption benefited all types of farmers even if they did not exactly follow the prescribed recommendations.[1] The key components of the GR technologies were (i) good seed (high-yielding varieties), (ii) availability of needed fertiliser, (iii) well-developed rural infrastructure, (iv) enabling policies and (v) availability of good quality land and water. However, the heavily 'supply-driven' and single commodity reductionist research approach was less successful in addressing the needs of farmers in less favourable and more heterogeneous production environments so common in Sub-Saharan Africa (SSA) and non-GR parts of Asia and Latin America.[2] Smallholder farms in Africa are extremely heterogeneous and diverse in both crop and livestock components, and are less compatible with the classic GR model, which explains why the GR had little impact in these areas.

Farmers in high-income countries (HICs) have historically been effective in articulating their needs – not only technological but also institutional – via more responsive research and extension systems, commodity-based groups, lobbying platforms and so forth.[3] However, because farmers in low-income countries (LICs) – the major focus of this chapter – have generally benefitted much less in terms of education and linkages with research, extension and policy institutions, their views have historically not been adequately taken into account, nor have they been involved in shaping policy on issues that concern agriculture and their livelihoods. Generally they have had no 'voice' in the kind of research that is supposedly done on their behalf. Mostly such research had been based only on researcher perspectives, and usually focused on individual commodities or specific components of the system, rather than embracing the diverse and integrated nature of the farming system and its linkage to livelihood systems that support smallholder farmers. However, since the 1970s the 'top-down' agricultural research/developmental paradigm has been criticised for excluding the farmers. It was this need that led to the emergence of farming systems research (FSR).

This chapter initially examines the origins of FSR and the path and reasons for its evolution and transformation into what is now called integrated systems research (ISR). In doing so we stress the need for more integrated system approaches, aimed at enhancing the livelihoods of smallholder farmers. The specific experiences of the international agricultural research centers (IARCs) under the umbrella of the Consultative Group of International Agricultural Research (CGIAR) (http://www.cgiar.org) with ISR are used to illustrate this evolution from FSR.

Building on the specific experiences of the CGIAR, and also based on FSR transitioning to a broader integrated livelihood systems focus, the chapter identifies a number of elements and pre-requisites that are considered essential for the conduct of ISR with a livelihoods orientation. The chapter concludes with an affirmation of the continued need for systems research in agriculture and for increased integrated and holistic analysis, taking into account the research-development continuum involving multiple stakeholders. In this regard, mechanisms for enabling multi-stakeholder processes in agricultural research, together with the need for farmer empowerment to ensure their full participation, are emphasised as essential.

Evolution of farming systems research and farmer participatory approaches[4]

Until the 1960s, there was little research collaboration between technical agricultural scientists (usually located on experiment stations), economists (mainly in planning units) and anthropologists/sociologists (generally in academia). However, in the early 1960s and later, many village-level studies were undertaken, initially by anthropologists/sociologists (i.e. especially in francophone SSA) and later by agricultural economists (i.e. mainly in Anglophone countries), that involved elements of whole farm dynamics and their relationship to the farming community. The major conclusion (Collinson, 1972; Spencer et al., 1979; Norman et al., 1982; Walker and Ryan, 1990) was that resource-limited farmers and their households had a very good understanding of the variable and risky production environments in which they operated and adopted farming systems (i.e. combining crop, livestock and off-farm enterprises) that were fundamentally sound (i.e. in terms of their goal(s) and resources (inputs) available) and that, historically at least, were sustainable.

Such positive conclusions about the rationality of farmers and the farming systems they operated (e.g. mixed cropping (Norman, 1974)) began to throw light on why many recommended research technologies were not adopted by farmers. Until the 1960s, most recommendations were derived from station-based trials, using technical evaluation criteria (e.g. yield increases) with practically no involvement of farmers. Farmer-implemented evaluation exercises indicated that many existing recommendations were inappropriate

(Norman et al., 1982). In fact, many of the recommendations compatible with farmers' biophysical environments were found to be incompatible with their socioeconomic environments. Consequently using technical evaluation and standard conventional economic criteria alone were inadequate for evaluating the suitability of technologies for resource-limited farmers, often operating in unfavourable and heterogeneous production environments. Farmers and their households usually had goals that go beyond profit maximisation, such as being risk averse in operational situations where markets for capital, land and labour worked very imperfectly. In spite of this, farmers were not inherently conservative since they were natural informal experimenters (Biggs and Clay, 1981). Another important conclusion was that it would be desirable to introduce some flexibility in formal recommendations enabling farmers to better respond to location-specific differences rather than relying on a few fixed technological packages (i.e. one size fits all syndrome) (Norman et al., 1982).

Two other factors fuelling a change in the conventional 'top-down' (i.e. supply driven) research paradigm were that:

- Those of us working the field increasingly recognised that the neoclassical economic paradigm training approach that most of us agricultural economists received had limitations in addressing all issues faced by resource-limited farmers, including that they operated in dynamic and very uncertain production environments.
- We also realised that there would be synergistic benefits in directly interacting with farmers in the technology design and development process itself (i.e. *ex ante* involvement), rather than treating them only as persons from whom data is extracted and whose only involvement occurred *ex post* after the recommendations had been formulated.

Thus a radical change in the research approach took place, with greater emphasis on the importance of taking a whole farm analytical approach, zooming out from plot level to farm/household level, and seeking to better understand socio-technical interaction issues such as labour/land and input/output dynamics between different crops/commodities at the farm level. This new thinking also required involving farmers in the research design and implementation, leading to the emergence of farmer participatory approaches as a critical component of agricultural research. This required an interdisciplinary[5] strategy and involving farmers throughout the technology design/evaluation process. Consequently in the mid-1970s the FSR approach emerged in response to the need for a more integrated 'bottom-up' and 'demand-driven' paradigm for agricultural research, focusing on the farmer in his/her environment/context. The farming systems perspective required new types of relationships between farmers and researchers (technical and social scientists). Over time, this expanded into farmers interacting with agricultural development stakeholders, and the incorporation of farmer participatory methodologies into national and international agricultural research programs.

The farming systems research approach process began with an understanding, from the perspective of the farmers and farm households, of their problems and opportunities, and using those as an input in the design/evaluation of solutions compatible with their objectives and production environments. In addition to farmers' involvement being critically important in the technology development/evaluation process (Matlon et al., 1984; Chambers et al., 1989), other significant characteristics of farming systems research were: its holistic perspective, the iterative nature of the process and the involvement of both technical and social scientists. One of the early schematic frameworks for implementing FSR was developed at a Ford Foundation-sponsored workshop at the *Institut d'Économie Rurale* in Bamako, Mali, in 1976 (Figure 2.1) (Norman et al., 1982).

Operationalising FSR first required classifying farming households into different farm types in which those within one type had analogous resources, basically experienced similar problems and opportunities, and hence would likely benefit from adopting the same potential solutions (i.e. recommendations). These different types/groups of farming households in essence constituted what later became known as recommendation domains. Through selecting farming households, representative of the different farm types, it was then possible to target activities while the recommendation domains provided a basis for scaling-up or introducing any recommendations to other farming households of a similar farm type.

Farming systems research has undergone a major evolution over time. Generally, four phases can be differentiated (Figure 2.2) based on the ability to deal with progressively higher ratios of variables to parameters. Over time, thanks to methodological developments, evolution through the four phases occurred, making it possible to handle increasingly complex situations in the later phases.

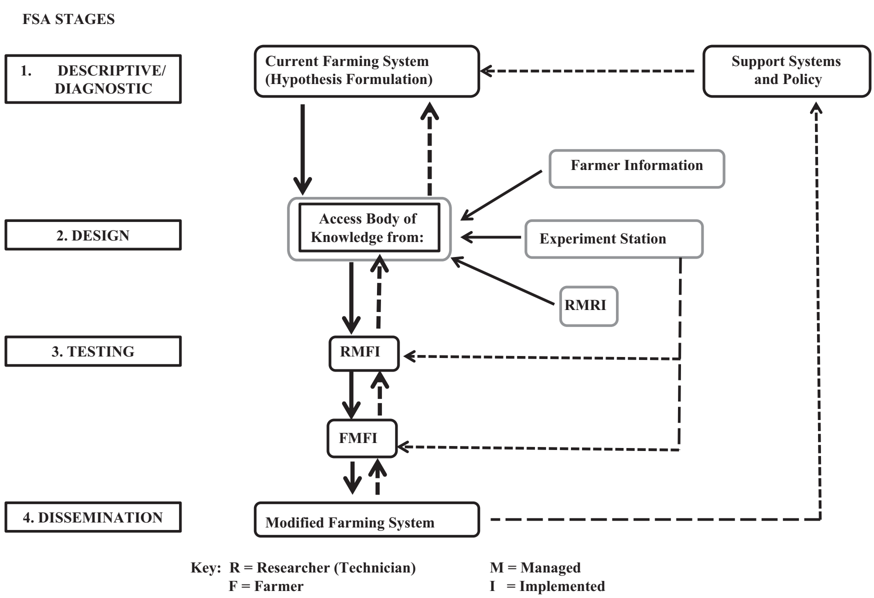

Figure 2.1 The farming systems approach in technology generation

Source: Norman et al., 1982.

A brief overview of the different phases of FSR since its beginning in 1970s is presented below, and illustrated in Figure 2.2.

1. ***Farming systems with a predetermined focus.*** Initially FSR considered only one specific commodity, with focus on identifying improvements within that commodity that were compatible with the whole farming system. For example, given their specific crop mandates, the International Maize and Wheat Improvement Center (CIMMYT) and the International Rice Research Institute (IRRI) focused on maize-, wheat- and rice-based systems, thereby introducing a systems perspective to commodity-based research programs – which by themselves often had a strong reductionist orientation. This approach was relevant to farming systems dominated by one crop, since improving the productivity of that enterprise would have the greatest impact on the productivity of the overall farming system. Because of their networks and training programs in Africa and Asia, these two IARCs were very influential in disseminating FSR principles in the early years, though the principles were coloured to a large extent by the commodities that these institutions focused on.
2. ***Farming systems with a whole farm focus.*** Although the IARCs, as peer research institutions, were important in popularising FSR, national

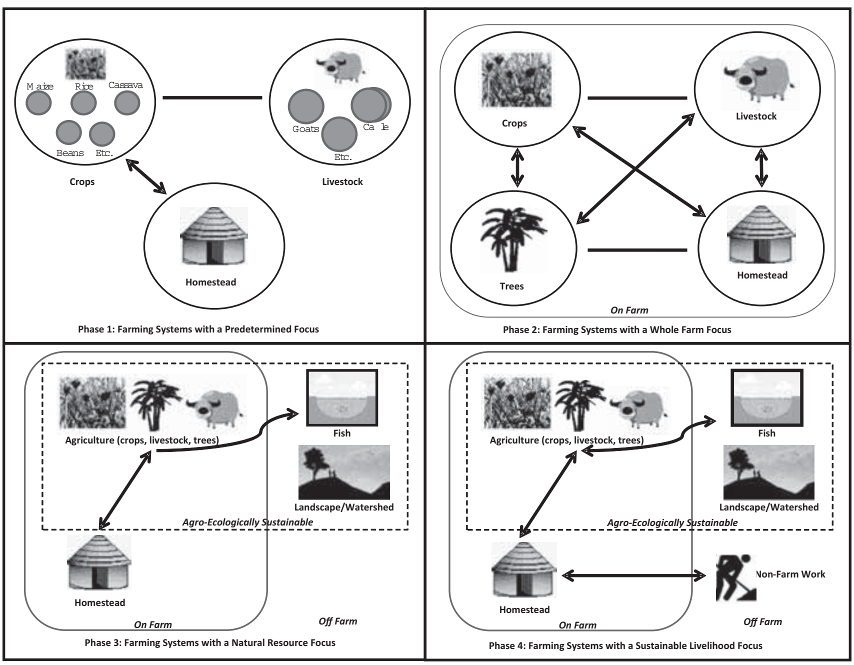

Figure 2.2 Progression in the farming systems approach

Source: Modified from Norman (2015).

agricultural research systems (NARS), with their multi-commodity mandates, were primarily responsible for the approach becoming more holistic. This required that focus on any commodity and its linkages with other commodities had to be based on the needs articulated by farmers and their households. Substantial donor funding supported the promotion of this FSR approach with early examples occurring in Guatemala, Thailand, Senegal and Nigeria. Its growth within the NARS resulted in distinct area-based farming system teams working directly with farmers. This phase encouraged greater farmer participation, as they found research targeting their needs.

Early experiences with these two phases of farming systems research encouraged technical scientists to design more flexible technological components and packages suitable for different types of farmers. Increased respect for the roles of, and tools used by, different disciplines resulted in improved cooperation between technical and social scientists. Finally, there was increased appreciation of the critical importance of appropriate policy/support systems (i.e. input distribution systems and product markets) in determining the relevance of new technologies.[6] These developments did not occur overnight, but were evolutionary based on growing confidence, discovery and learning within FSR.

3. ***Farming systems with a natural resource focus.*** In the late 1980s, ecological sustainability issues became more important. It was realised that a number of practices within traditional systems of agriculture (e.g. shifting cultivation, bush fallowing and ring cultivation) ensured ecological stability, but that these systems were under pressure and no longer feasible because of exogenous influences such as rapidly increasing populations (human and/or animal) and climatic changes. Short-term survival concerns were increasingly forcing farmers to adopt strategies ensuring short-term food supplies, such as continuous cropping (without fertiliser inputs), which had detrimental long-term environmental consequences. In SSA, increasing human population densities meant that lands unsuitable for cultivation were being cropped, raising issues of land degradation. Generally, cropping systems were being intensified, but without the means to supply plant nutrients to maintain soil fertility (such as through recycling crop residues or adding organic/inorganic fertilisers). In GR areas (e.g. the intensive rice–wheat systems of South Asia), farmers using high levels of inorganic fertiliser and other external inputs were also experiencing decreasing productivity. Although scientific analysis can foresee the challenge of ecological degradation, farmers, mainly driven by short-term survival, might not see such an issue as a major concern, unless it threatens immediate survival (Fujiska, 1989). Consequently, it is unlikely that such issues would be addressed in phases 1 and 2 of FSR. It therefore became necessary for external stakeholders (e.g. researchers and development practitioners) to study possible conflicts between strategies designed to improve short-run productivity and those ensuring long-run ecological sustainability. These concerns led to the introduction of an ecological sustainability dimension into FSR, mainly driven by researchers.

Two ways in which this FSR phase has been operationalised are as follows:

- Introduction/adoption of new methodologies that involved working with farmers to evaluate bio-resource (nutrient) trends and flows on the farm. These enabled the identification of vulnerable parts of the farming system and helped researchers, in collaboration with farmers, determine how current practices could be modified to promote ecological sustainability (Lightfoot et al., 1991; Defoer and Budelman, 2000). This approach helped farmers in transforming ecological problems from being a *foreseen* to a *felt* problem (Norman, Umar et al., 1995). Since solutions were usually farm-specific, with implementation being the primary responsibility of farmers themselves, it was important for them to assume ownership for the necessary changes identified during the participatory design exercises.
- Shift towards eco-regional research, undertaken by some IARCs in association with national research and development institutions. The focus of this kind of research was on priority eco-regional problems, with elements of productivity enhancement combined with natural resources management and environmental sustainability. The operational mode required the collaboration of all the stakeholders in the agricultural research/development continuum. A good example of eco-regional research was the African Highlands Initiative (AHI) project, which was conducted in the highlands of East and Central Africa (ECA) in the period 1995 to 2011 (http://www.worldagroforestry.org/programmes/african-highlands/evolution.html) with the aim of developing methodologies for integrated natural resources management (INRM) and their institutionalisation in partner NARS in the humid highlands of ECA. The AHI worked with teams from NARS, extension and non-governmental organisations (NGOs), and hence maintained a network of partner organisations on research for development in natural resources management (NRM). Using both action and empirical research, AHI developed several methods, tools and approaches for INRM, and at the pilot project level demonstrated an INRM approach that works. The strategy was to demonstrate it on a larger scale via cross-scale interventions and adaptive management. This constitutes the essence of eco-regional research, tying NRM issues into FSR.[7] This study contributed to the development of a guideline on the implementation of INRM research for development (Campbell et al., 2006).[8]

Three important challenges in implementing this phase of FSR are worth noting. The first is that significant resources (i.e. time and financial) were required to address the complex processes and to show results especially related to the sustainability element. Secondly, assessment of progress in improving ecological sustainability required a long time-frame. Thirdly, because of the poverty level of many farming households, ecological sustainability initiatives were likely to be attractive only if they simultaneously improved short-run welfare,[9] or had some incentives built into them.

4. ***Farming systems with a sustainable livelihood focus.*** In this fourth phase of FSR, of which ISR is an example, the ratio of variables to parameters is the highest.[10] This phase explicitly involved linking change at the household level with complementary changes at the meso- and macro-levels. The objective is to strengthen the abilities of households and communities to use existing and new knowledge in analysing their circumstances, ascertain problems and opportunities, evaluate possible strategies and, consequently, plan and implement action. Ideally, emphasis is on designing interventions improving productivity and income (i.e. reduce poverty) while simultaneously protecting the environment.[11] Preferably they should also strengthen the coping and adaptive strategies of the most vulnerable groups in the community. New technologies that fulfil such conditions are likely to have the following properties: be flexible through increasing the ability of farmers to adapt their production/livelihood systems to stochastic shocks and to a constantly changing economic environment (Chambers, 1991); reduce risk, such as the new more resistant/tolerant crop varieties and agronomic practices that reduce the impact of biotic and abiotic stresses, that promote enterprise diversification, etc.; and complement the complex livelihood systems of poor households.

   Since assets, entitlements and social relationships of households vary according to household and socioeconomic stratum, resulting in different livelihood strategies (Chambers, 1989; Frankenberger and Coyle, 1992), attention is usually focused on the most vulnerable (i.e. poorest) households facing chronic or temporary food insecurity. A combination of analytical methods, including conventional farming system (farmer participatory) approaches, political economics, anthropology and environmental science, are used with the involvement of interdisciplinary teams working in conjunction with local communities. This phase of FSR includes and combines elements of all three phases described above, and thus constitutes the most advanced manifestation of FSR. It has often been said that in spite of the holistic characteristic of this phase, its application has been a challenge due to the greater complexities involved. A principal question, however, is 'adoption of what?' It can be argued that the application of such integrated system approaches should not viewed simply as the wholesale adoption of processes and products. The particular research processes and the outcomes resulting will be situation-specific. Among other challenges relating to scaling-out and dissemination are the location specificity of solutions, and the skill sets required of the interdisciplinary teams involved in implementation. As mentioned earlier, the CGIAR developed guidelines for this (Campbell et al., 2006) that stressed the need to focus on the weaker aspects of a proposed 'learning wheel', thus avoiding becoming bogged down in too much detail and complexity.[12] Unfortunately experience in applying this approach has been insufficient to determine its usefulness.

Methodological developments

Methodologies for eliciting the attitudes and expertise of smallholder farmers have evolved greatly since the 1970s, thus creating more avenues for their involvement in identifying and implementing relevant research and development initiatives. Initial methodological developments occurred in response to a specific need/stage in implementing the FSR, namely: description of the situation; diagnosis of problems and/or opportunities; testing/evaluation of solutions/opportunities; and dissemination (Figure 2.1). Over time, many of the techniques were found to be useful in addressing or operationalising more than one stage of the approach.

Among the most important methodological developments have been the following:

- Rapid rural appraisal (RRA) and later participatory rural appraisal (PRA), which were methods developed for obtaining information from farmers (Program for International Development, 1994; Pretty et al., 1995). Such techniques provided a means of ascertaining how farmers interpreted their production environments and could help them articulate their constraints and needs to researchers. It thus enabled them to contribute more directly and effectively to the design and evaluation of new technologies. PRA techniques, in particular, improved the potential effectiveness of farmers' participation through greater systematisation of their knowledge and opinions.
- Farming systems research dispelled the simplistic notion of the farming household being monolithic, with one decision-maker pursuing one goal, making all farming decisions, and every household member benefitting equally from the results. Many researchers helped develop techniques for examining intra-household relationships, particularly those that were gender-related (Feldstein and Jiggins, 1994). Consequently there evolved greater sensitivity to incorporating gender and other intra-household related issues in the research and development process.
- Prior to FSR, technology evaluation was usually accomplished through experimental station trials, where design, management and implementation were all done by the researcher. This was tagged as researcher-managed and researcher-implemented (RMRI) with the researcher (R) being responsible for deciding the treatments (i.e. management (M)) and their implementation (I). However, FSR encouraged use of two other types of trials, specifically researcher-managed and farmer-implemented (RMFI) and farmer-managed and farmer-implemented (FMFI). These three trial types differ according to several characteristics (Table 2.1) (Norman, Worman et al., 1998). RMRI trials generally dominating in the technology design stage are later increasingly substituted with RMFI and FMFI trials. This farmer 'learning by doing approach' is important in improving farmers' assessment of, and potential commitment to, adopting technological components/packages.
- Prior to FSR, farmers' participation in the technology development process was only at the adaptive end of the research spectrum. However, Sperling

Table 2.1 Expectations of different types of trials

Item	*Researcher-managed and researcher-implemented (RMRI)*	*Researcher-managed and farmer-implemented (RMFI)*	*Farmer-managed and farmer-implemented (FMFI)*
Experimental:			
Stage:	Design	1st stage testing	2nd stage testing
Design:			
Complexity		Less	Least
Type	Standard	Simple standard	With and without
Replication	Within and between sites	Usually only between sites but can also be within	Between sites only
Levels of treatment	Most		Least
Standardised level of non-experimental variables	Most	Less	Least
Plot size	Smallest	Less Larger	Usually largest
Who selects technology?	Researcher	Researcher/farmer	Farmer
Who shoulders risk?	Mainly researcher	Researcher/farmer	Mainly farmer
Main discipline of researcher	Mainly technical	Technical/social	Mainly social
Participation by:			
Farmer	Least	More	Most
Researcher	Most	Less	Least
Number of farmers	None	Some	Most
Farmer groups	Least	More	Most

Potential:			
"Yield"	Most	Less	Least
Measurement errors	Least	More	Most
Degree of precision	Highest	Less	Least
Data:			
"Hard" (objective)	Most	Less	Least
"Soft" (subjective)	Least	More	Most
Determination of cause/ effect relationships	Easiest	Less easy	Least likely
Incorporation into farming system	Least	More	Most
Evaluation:	Mainly researcher	Researcher/farmer	Mainly farmer
Who by?	Assess technical feasibility	Technical feasibility plus economic evaluation	Validity for farmers – practicality, acceptability
Nature of test			
Appeal to: Researchers			
Extension staff	Most	Less	Least
Farmers	Usually least	More	Most
	Least	More	Most
Ease of acceptance of trial results	Researcher	Researcher/farmer/extension	Farmer

Source: Adapted from Norman, Worman et al., 1995.

and Berkowitz (1994), working with beans in Rwanda, demonstrated farmers could make uniquely valuable contributions in the evaluation through, for example, participatory varietal selection (PVS) of suitable bean germplasm. This concept was further developed with farmers' involvement in participatory plant breeding (PPB) of improved varieties (Joshi and Witcombe, 1996; Witcombe et al., 1996) in both IARCs and NARS.
- Two approaches developed for analysing results of on-farm research and making recommendations based on them were: adaptability (formerly modified stability) analysis, a statistical tool for analysing RMFI and FMFI on-farm trials (Hildebrand and Russell, 1996; Sall et al., 1998); and PRA techniques – in particular matrix ranking and scoring – enabling farmers' criteria to be systematized,, that is ranked, both in designing and evaluating on-farm trials. Another less common approach developed was a quasi-arbitrary ordinal weighting approach for determining criteria farmers use in deciding, for example, which rice crop varieties to adopt (Sall et al., 2000).

Such methodological developments, greatly improving farmers' effectiveness in FSR, have been accompanied by other very positive changes, namely: more collaborative and collegial relationships between farmers themselves and with researchers, extension and other developmental stakeholders; and initiatives to improve the efficiency and potential multiplier impact of FSR activities. Examples of initiatives accomplishing this have been the following:

- Farmer groups (both formal and informal) have been extensively used, enabling researchers and developmental stakeholders to interact efficiently with farmers (Heinrich, 1993; Norman, Worman et al., 1995). These are effective in influencing research/development agendas, in testing/evaluating and in disseminating relevant technologies/strategies. A less common but potentially even more powerful means of farmer empowerment has been for farmer groups having a say in the allocating of research funds, thus helping in tailoring the research agenda to their needs (e.g. Colombia (Ashby et al., 1995); Mali and Senegal (Collion and Rondot, 1998)).
- The farmer field school (FFS) approach was developed by the Food and Agricultural Organisation (FAO) and partners nearly 25 years ago in South-east Asia as an alternative to the prevailing top-down extension method of the GR, which failed to work in situations where more complex and counter-intuitive problems existed, such as pesticide-induced pest outbreaks (http://www.fao.org/agriculture/ippm/programme/ffs-approach/en/). FFSs have increasingly been used for encouraging farmer interaction, direct involvement as trained 'farmer researchers', and for disseminating technologies via FFS trained farmers.
- Somewhat later in the FSR era, in recognition of the importance of interactive linkages between the research and developmental stakeholders, committees were sometimes established at the national, regional and district levels, consisting of representatives of the different stakeholder groups (including farmer representation), for the purpose of exchanging and

disseminating information, and improving the coordination and the design and implementation of collaborative initiatives. Sometimes, decentralisation of governance and 'local' approval of technological recommendations have facilitated this process. Currently major emphasis is being placed on encouraging interaction between all agricultural development stakeholders via 'innovation platforms' (IPs). These are discussed later in this chapter.

Evolution in agricultural innovation thinking

A discussion on the evolution and development of FSR would not be complete without reference to agricultural innovation systems approaches, which are rapidly gaining recognition in systems research, both conceptually and programmatically. A paper tracking the evolution of systems approaches to agricultural innovation (Klerkx, van Mierlo et al., 2012) provides a lens through which such evolution can be seen. The paper asserts that innovation is not simply about adopting new technologies. Instead, agricultural innovation is presented as a co-evolutionary process that combines technological, social, economic and institutional change resulting from multiple interactions between components of farming systems, supply chains and economic systems, policy environments and societal systems. For these 'agricultural innovation systems', a wide range of analytical approaches have emerged, such as the Agricultural Knowledge and Information Systems (AKIS) (Röling, 2009) and Agricultural Innovation Systems (AIS) (Hall et al., 2001). These agricultural innovation systems can be viewed as the most recent manifestation of systems approaches in agricultural research. In the context of the broader evolution of FSR described earlier in this chapter, it is associated with the fourth phase of FSR, namely farming systems with a sustainable livelihood focus.

The CGIAR experience and role in farming systems research

In the early years (mid-1970s and 1980s), FSR was a strong component of the research portfolio of the CGIAR Centers. The roles played by two Centers, CIMMYT and IRRI, in the early years of FSR have already been mentioned. FSR was also very important within agro-ecology or region-based research Centers of the CGIAR, such as the: International Institute for Tropical Agriculture (IITA), focusing on agro-ecologies and farming systems within SSA; International Center for Tropical Agriculture (CIAT), focusing on agricultural systems within tropical America; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), focusing on agricultural systems within the semi-arid tropics; International Center for Agriculture in the Dry Areas (ICARDA), focusing on agricultural systems in drylands; and the International Livestock Research Institute (ILRI), focusing on integrated livestock systems in humid, sub-humid and semi-arid areas.

For example, in IITA, one of four research programs during the 1970s was the 'Farming Systems Program', which later became the 'Resource and Crop

Management Division'. This division, conducting research in resource management, involving soil and water management interactions, incorporated various dimensions of systems research, both on-station and on-farm and involved an interdisciplinary team of scientists (such as agronomy, sociology, economics, anthropology, ecology, etc.). The other three divisions were commodity-defined and focused mainly on breeding and research for enhancing the productivity of major food security crops – cereals, grain legumes, and root and tuber crops. In an article reviewing 40 years of research functioning and governance of the CGIAR, McCalla (2014) indicated that the early successes in commodity breeding (i.e. semi-dwarf rice and wheat) skewed donor interest strongly towards commodity breeding/productivity improvement at the expense of farming systems research/productivity. McCalla went on to postulate that "promising systems programs at IITA (understanding and managing cleared tropical soils) and CIAT (understanding complex crop/livestock systems using systems modeling) were abandoned and the Institutes were quickly converted into commodity focused Centers" (2014, 16).

Consequently, interest in systems research within the CGIAR Centers waned from the mid-1990s into the new millennium (21st century). A number of Centers actually reformed their research programs during this period, placing greater emphasis on commodity-based programming, and de-emphasising or, sometimes, eliminating FSR programs *per se*, apparently on the understanding that systems research dimensions would be integrated in the commodity research programs. This integration, however, rarely functioned optimally and the emphasis of research in the commodity programs continued to be dominated by breeding and crop improvement interests, often with little involvement of farmers and communities for whom the technologies were supposedly developed. Consequently the needs of most smallholder farmers with their diversified farming systems and specific socioeconomic, environmental and productivity challenges were once again not adequately addressed.

A review of the CGIAR research structure between 2008 and 2010 concluded that greater research coordination, integration and collaboration was needed between the various Centers, to enhance the overall effectiveness and productivity of research. A consortium of CGIAR Centers was created under one governance mechanism, with one Chief Executive Officer and one Consortium Board. Research was to be developed in an integrated manner across the various Centers to tackle identified global development challenges. In 2011–2012 fifteen cross-Center CGIAR Research Programs (CRPs) were created which constituted a new research portfolio for the entire CGIAR system. The CRPs were to contribute directly to agricultural development through partnerships and collaboration across very diverse groups of research and development actors (Sumberg et al., 2013). In this new iteration of research within the CGIAR, systems research re-surfaced as part of the research portfolio, not in the framework of farming systems, but more as integrated systems with a livelihoods focus. Three of 15 CRPs created were systems CRPs, with agro-ecological mandates. These were the: Integrated Systems for the Humid Tropics (Humidtropics), focusing on the humid and sub-humid tropics region; Dryland Systems

(Drylands), focusing on the drylands ecosystem; and Aquatic Agricultural Systems (AAS), focusing on farming and fishing systems around natural freshwater and/or coastal ecosystems. Systems research in the CGIAR was therefore reborn, and systems research processes and activities were initiated in various locations with partners from different agricultural stakeholder organisations.

This revival of systems research was, however, short-lived. In yet another review of the CGIAR research structure undertaken in 2015, barely 3–4 years after initiation of the first phase of the CRPs, it was decided that the research portfolio needed to be reformed to make it better aligned to a new Strategy and Results Framework (SRF) of the CGIAR (CGIAR, 2015a). Consequently, the CRP portfolio was re-structured into two key domain groups: (i) Agri-Food Systems CRPs (AFS-CRPs), consisting of eight CRPs; and (ii) Global Integrative CRPs, consisting of four crosscutting CRPs (CGIAR, 2015b). A key consequence of this reformulation was that the three systems CRPs would not continue to exist as separate CRP entities beyond 2016. The understanding was that systems thinking and approaches would continue through direct integration into the eight defined commodity CRPs, now branded as AFS-CRPs.

Many have questioned whether this latest development signals yet another downturn for agricultural systems research within the CGIAR. The answer to this question will depend to a large degree on how the implication of systems integration is understood and implemented, and what real integration and systems reform takes place within the AFS-CRPs. However, it could be argued that this new development might be positive, as systems research now moves from being in the periphery of agricultural research, where it has been over the years, into mainstream research. The idea of 'systems research' seen as being in one camp, and 'commodity research' in the other camp, will be eliminated, and new efforts can now relate to implementing core research agendas involving major commodity crops within the systems research framework. Only time will tell if this is successful. The hope is that everything necessary will be done to ensure proper alignment and integration of systems thinking into the development of the AFS-CRPs.

Looking forward: Key-lessons and methodological implications

The experiences with systems research in the CGIAR, exemplified through the Humidtropics and other system CRPs, provide a good example of seeing how the science and practice of FSR has evolved over the years from its inception in the 1970s to its role today. The question often asked is 'What is different between FSR at its inception and as it is currently practiced?' Using Humidtropics as an example to illustrate this, four key differences are worth mentioning:

- The emphasis has shifted from 'farming systems' to 'livelihood systems'. This is not just a terminology issue. The original FSR was inward (farm) looking. It was designed to focus almost exclusively on the farm and the components within it, with little attention to the outside realities. The ISR approach sees the farm as one component of a larger system influencing the livelihoods of the farmer households and therefore integrates on-farm and off-farm developments and their implications.

- Emphasis in FSR was on farmer participatory approaches and multidisciplinary interactions within the farm setting. Now with ISR the emphasis has broadened beyond the farm with off-farm dimensions seen as key for influencing the livelihoods of the farmers. Multi-sector and multi-stakeholder involvement and analysis, and linking research to major transformation goals, are important. This also implies that constraints and opportunities for innovation above the farm level need to be taken into account (Giller et al., 2008; Schut et al., 2014).
- Early FSR sometimes focused on the harvested yield of commodities as the principal determinant of the productivity of the system. Currently the emphasis goes much beyond yields of the specific commodities to whole systems performance (e.g., http://mel.cgiar.org/xmlui/handle/20.500.11766/4505) and explorations on value addition through value chain analysis and processing, linking farm produce to off-farm interventions that add value to the commodity, and assistance to link it to markets and income.
- There is now a much stronger emphasis on innovation systems, involving creating a platform that enables farmers and other stakeholder groups to be involved in innovation systems. This also includes the desired objective of fostering the capacity to innovate among farmers and other agricultural stakeholders at different levels (Hall et al., 2003; Klerkx, Schut et al., 2012; Adekunle et al., 2013; Leeuwis et al., 2014; Schut et al., 2016).

Ingredients of a systems approach

Building on experiences and lessons spanning the evolution of FSR in its various forms, and combining this with the experience of implementation of ISR, Humidtropics has established a set of ingredients required for a systems approach in the conduct of ISR. These can be used as a guide in the establishment of new systems research undertakings, or for assessment of existing projects with respect to their systems research considerations and opportunities. It can also be used to identify areas for capacity development for strengthening the integrated systems elements in agricultural research. Essential elements in ensuring a systems approach are the following:

- **Research team**: Systems research is never a one-person or one discipline undertaking. It requires team effort, ensuring not only multi- but preferably inter-disciplinarity in the conduct of research. This is necessary to ensure that problems and opportunities are analysed from multiple perspectives, incorporating both socioeconomic and biophysical considerations. Thus disciplines such as economics, sociology and anthropology need to be considered along with agronomy, soil science, animal science and ecology. The right combination of the team will of course depend on the research issues at hand. This is not to say that all these positions need to be available in every systems research activity, or in any one institution before systems research can be embarked upon. This can form the basis for partnerships among institutions and inter-sectorial collaboration.

- **The role of the farmer in systems research**: The centrality of the farmer and his/her community in the conduct of systems research cannot be overemphasised. Farmers have been operating complex farming systems over many generations; they are indeed 'system researchers' in their own right, and need to be viewed as such. Since the inception of FSR, farmer participation has been considered important. However, in reality farmers have often not been adequately recognised in such research. They have often been seen more as objects of study, or as participant observers, or simply considered as ultimate beneficiaries, rather than as full partners in the conduct of research. The reason for this may be that most of these farmers are poor smallholder farmers, who are often uneducated and generally powerless. Their participation in research is often for them to do what the researchers want them to do, rather than contribute their knowledge and experience built up over generations (i.e. including an intimate knowledge of their production environments). In this context there is a crucial need for farmer empowerment, which enables farmers to see themselves as *bona fide* members of the research team. This involves giving more authority to farmers, such as in being able to identify markets and influence prices for their commodities (Norman, 2004).[13] Recently Lundy et al. (2012)[14] have developed important participatory methodological guides for linking limited resourced farmers to markets. This is a good example of farmer empowerment.
- **Multi-stakeholder processes**: Multi-stakeholder engagement is not easy and does not just happen on its own. It requires processes and instruments to bring it about. Systems research therefore needs to incorporate mechanisms that enable engagement of stakeholders in the process of developing the research agenda and in the implementation of research activities. Examples of such mechanisms are Research for Development (R4D) platforms and IPs, used in programs such as Humidtropics (Schut et al., 2016) and the Forum of Agricultural Research in Africa (FARA) (Tenywa et al., 2010). These two mechanisms are interrelated. The R4D platform brings together stakeholders from the broader dimension of systems research covering the key components and sectors within the system, and helps in the confirmation of entry points, intervention domains or work packages, upon which research can be undertaken. On the other hand, IPs are specific platforms developed to undertake analysis and action research on specific constraints, challenges or opportunities (entry points) identified through the R4D platform. It can therefore be said that IPs are often spawned from R4D platforms, and involve partners and stakeholders in specific innovation domains. Membership in R4D platforms is generally much more diverse than for IPs, which usually tends to be focused on a particular issue such as a value chain for a particular commodity. However, in both cases membership will include various combinations of researchers, farmers, developmental NGOs, extension departments, private sector, traders and policy makers at different levels.

- **System diagnosis and analysis**: Implementation of systems research in a location-based context must begin with an understanding of the key components within the system, and more importantly also of the interactions, synergies and trade-offs, as well as the constraints and opportunities faced by the smallholder farmers in the area. Various tools and methods are available for addressing this, ranging from formal (structured or semi-structured) questionnaire surveys in some instances to more informal participatory methods such as RRA and PRA, discussed earlier in this chapter. Recently even newer methods have evolved such as Rapid Appraisal of Agricultural Innovation Systems (RAAIS) for creative diagnosis, observation and analysis (Schut et al., 2015), which incorporate an innovation systems dimension. Within Humidtropics, this is done in the context of situation analysis, using a variety of tools, and leads to identification of baselines and typologies, and indicates priority interventions and entry points to be explored in research.
- **Systems improvement orientation**: A key expectation in systems research is the accruing of benefits to farmers within the system through both sustainable productivity increases and livelihoods enhancement. Systems diagnosis and analysis is therefore expected to lead to technology development research addressing biological, socioeconomic and policy constraints that result in improvements in the system, and in livelihood conditions of smallholder farmers. This research includes an assessment and analysis of best-bet technologies, and ultimately leads to identification of best-fit technologies for further testing and eventually dissemination via development initiatives. The technologies address productivity enhancement, natural resources management, market linkage development and institutional dynamics, all focused on improving the system as a whole. An essential ingredient of this research domain is the analysis of trade-offs and synergies among key components, and the effect and impacts on overall productivity and sustainability of the targeted system.
- **Institutional and technological innovation**: Systems are not static but dynamic and constantly evolving. For this reason it is important to ensure that ISR always has an element of innovation built into it. Here, innovation is seen as embodying both institutional innovation and socio-technical innovation, requiring creating mechanisms to be able to encourage and recognise innovation at different levels among system actors. The IP is an example of a mechanism for institutional innovation, and for triggering the capacity to innovate among all agricultural stakeholders within the system (Adekunle et al., 2013; Schut et al., 2016).
- **Gender**: A central dimension in ISR are the people themselves. It is therefore essential to understand the people within the system, typologies and roles they play, the desires and constraints they face, and how the system impacts on their lives. In this connection the importance of women and the gender dimension, in general, cannot be over-emphasised. A good systems research program must have a built-in element of gender analysis and mainstreaming with respect to all key components, as well as including research analysing gender norms and facilitating positive transformative

change in the targeted communities. This requires involvement of women and youth in the research process.

- **Capacity development**: Undertaking ISR often involves a mind-set change and building capacities of the different agricultural stakeholders involved in the development process. This is particularly important as most researchers who end up engaging in systems research and development come, for example, with a background in commodity research, heavily focused on reductionist approaches. They have rarely been specifically trained in systems thinking and methodologies, and in complex interaction analytical techniques. Of course a notable exception, as indicated earlier, are the smallholder farmers themselves, who have applied systems thinking to their farming practices over the generations (i.e. traditional wisdom). However, for other agricultural stakeholders capacity development is essential to avoid the situation where people 'talk the talk' of systems research, but continue to do research in a business-as-usual fashion, based on prior experience and familiarity with specific disciplines and a traditional research orientation. This essential element must be built into the process of integrated systems research and development.
- **Scaling-out and dissemination towards impact at scale**: One of the continuing challenges of FSR is the transferability of the results of place/location-based systems research to other geographical areas. It has been said that systems research is context-specific and that the contextual differences from one site to another make it difficult to have effective scaling-out and dissemination of the results of systems research. As indicated earlier this becomes particularly challenging with the more complex phases of FSR involving agro-ecological and livelihood components. This challenge has stimulated research targeted to determining and synthesising the conditions and in what configurations different models, approaches and strategies are likely to be effective in generating positive impact at scale. Special attention is given to assessing the comparative value of different configurations and relative added value of different multi-stakeholder approaches. Such analysis can potentially help uncover the mechanisms, processes and contextual factors that influence the effectiveness of such approaches at different stages of the impact pathway. Considerations on scaling-out require that partnerships in systems research need to include both research and development/extension partners. New approaches and methodologies being used to enhance targeting and dissemination of systems research experiences include tools such as suitability (or similarity) analysis, which produces maps indicating varying degrees of suitability or similarity of particular areas for the technologies developed within the system (Pfeifer et al., 2014). However, further research and development work is needed in this area.

Conclusion

Farming systems research has evolved significantly since its inception in the early 1970s and now has a broader integrated systems dimension that recognises the importance of viewing the farm as part of a larger integrated whole, with interactions between on-farm and off-farm entities, and incorporation of elements such as value chain, innovation systems and institutional and policy analysis. The central focus remains on the limited resource farmer and farming household and his/her livelihoods. The need for a more holistic approach to agricultural research in addressing the realities faced by smallholder farmers, in farming with mixed, diverse and multi-component entities, often in difficult, heterogeneous environments, remains as relevant today as it was in the early days of FSR. Integrated systems research has built on the foundation initially established by FSR.

We have argued that addressing and fulfilling the productivity and sustainability requirements of this century will necessitate greater focus on ISR with a livelihoods orientation in order to effectively address the needs of smallholder farmers. This will need multi-stakeholder involvement and participation, through using mechanisms such as R4D platforms and IPs. Farmer participation and empowerment will be a critical component in unleashing the full potential of systems research, through a complete inversion of the agricultural development paradigm to one with a 'demand-driven' orientation.

Although we emphasise the need of an ISR approach and its demand-driven and multi-stakeholder participation as being critically important in successfully addressing the challenges facing smallholder farmers in LICs, we recognise that other agricultural research approaches still have major contributions to make, particularly more reductionist-oriented types of research.[15] Examples include breeding improved crop varieties or livestock breeds, soil fertility management, plant nutrition, integrated pest management, etc. One of the major issues in the implementation of systems research, and agricultural research for development in general, has been the apparent disconnect and 'tension' that often exists between the two dimensions of research, categorised as 'systems research' versus 'commodity research'.

Systems and situation analytical techniques can help in identifying opportunities, challenges, trade-offs and also potential entry points, on the basis of which more targeted research initiatives can be developed. Thus systems perspectives help prioritise the problems and relationships to be addressed. Nevertheless, addressing global and local agricultural challenges in the 21st century will require placing greater emphasis on integrated agricultural systems for development, requiring not only systems research but also component research.

We have shown in this chapter the evolution of partnerships and involvement in systems research evolving from an early emphasis on interdisciplinary and farmer participatory approaches to a broader engagement, based on multi-stakeholder, multi-sector approaches, using instruments such as R4D platforms and IPs, now being advocated in the integrated systems approaches. This, however, does not in any way dilute the centrality of smallholder farmers playing major participatory roles. In essence, farmers' minds provide critically important informal modelling simulation functions in identifying and evaluating relevant pathways to improving agricultural productivity and sustainability. Capacity development will be needed across all the partnership and stakeholder categories. Fostering the capacity to innovate, a key element in ISR, must focus not only on the farmer but also on other agricultural stakeholders such as the private sector, development partners, advisory services, policy makers, etc. The current popularity of IPs provides a promising avenue for addressing such problems and in helping to improve the efficiency and payoff from ISR.

Notes

1 However, larger-scale farmers did benefit more than more limited resource farmers.
2 The world's drylands occupy 40 percent of the farming area and house the majority of poor smallholder/limited resource farmers.
3 The United States University Land Grant System was set up to foster close links between education, research and extension. The Netherlands and Australia (e.g., Birchip Cropping Group (BCG) in New South Wales, Australia (http://www.bcg.au)) are examples of other countries where linkages have been strong.
4 See also Norman (2015) for material discussed in this and the next section.
5 Interdisciplinary in the sense of different disciplines collaborating on solving an identified problem rather than different disciplines working independently on an identified problem (i.e. a multidisciplinary approach).
6 Thus justifying closer linkages with policy and planning units (Upton and Dixon, 1994)
7 An example of some of the results arising out of the AHI project can be found in Pender et al. (2006).
8 This CGIAR guideline resulted from a series of workshops and represented a culmination of the CGIAR's work at that time. We acknowledge the significant contribution of the late Ann Stroud in developing this guideline.
9 Unfortunately, contradictory policy frameworks often arise from conservation/ecological sustainability policies being separated from those targeting short-run productivity.
10 In fact, another FSR phase could be the application of farming systems to targeting, planning and policy making, an example being the FAO/World Bank study (Dixon et al., 2001), currently being updated.
11 However, this is not always easy or even possible. Later in the chapter we indicate the need for evaluating the relative merits or trade-offs of different scenarios for improving the overall productivity and sustainability of the targeted system.
12 See also the CGIAR 2012 Stripe Review of Natural Resources Management Research (CGIAR, 2012).
13 Also see http://www.fao.org/ag/ags/agricultural-marketing-linkages/en.
14 See http://dapa.ciat.cgiar.org/methodologies-to-make-market-linkages-work. Other organisations focusing on linking limited resource farmers to markets include the International Institute for Environment and Development (IIED) (http://www.iied.org/group/sustainable-markets) and the Institute of Development Studies (IDS) (http://www.future-agricultures.org/research/agricultural-commercialisations).
15 However, systems research at the farm level can help in prioritising topics for reductionist type research.

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