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How can we make smallholder agriculture in the semi-arid tropics more profitable and resilient?

A research perspective from ICRISAT-led CGIAR Research Programs

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Summary

This White Paper synthesizes current knowledge about how to make smallholder agriculture in the semi-arid tropics (SAT) more profitable and resilient.

To structure the discussion, we developed a simple conceptual framework based on the CGIAR Research Programs for Dryland Cereals and Grain Legumes, which are led by ICRISAT. The framework links demand drivers, smallholder diversity, product lines, impact pathways, and impacts. Product lines are developed in response to demand drivers, which include not only income and urbanization but also shocks. We distinguish between reducing vulnerability and increasing resilience and how these operate at crop, household, and system level. Smallholder diversity is recognized by developing product lines for two target groups, namely subsistence- and market-oriented farmers. We identify the key demand drivers and shocks that create demand for new technology. Development domains show the role of endowments in determining smallholder demand for different types of product lines.

Mapping the potential impact of 13 product lines from the CGIAR Research Programs for Dryland Cereals and Grain Legumes reveals, product lines increasing either resilience or profitability but not both. This reflects a business view of smallholder agriculture, with 'products' designed to meet the needs of different 'market segments'. Research is being channeled into two different product streams, one based on hybrid seed and high levels of management that is driven by profitability and access to markets, and a second based on Open-Pollinated Varieties (OPVs) and lower levels of management, driven by the need for resilience and household food security. By contrast, the mapping of 20 ICRISAT 'success stories' shows that impacts were equally spread between improving subsistence- and market-orientation while others addressed both profitability and resilience.

We outline the conceptual difficulties of this approach for product lines and for thinking about farm households. The distinction between profitability and resilience reflects the views of plant breeders rather than crop management scientists. We use case studies of ICRISAT 'success stories' to illustrate how these may be combined in a single technology and not be restricted to one target group. However, focusing attention on smallholder diversity, on what product lines are for, and on different impact pathways, helps structure the research process.

Product lines have different impact pathways. Those that improve profitability for market-oriented farmers will attract private sector investment in smallholder agriculture. This promises to solve the problem of scaling up and out. Product lines that improve resilience for subsistence-oriented farmers will continue to rely primarily on the public sector for scaling out. ICRISAT can play a facilitating role in this process. Research spillovers from product lines that involve hybrid seed may be difficult to achieve in sub-Saharan Africa (SSA) where the private sector is smaller and infrastructure is less developed. We should expect divergence between ICRISAT regions in terms of product lines, with growing convergence over time.

We conclude by summarizing key principles on how research can make smallholder agriculture in the SAT more profitable and resilient.

1. Introduction

1.1 Smallholder crop production in the SAT faces twin challenges of resilience and profitability. On one hand, smallholder agriculture must be resilient to shocks that threaten crop yields, household food security, and livelihoods. On the other hand, agriculture must also be profitable for smallholders selling small amounts and often living far from markets. These challenges are connected. Profitability requires that crops are resilient to biotic and abiotic stresses because markets require consistent supply. Similarly, smallholder farming systems must be resilient to price fluctuations so that volatile markets for food and cash crops do not threaten income and food security.

1.2 The general objective of this paper is to identify ways to make smallholder agriculture more profitable and resilient. The specific objectives are to:

- Understand the context for ICRISAT's new research investments;
- Assess the implications of the CGIAR Research Program's strategy for Dryland Cereals and Grain Legumes; and
- Against this background, evaluate what has worked in the past and why.

1.3 The paper was designed to provide background information for ICRISAT's Planning Meetings held in each region in January-February 2014. Hence, the aim was not to provide recipes for making smallholder agriculture more profitable and resilient. Differences between ICRISAT regions and between the five mandate crops mean that the answer will be context-specific. Instead, the aim was to inform the planning process by synthesizing existing knowledge. Since the paper covers a lot of ground in a short space, the treatment is selective rather than exhaustive. The main sources used were the two research proposals for the CGIAR Research Programs for Dryland Cereals and Grain Legumes, because these are led by ICRISAT and contain the latest thinking on a research strategy for its mandate crops; publications by ICRISAT scientists that relate directly to the topics under discussion; and secondary literature on demand drivers and the research context.

The ideas presented in this paper did not originate with us, but are contained in the two ICRISAT-led CGIAR Research Programs. The components of the conceptual framework, the categorization of product lines by profitability and resilience, and the typology of market- and subsistence-oriented farmers can all be found in the proposals submitted to the Fund Council in August 2012. This paper attempts only to bring these ideas into sharper focus and to explore their implications for the research process.

2. Conceptual framework

Figure 1 provides a simplified framework that brings together the main concepts discussed in this paper. We see ICRISAT's research outputs (or product lines) as determined by two factors. One is the set of factors driving demand for these product lines (demand drivers), which we classify into markets and shocks. The second is the set of actors who need this technology (smallholder diversity), whom we classify into market-oriented and subsistence-oriented farmers. The result is two streams of product lines, one with a stronger market-orientation and emphasis on improving profitability, the other with a stronger subsistence-orientation and improving resilience. As noted above, this distinction cannot be absolute since profitability also requires resilience, while resilience is partly determined by cash incomes and therefore by profitability.

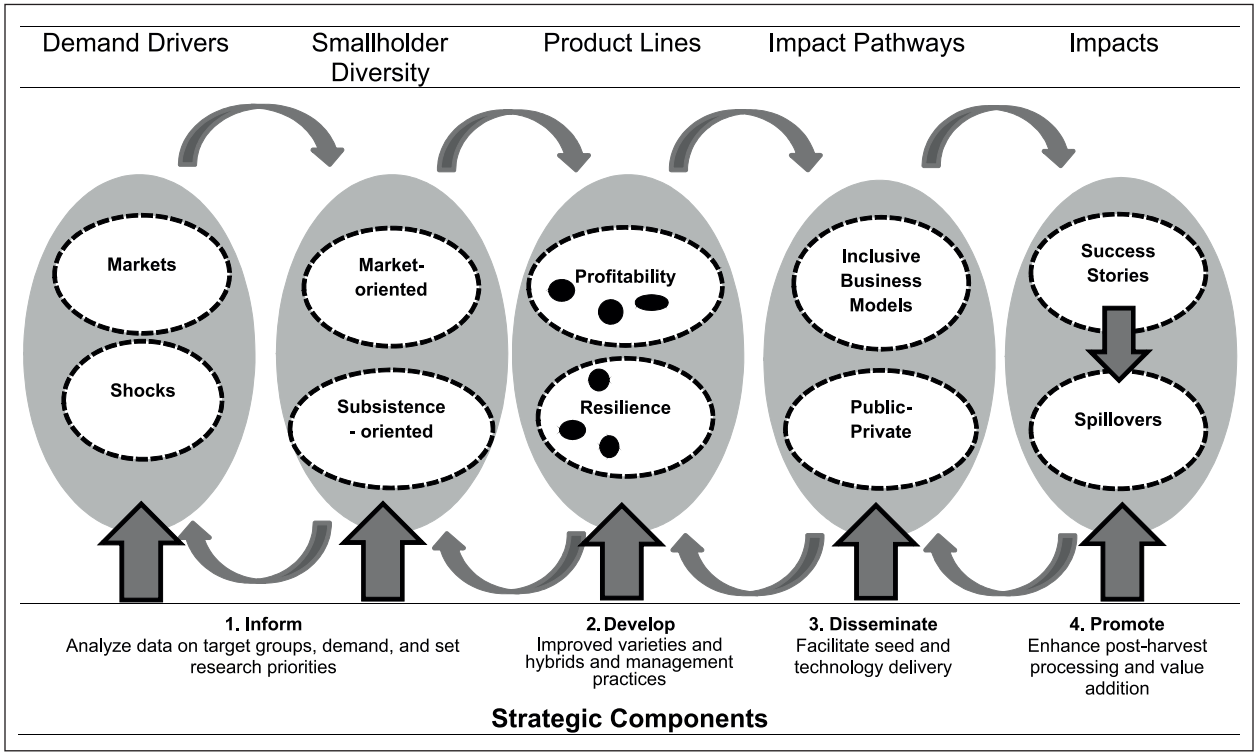

Figure 1: A simplified impact model.

Each stream of product lines requires a different type of impact pathway. The impact pathway for product lines targeted at market-oriented farmers is led by the private sector. Inclusive business models are required to ensure market participation by smallholders. By contrast, the impact pathway for product lines targeted at subsistence-oriented farmers is led by a mix of stakeholders (both public and private-sector). Public sector agencies may have a greater development role, for example in supplying seed. The result is impacts, which include both 'success stories' in locations for which new technology was originally designed and 'spillovers' where products are successfully transferred to other locations.

The Strategic Components in the CRPs provide feedback loops that inform the research process. Strategic Components 1 and 2 show how new technology (product lines) will be developed in consultation with smallholders and other stakeholders to ensure the development of product lines that respond to farmers' needs and market requirements. Strategic Component 3 facilitates feedback between research and stakeholders in the impact pathway, while Strategic Component 4 facilitates learning from successful impacts. These feedback loops ensure that the research process remains interactive and driven by the needs of the end-users.

3. What do we mean by 'profitability' and 'resilience'?

Profit: 1. "Advantage, benefit; 2. pecuniary gain, excess of returns over outlay". *(Concise Oxford Dictionary).*

3.1 Commercially, profitability is measured as the income left after deducting the opportunity cost of inputs, including the cost of labor and management. For smallholder farmers, however, it is typical not to include the opportunity cost of land, family labor, or management in estimating total costs. Thus, what smallholders actually measure is not profitability but *net returns*. If we defined profitability in the same way as entrepreneurs, most smallholder crops would give relatively low profits. For example, a meta-analysis of the profitability of 69 new technologies for rainfed crops that included the cost of family labor gave a median profit of USD 558/ha/season at 2005 Purchasing Power Parity (PPP) (Harris and Orr, 2013). For a family of five on a 1 ha farm, this represents a daily income of 30 US cents per person.

Resilient: "recoiling, springing back; resuming original form after bending, etc." (*Concise Oxford Dictionary*).

3.2 Scientists use the word resilience in two ways. One is resilience as reducing vulnerability *to* shocks. The second is resilience as the ability to recover *from* shocks. The latter is the dictionary definition of resilience. We can think of reducing vulnerability to crop losses as vertical, reducing the damage caused by a specific shock, and of increasing resilience as horizontal, extending the ability to compensate for that damage. In agriculture, resilience operates at several levels: crops, households, and farming systems (eg. van Ginkel et al. 2013; Walker et al. 2002; Alinovi et al. 2010).

3.3 Resilient crops… By describing an improved variety as resilient, plant breeders mean that it is *less vulnerable to shocks*. Another way of describing this is improved *yield stability*, defined as lower variability in yield over time and space.

3.4 Resilient households… Improving resilience at the household level can be seen either as reducing vulnerability to shocks, or as enabling households to recover from shocks. As a result, households are better equipped to seize new market opportunities and invest in more profitable enterprises that will enable them to cope with shocks in the future because their higher level of assets reduces the danger of being pushed below the poverty line.

Figure 2 visualizes how to reduce vulnerability to shocks for a 1 ha farm in sub-Saharan Africa (SSA). This visualization depicts the reduction of vulnerability as a series of discrete steps, or breeding objectives, while crop management scientists view reduction more holistically, as a combination of interventions that create a healthy crop.

To survive, the family needs a yield of about 1 t ha^{-1} from staple food crops, so if everything goes right and the maximum harvest is achieved, this would be enough for their needs and even generate a modest income. However, during the growing season the family faces several threats to their crops that reduce yields. In combination, these shocks can push the household below the survival line. The challenge is how to improve resilience. This can be achieved in two ways. First, with a bigger harvest, at 3 t ha^{-1}, the impact of these shocks is reduced so that they do not push the household below the survival line. Second, the impact of individual shocks is reduced by introducing new technology. This includes technology to improve soil fertility, or more resilient crops, or water

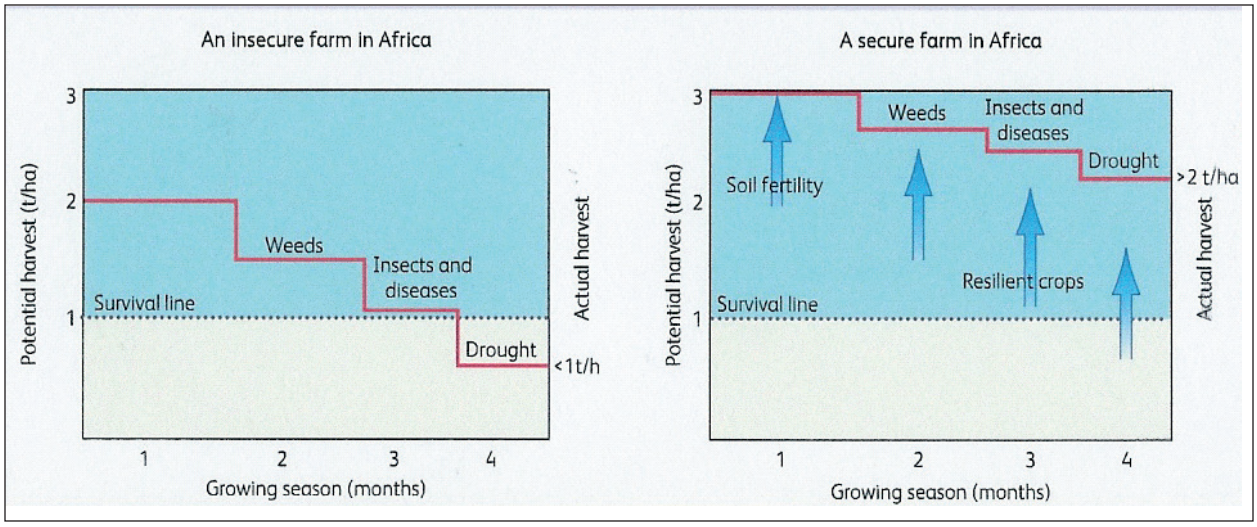

Figure 2: The harvest on an insecure and secure 1-ha farm in Africa
Source: Conway and Waage (2010).

harvesting to tackle drought. These usually require increased investment, although genetic gains from improved crop varieties may require no additional costs for farmers.

Other scientists see resilience at the household level as the ability to recover or bounce back from shocks. In this view, household resilience is the result of income diversification – if one source fails, another takes its place. In SSA, most farms of 2 ha or less get up to 50% of their income from other sources, and as average farm size gets smaller the share of nonfarm income is growing. Two things follow. First, the growing share of nonfarm income reduces the impact of sudden agriculture shocks. Second, where crops are just one part of total income, the benefits from making crops more resilient may be relatively small. Other sources of resilience include social networks that provide support in cash or kind, access to loans, or insurance that allows households to recover quickly. The message here is that small farms have *multiple sources of resilience*. For most farm households in the SAT, crops are only one source of resilience.

3.5 Resilient systems… Systems are described as resilient when they can quickly recover from shocks. In an ecosystem, resilience is identified with species diversity. Similarly, farming systems are described as resilient if they contain a range of enterprises (crops and livestock) that enable them to recover quickly from shocks. Too much diversity, on the other hand, may prevent specialization and production of a surplus for sale.

Resilience at the system level can also be extended to include innovation systems, where stakeholders combine to promote a common goal. Building trust between different actors in the same value chain reduces their vulnerability to shocks and can generate innovations that attract new investments, which will themselves create the context for making agriculture more profitable and resilient.

The ICRISAT team in Zimbabwe has used a ‘Cup and Ball’ model to visualize resilience in dryland farming systems (Figure 3). They define resilience as the ability of a ‘social-ecological system’ to

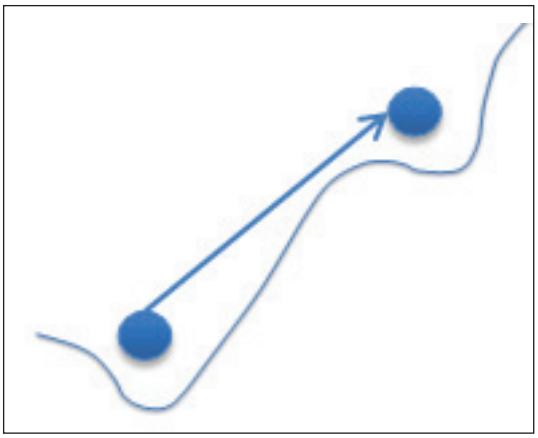

Figure 3: Visualizing Resilience: the Cup and Ball model.

Source: (van Rooyen et. al., 2013)

recover from shocks, react to gradual change, and make use of opportunities (van Rooyen et al. 2013). They compare building resilience to moving a ball upwards over a series of gradients. At stage 1, the system is resilient, but at a low level of profitability. Thus, resilience alone is not a desirable state. At stage 2, the system is at a higher level of profitability but it is not necessarily resilient because the cup in which the ball rests is shallow. The ball can easily be dislodged and roll backwards to its original starting point. The message is that R&D often pushes upwards to higher and more profitable systems but does not necessarily build in structures that make the system resilient, so that the system collapses in the face of shocks. We need to think of solutions that both deepen the cup and move the ball.

4. The context

4.1 Smallholder diversity

Smallholders are usually defined as farm households cultivating less than 2 ha (Hazell and Rahman, 2013). By this definition, India has 93 million small farms and Africa has 33 million small farms, representing about 80% of all farms in each region (Nagayets, 2005).

Table 1. Farms under 2 ha, selected countries.

Country	Census Year	Number of farms under 2 ha	Percent of farms under 2 ha
India	1995-96	92,822,000	80
Ethiopia	2001-02	9,374,455	87
Nigeria	2000	6,252,235	74
Tanzania	1994-95	2,904,241	75

Source: Nagayets (2005).

Within small farms, however, there is a lot of diversity. Smallholders can be categorized in many ways, such as land size or economic viability. For this White Paper, the important distinction to recognize is between two broad types of smallholders:

- Subsistence-oriented, who place a higher value on food security.
- Market-oriented, who place a higher value on income generation.

This does *not* mean that there are only two types of smallholders. Besides subsistence-oriented and market-oriented farmers, there is a third category of smallholders 'in transition'. Transition can take two forms. One is the transition from farmer to nonfarmer as smallholders exit agriculture for better-paid jobs. This is the 'agricultural transition' that is a natural part of the development process (Timmer, 2009). The second is the transition from subsistence to market-oriented farming, or the Inclusive Market-Oriented Development (IMOD) transition promoted by ICRISAT (ICRISAT, 2010). ICRISAT's Village Level Studies in South Asia (SA) and West and Central Africa (WCA) can provide evidence on these transitions (Box 1).

Subsistence- and market-oriented farmers have different technology needs because they have different production objectives (Table 2). Technology for subsistence farmers has to meet the needs of poor, hungry, and risk-averse smallholder farmers. It should improve household food security, stabilize yields, reduce risks and require little additional cash. These farmers are more likely to want new technology that increases resilience. By contrast, market-oriented farmers have more resources, are less risk-averse, and typically have better access to new technology and information. These farmers are more likely to want new technology that increases profitability.

Table 2. Characteristics of subsistence versus market-oriented smallholder farmers.

Subsistence	Smallholder Farmer	Market-oriented
High	Vulnerability to shocks	Low
High	Varietal diversity	Low
High	Multipurpose use	Low
Varieties	Cultivar type	Hybrids
High	Yield gap	Low
Household	Quality demand	Market
Low	Access to information	High
Low	Access to improved seed	High
Low	Access to fertilizer	High
Low	Access to credit	High
Low	Access to markets	High

Source: ICRISAT and ICARDA (2012).
Note: this Figure polarizes the difference between these two groups and has been exaggerated for illustrative purposes.

This does *not* mean that subsistence-oriented smallholders do not need crops that give cash income, or that market-oriented farmers do not need crops that give food security and resilience. The difference is one of degree rather than of kind. From a breeding perspective, the same is true for product lines. Market-oriented farmers do not require *only* product lines that give cash income while subsistence-oriented smallholders do not require *only* product lines that build resilience. Just as smallholders have a mix of objectives, so they require a mix of product lines. Market-oriented smallholders also require resilient product lines to provide them with some food security, just as subsistence-oriented farmers require profitable product lines to provide them with some cash income. Hence, although market- and subsistence-oriented farmers will differ in their overall portfolio of product lines, their need for certain product lines will overlap.

Smallholder diversity can also be conceptualized in terms of 'development domains', which links a location's demand for 'profitable' or 'resilient' product lines with agricultural potential as well as demand drivers such as access to markets and population density (Table 3). In locations with high agricultural potential and where population density and/or access to markets are high, the research focus is on profitability for market-oriented smallholders. Similarly, in locations where agricultural potential is low but there is high population density and/or good access to markets, smallholders may prioritize profitability. Conversely, where agricultural potential, population density and/or access to markets are low, the research focus shifts to increasing resilience among subsistence-oriented farmers. In this development domain, the need for cash income may result in high rates of migration to high-potential development domains where there is higher demand for labor.

Table 3. Generalized development domains.

Agricultural Potential	Access to market	Population Density	Farmer Priority	Examples of Product Lines	Impact pathway
High	High	High	Profitability	Hybrids, early-maturing legumes	Inclusive Business Models
		Low			
	Low	High	Profitability	Multipurpose crops	Collective marketing
		Low			
Low	High	High	Profitability	Improved varieties Crop-livestock	Collective marketing
		Low			
	Low	High	Resilience	Crops for food security	
		Low			

Refining our definitions of market- and subsistence-oriented farmers and estimating how many belong to each group is a task for further research. Other important questions include:

- Is investment in technology for resilience and profitability a stepwise process? Will farmers only invest in new technology that increases profitability after they have met some threshold for resilience?
- What level of resilience do smallholders require before they will invest in improving profitability?
- What are the consequences of market-oriented technology for women's control over household resources and income?

Box 1. 'Agricultural transitions': Insights from ICRISAT's Village Level Studies (VLS)

Poverty among rural households of the original six villages studied in semi-arid India declined rapidly in the late 2000s, compared to the early 2000s and mid-1970s and 1980s. Per capita real income increased from USD 90 in 1975/76 to USD 576 in 2011/12 (Figure 4). Multiple pathways out of poverty were observed. These included intensification of agriculture through adoption of improved varieties and changes in cropping pattern, as well as diversification of agriculture through cultivation of high value crops, non-crop farming activities, and integration of crop-livestock. However, the main driver was the increase in nonfarm income. Whereas in the mid-1970s income from nonfarm sources made up only 25 – 30 % of total household income, by the late 2000s it contributed 40-51 %. This diversification of income sources has increased resilience, as have social safety net programs such as employment guarantee schemes and public food distribution at subsidized prices.

The 'IMOD transition' was evidenced by farmers' greater willingness to take risks. Whereas farmers in the 1970s were risk-averse, farmers in the late 2000s were risk lovers, quick to adopt profitable technology and responding swiftly to changes in prices. For example, traditional cotton growers in the Akola region of Maharashtra shifted completely to cultivation of soybean within five years. Farmers in Mahbubnagar, Andhra Pradesh, have switched from growing cereals in the wet season to the cultivation of Bt Cotton. Finally, within the last seven years, chickpea has become the dominant dry season crop on vertisol fields in Andhra Pradesh. Access to markets has improved thanks to better connectivity and road infrastructure.

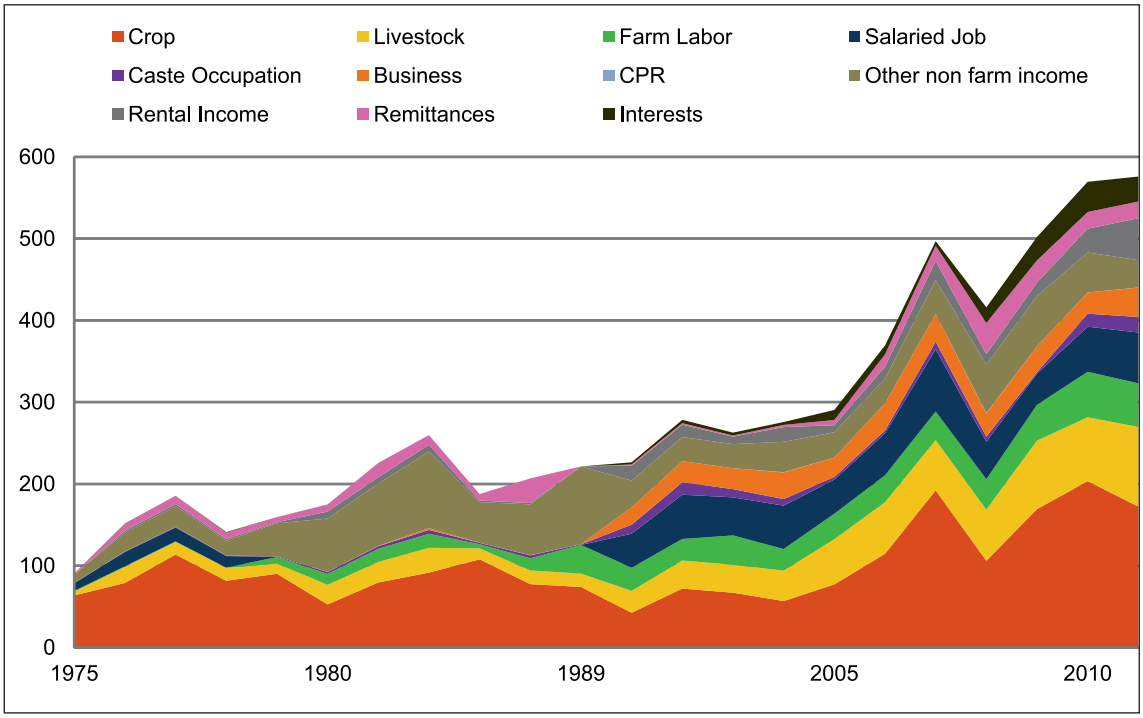

Figure 4: Trends in per capita real income (USD) among sample households in Andhra Pradesh and Maharashtra, India: 1975/76 to 2011/12

Source: Uttam Kumar Deb

4.2 Institutions

Innovations require an enabling institutional setting. The innovation systems framework emphasizes the role of 'framework conditions' (eg. policy, trust), 'intermediaries' (eg. NGOs, farmers organizations, manufacturers) that provide farmers with access to new technology, and the 'business system' that supplies consumers (DFID, no date). Access to information and seed are major adoption constraints for dryland cereals and non-hybrid legumes. Since there is often no commercial incentive for the private sector, social capital and social networks play an important role in providing farmers with access to new technology. Consequently, innovations for subsistence farmers require impact pathways that use farmers' organizations and other forms of social capital to promote adoption and achieve impact. In WCA, for example, farmers' organizations have tested improved sorghum varieties, multiplied certified seed, and used radio to provide farmers with information.

4.3 Demand drivers

Several factors will drive the need for more profitable and resilient smallholder agriculture. We provide a quick *tour d'horizon*:

Rapid population growth. Around 2028, India's population will overtake China's to reach 1.45 billion. Similarly, many countries in SSA are experiencing rapid population growth. Nigeria's population is expected to grow from 165 million in 2015 to 202 million by 2025 (UN, 2012).Growing populations will increase the demand for staple food crops.

Falling poverty. Global poverty is falling, from more than half the population in the 1980s to 10% by 2015. The global distribution of poverty is also changing. By 2015, about 60% of the world's poor will be in Africa (Chandy and Gertz, 2011). Although middle income countries like India will still have pockets of poverty and the absolute number of poor people will be large (88 million), poverty will no longer be concentrated in one or two big countries, but will instead be concentrated in a number of smaller countries. Above all, poverty will "increasingly be seen as an African problem" (Chandy and Gertz, 2010). One consequence is a shift in agricultural research funding to Africa.

A fast-growing middle class. The flip side of falling poverty is a growing middle-class. Defining middle class as an income of $10-100 per day at 2005 PPP, India's middle class numbered 117 million in 2009, and may reach 240 million by 2025. SSA's middle class is about 32 million, rising to 107 million by 2030 (Khamas, 2010). Middle-class households offer new markets because they spend more on healthy and nutritious foods, and on 'bottom of the pyramid' processed products like cheap beer made from sorghum rather than malted barley. In 2008, consumption expenditure by households above the $2 per day poverty line in SSA reached $680 billion, representing about one quarter of Africa's GDP (AfDB, 2011).

Growing urban markets. In 2008, 340 million Indians lived in cities, and by 2030 the figure will reach 590 million, or 40% of the population (McKinsey, 2010). Similarly, almost half of Africans live in cities, and 55 African cities have populations of over 1 million (African Studies Centre, 2012). Urban consumers are an expanding, concentrated market for ICRISAT's crops.

Expanding trade. Rising income and liberalized markets will stimulate trade, providing opportunities for market-oriented small farmers. Sorghum and millets will benefit from growth in regional trade, while legumes will benefit from international trade provided non-tariff barriers are overcome to

allow smallholders to penetrate high-value markets. India is already a net importer of groundnuts, pigeonpea, and chickpea, providing a market for African growers (Abate et al., 2012).

Novel end-uses. The 'livestock revolution' in SA has increased the need for multipurpose sorghum with high stover quality, and for pearl millet as chicken feed. About 30% of sorghum stover in India is now being sold to dairies in urban and peri-urban areas (Rao et al., 2010). Similarly, demand for sorghum beer in SSA requires white-grained, low-tannin varieties.

4.4 Sources of shocks

The main agriculture-related shocks that will affect smallholder agriculture include:

Drought. Although climate statistics for India show no increase in rainfall variability (Pant, 2003), many smallholders think otherwise, and this makes them more risk averse than they need be. For example, farmers in Kenya exaggerate the frequency of bad years (Rao et al., 2013). Providing farmers with rainfall forecasts can correct this perception, improve decision-making, and reduce the perceived risk of adopting new technology.

Pests and diseases. Yield loss from insects and diseases is always present but damage from specific pests may be so great (eg. Fusarium wilt in ESA) that it prevents the adoption of new technology or developing new markets.

Climate change. Over the long term, climate change will extend the area classed as semi-arid in some regions. However, the impacts may be less severe than expected. Under existing low management conditions, the impact on yields will be relatively small. Moreover, if farmers adopt existing recommendations, the result will be significantly higher yields even under climate change (Cooper et al., 2009). This offers hope that the worst impacts can be averted.

Price shocks. Subsistence farmers are affected by sudden price increases because they are net food buyers. Similarly, more market-oriented farmers who rely on sales to ensure their livelihoods are also affected by sudden price decreases. The price volatility of staple food crops in Africa is high, partly because of price and trade policies (Minot, 2014). Thus, policy reforms can reduce vulnerability to price shocks. In SA, for example, social protection helps cushion smallholders against price fluctuations.

5. Product lines

We conducted a mapping exercise to determine whether product lines were primarily market-oriented or subsistence-oriented. Market-oriented product lines were defined as those associated more with increases in profitability, whereas subsistence-oriented product lines were associated more with increases in resilience. The exercise was made for the 13 product lines for Dryland Cereals and Grain Legumes (six for cereals and seven for legumes, excluding product lines for other CG centers involved in these programs). Although ICRISAT is also involved in CGIAR Research Programs on Dryland Systems; Policies, Institutions and Markets; Climate Change, Agriculture and Food Security; and others, these were excluded because they are concerned with context and not with the development of new technology that will impact directly on resilience and profitability.

The ICRISAT-led CRPs on Dryland Cereals and Grain Legumes conceived product lines as 'game-changers' that would have the greatest impact. All 13 product lines focus on crop improvement, with the importance of crop management recognized by visualizing each product line as an integrated 'technology package' that included improved management practices. Although the CRPs recognized that product lines are more than just improved varieties, the crop management practices appropriate for each product line were not specified. We scored the 13 product lines based on the written description of each product line found in the CGIAR Research Program proposals. Product lines were ranked on a 1-4 scale for each criterion (see Appendix 1). While the scoring is subjective, it is based on the written descriptions of the technology and the words used to highlight the most important anticipated impacts.

Figure 5 shows the results. All the 13 product lines fall into the two high-low quadrants. Three product lines score high potential impacts on resilience but low changes in profitability are

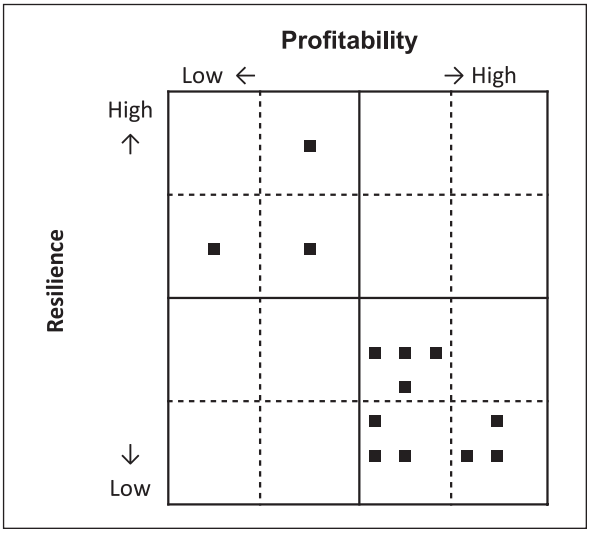

Figure 5. Cereals and Legumes product lines mapped by potential impacts on profitability and resilience.

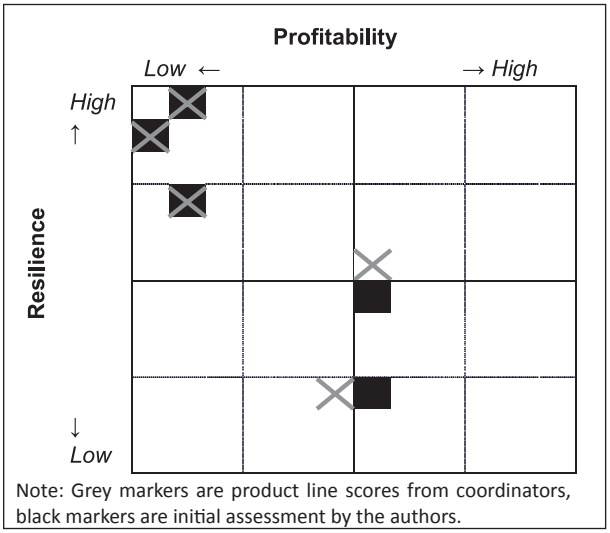

Figure 6. Overlap with scores by product line coordinators.

expected, whereas 10 product lines have high potential impact on profitability but low expected change in resilience. But the win-win quadrant is empty.

Scoring product lines in this way can only be approximate and the results should be seen as illustrative. However, our scoring closely matches that of product line coordinators. Figure 6 compares our original scores with those given by 5 product line coordinators who reviewed the scores. In three cases no revisions were required. For one product line the profitability score was lowered by one and in another case the resilience score was increased by one. This overlap gives us confidence that while our scores are subjective they are not arbitrary. Moreover, scoring was not intended to reach a definitive judgment about the precise nature of each product line. Rather, the objective was to focus attention on what specific product lines are for in terms of development outcomes (income, resilience), and for whom specific product lines are for market- or subsistence-oriented farmers. Scoring was not an end in itself but a means of thinking about outcomes and end users.

What is the message here on how to make smallholder agriculture more profitable and resilient? These results suggest that plant breeders are moving towards a 'twin-track approach' that identifies product lines for different target groups. This distinction is not absolute. 'Profitable' product lines have to be resilient too, in order to reduce risks for market-oriented farmers. In practice, therefore, some product lines may combine both profitability and resilience. By contrast, 'resilient' product lines do not necessarily have to be 'profitable'. This approach will also require 'profitability' and 'resilient' descriptors for each product line. Previously, descriptors for new technology were based on mean yields, usually under high levels of crop management. As a result, it proved difficult to replicate these yields in farmers' fields. To classify product lines as 'profitable' or 'resilient', additional descriptors are required that measure variability in yields and economic returns not only under optimum conditions, but also under farmers' levels of crop management.

The results for the 13 product lines in Figure 5 have important implications for ICRISAT's research strategy. They suggest a different way of looking at the research process that separates product lines into two groups. Why is this? Were these two CRPs just a re-branding exercise that will not affect the research process, or is the difference real? We believe that the difference is real, and suggest three explanations:

- Many commodity CG Research Programs want to see the commercialization of smallholder agriculture, viewing agricultural research as a business, farmers as 'consumers' of new technology, and new technology as 'product lines' targeted at different 'market segments'. This is reinforced by the power of "philanthrocapitalism" – influential donors with a background in the private sector (Brooks, 2013).
- The review process for the two CG Research Programs led by ICRISAT pressured scientists into linking new technology to two target groups, namely market-oriented farmers focused on profitability and subsistence-oriented farmers focused on resilience. This discouraged thinking about technologies that combined profitability and resilience and that cut across target groups.
- The nature of new technology is changing. Increasingly, new technology is diverging into two types of product lines: high-input product lines based on hybrid seed and intensive, knowledge-based management, which are designed for market-oriented farmers, and low-input product lines based on OPVs and lower levels of management, which are designed for subsistence farmers. This divergence reflects supply and demand. On the supply side, hybrid seed means that the private sector now sees commercial opportunities in smallholder agriculture. On the demand side, farmers are more willing to invest in these high-input product lines because they see market opportunities.

6. Problems with a twin-track approach to product lines

There are four difficulties with the distinction between resilient and 'profitable' product lines made by the two CGIAR Research Programs led by ICRISAT.

6.1 Lessons from 'success stories'

ICRISAT's 'success stories' were defined as research products that have achieved significant and measurable impacts and draw mainly from the 'Jewels of ICRISAT' (ICRISAT, 2012). Furthermore, some case studies were selected as success stories based on a brainstorming session of the Markets,

Institutions and Policy group of ICRISAT. Twenty success stories were identified, which were then ranked on a 1-4 scale for each criterion following the same method as for the 13 CRP product lines (Appendix 1). As with product lines, scoring success stories in this way can only be approximate and the results should be seen as illustrative.

Figure 7 shows that:

- Of the 20 success stories, 13 (65 %) had high impact on resilience.
- Of the 20 success stories, 17 (85 %) have had a high impact on profitability.
- Ten of the 20 success stories (50 %) significantly increased both resilience and profitability.
- Ten of the success stories (50 %) improved one, but not the other.

Figure 7 suggests that, in terms of overall impact, ICRISAT's success stories have been evenly spread between increasing profitability and increasing resilience. This is an interesting result, given the emphasis ICRISAT has placed on markets. However, it has proved more difficult to have high impacts on profitability and resilience at the same time. "Win-win" success stories occur just five times out of 10. The recipe for success, therefore, is not necessarily to combine resilience and profitability but also to look for opportunities that can enhance either of them.

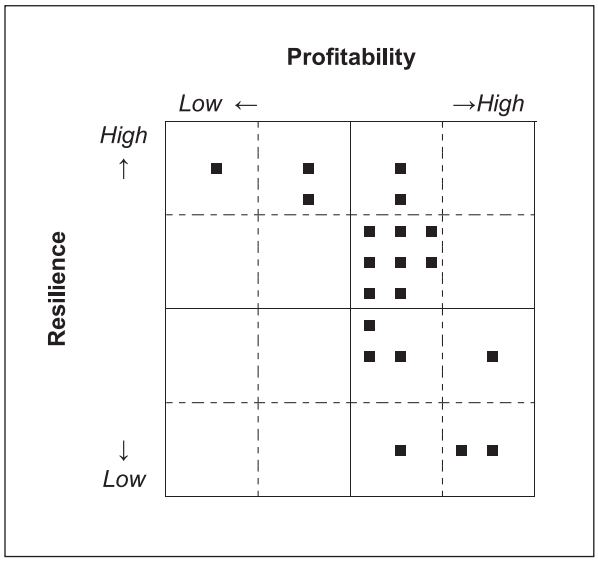

Figure 7. ICRISAT 'success stories mapped by profitability – resilience orientation.

Box 2. 'Success Story' Case Studies

1. Market-oriented innovation: improved chickpea in Andhra Pradesh

Short-duration cultivars (JG11, KAK-2 and Vihar) released in 1999 have been widely adopted in Andhra Pradesh (Bantilan et al., 2014). A typical farm household has increased its yield of chickpea from 1,443 to 1,975 kg ha^{-1}, which translates into a unit cost reduction of US$ 144 per ton. As a result, the acreage of chickpea in the state increased 10-fold between 1990 and 2010. Why this success? First, the new cultivars are resistant to Fusarium wilt, thus reducing the risk of crop loss. Second, they are short-duration, reducing the risk of yield loss from drought. Third, they are profitable because they require less labor than cereals, planting is easily mechanized, they have a ready market, and fetch high prices. Thus, success reflects the combination of market drivers with improved technology that improves profitability and resilience.

2. Subsistence-oriented innovation: pearl millet in WCA

The parasitic weed *Striga hermonthica* is found on half the fields growing sorghum and pearl millet in the Sahelian and Sudanean zones of West Africa. On 20% of fields with high levels of infestation, *Striga* can result in loss of up to half the yield of these staple food crops. Improving the soil fertility and resilience of these crops and using varieties tolerant or resistant to *Striga* is therefore vital for household food security.

The Integrated *Striga* and Soil Fertility Management (ISSFM) strategy for pearl millet and sorghum, developed by ICRISAT and its partners, combines several interventions, including intercropping with cowpea or groundnut, micro-dosing fertilizer at sowing and at 4-6 weeks after planting, manuring with compost, and hand-pulling *Striga* when it flowers, as well as the use of an improved variety that is resistant or tolerant to *Striga*. Choosing which components to use and how to use them depends on the environment.

Evaluation with Farmer Field Schools in Mali showed that the benefits from ISSFM were up to seven times higher than the benefits from farmers' normal practice. Although the costs of ISSFM (excluding the cost of labor) were twice the cost of farmers' normal practice, the benefits exceeded costs by a ratio of 2:1. The main benefits came from the additional grain and fodder from the cowpea or groundnut intercrops, rather than increased yields of the cereal crop. These gave farmers a 'profitable' product line that gave cash income. Millet yields will increase over time as ISSFM reduces the *Striga* seed bank (van Mourik et al. 2013).

What are the lessons? First, the product line was clearly designed to improve resilience and household food security. Second, researchers worked closely with farmers to fine-tune and evaluate the technology in agronomic and economic terms. Third, the 'resilient' product line also provided farmers with a 'profitable' product line (intercrops) that generated cash income and assisted the transition from subsistence to market-oriented farming.

3. Market- and subsistence-oriented innovation: crop-livestock in Zimbabwe

Goats are a major source of income in drought-prone Zimbabwe. Using an innovation platform approach that included all stakeholders, ICRISAT developed a set of interventions that allowed

Box 2 Contd.

Box 2 Contd.

smallholders to keep more goats, earn more income from goat sales, and spend more on inputs to boost yields of staple food crops. Interventions included the introduction of fodder crops that increased the supply of goat feed, veterinary services that reduced goat mortality, and regular goat auctions that increased prices, made pricing more transparent and allowed sales throughout the year. A small tax on each goat sold helps maintain the auctions, while private buyers purchase goats and sell fertilizer and vaccines. Households that have adopted these innovations have seen their income from goats double in four years. Models project a potential for over 300% income growth, from USD 89 to 302 per year, reaching USD 400 per year when buyers pay for higher-quality goats.

Why the success? First, the innovation platform approach was able to unblock a market bottleneck that required coordinated action by key stakeholders. Second, the innovations were market-oriented, which allowed smallholders to profit from the growing demand for goat meat in nearby Bulawayo. Third, the innovations improved resilience at the household level, since increased cash income could be used to reduce vulnerability to drought or illness, and enhance education.

Sources: Deevi Kumara Charyulu (Case Study 1); Tom van Mourik (Case Study 2); and Andre van Rooyen and Sabine Homann Kee-Tui (Case Study 3).

ICRISAT's 'success stories' also suggest that there are different routes to successful impact. This is illustrated by the three case studies in Box 2. Plotting these case studies on a resilience-profitability graph highlights these different trajectories (Figure 8).

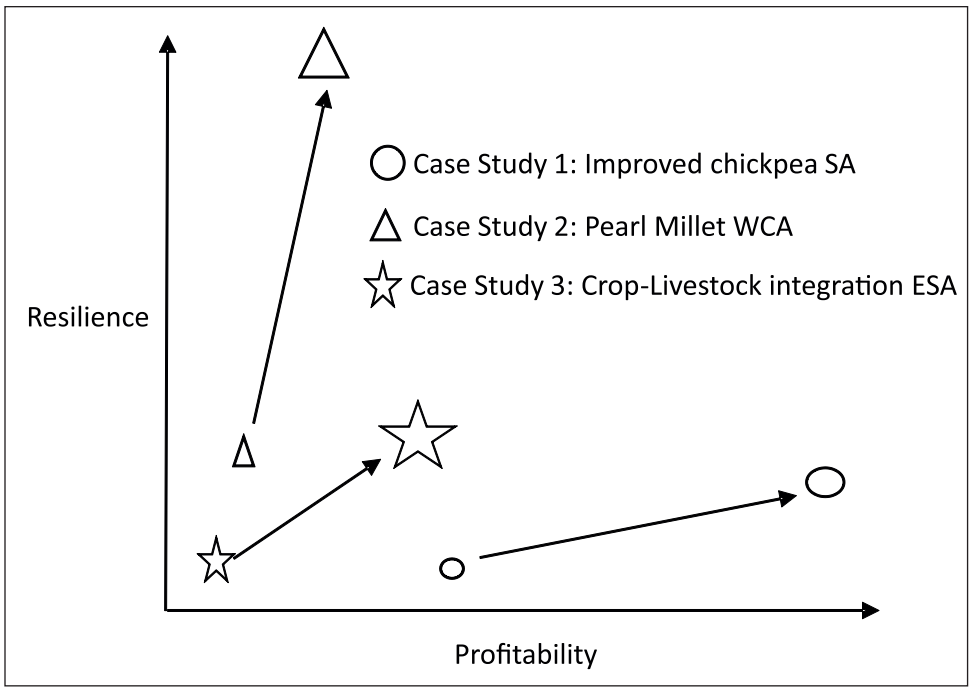

Figure 8. Success stories by profitability and resilience.

6.2 'Win-win' product lines evolve over time

The ICRISAT 'success stories' in Box 2 suggest that 'win-win' product lines can emerge in a two-step process as researchers learn and farmers innovate. For example:

Striga management in WCA

Step 1: Researchers use legume intercrops to suppress *Striga* and improve resilience.

Step 2: Farmers sell legumes and improve profitability.

Crop-Livestock in ESA

- Step 1: Researchers use goats to improve profitability
- Step 2: Farmers use profits from goats to fertilize maize, and improve resilience.

In both cases, researchers did not set out to create a 'win-win' product line, but the product line developed in unpredictable ways. The message is that 'win-win' product lines can evolve through a process of adaptation and discovery.

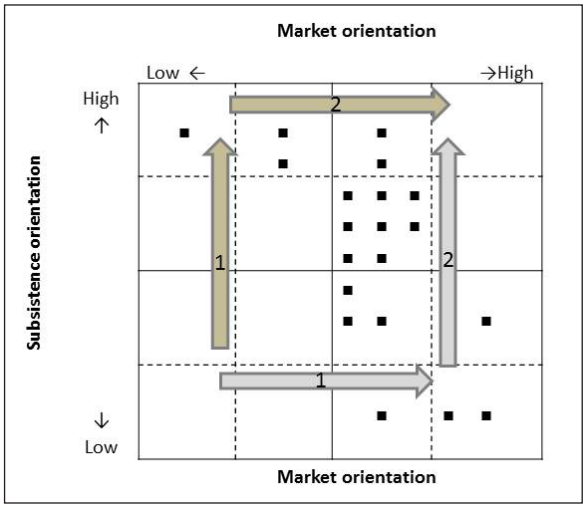

Figure 9. Win – win product lines as a two-step process.

6.3 Contrast with systems approaches

The distinction between 'profitable' and 'resilient' product lines is difficult to reconcile with the approach taken by the CGIAR Research Programs that take a systems approach. In the CG Research Program for Dryland Systems, for example, the emphasis is not on making distinctions between individual product lines but on integrating product lines in ways that fit specific farming systems and environments. While a 'twin-track approach' to developing product lines may make sense for plant breeders, crop management scientists look for ways to increase resilience and profitability not of single components but of the system as a whole. For example, the African Highlands Initiative in eastern Africa used profitable product lines that gave immediate financial returns as 'entry points' in combination with resilient product lines with slower benefits. Thus, forage grasses immediately raised milk yields, while building terraces to conserve soil fertility gave long-term returns (German et al., 2012: 57-60). Here, profitable and resilient product lines played complementary roles, resulting in a win-win package of innovations that gave both higher cash income and improved soil conservation for a specific farming system.

6.4 Product lines and target groups

Another difficulty is the identification of product lines with specific target groups. At the household level, farmers need to combine *both* profitability and resilience. Subsistence-oriented farmers require 'profitable' crops or livestock to provide cash income, whereas market-oriented farmers require 'resilient' crops that give them food security. Similarly, farm households 'in transition' from subsistence- to market oriented farming may use 'profitable' product lines to earn cash income which is then invested in strengthening resilience. Thus, different types of product line can be used in sequence as part of the 'IMOD transition'.

6.5 How useful?

How helpful are these distinctions? They were introduced for one purpose and one purpose only, which was to help research achieve greater impacts. The assumption was that if scientists knew who these products were for, what type of benefits they gave, and what kind of pathway was needed to achieve impacts, then research was more likely to be successful. From this perspective, therefore, what matters is not whether these distinctions give an exact picture of the real world, but whether this way of looking at the world helps to clarify and structure the research process. However, this does not mean that we cannot improve these distinctions or change them as we implement the CRPs.

7. Impact pathways

We can identify two archetypal Impact Pathways. For product lines focused on profitability and targeting market-oriented farmers, the logical development partner is the private sector. Where these product lines involve hybrid seed, the private sector has an incentive to invest. The exemplar here is hybrid pearl millet in India, where R & D and marketing is led by private seed companies. For product lines involving hybrid seed, ICRISAT does not have a major development role. However, the danger with market-led impact pathways is that they are dominated by large-scale commercial farmers. Inclusive business models are needed to ensure that the benefits go to smallholders (Byerlee, 2013). 'Inclusion' is a major theme of research on value chains by CRP 2 (Policies, Institutions and Markets).

Some product lines in the 'profitability' category (such as self-pollinated crops) may not attract private investors. Also, where 'profitable' product lines require new consumer products, such as ready-to-eat foods, there is a case for 'Business Incubators' to develop these. This requires close links between ICRISAT's Agri-Business Incubator platforms and the CRPs.

Product lines that focus on subsistence-oriented farmers and resilience require a different approach. Historically, it has proved difficult to create effective and sustainable impact pathways for these product lines because without the market incentives that attract private firms, success depends on cooperation among stakeholders that may have conflicting interests. Innovation Platforms offer one possible approach. A successful example is the Pan-African Bean Research Alliance (PABRA) which involves 28 countries (ICRISAT et al 2012b).

7.1 Spillovers

Product lines designed to improve profitability for market-oriented farmers require a dynamic private sector and suitable infrastructure. Where these conditions exist, as in India, spillovers from these product lines may be substantial. At present, however, these conditions are missing in some parts of Africa, which makes spillovers from India to Africa more difficult. For example, although there may be demand for sorghum hybrids in WCA, developing an impact pathway is problematic. Similarly, while there is potential demand for sweet sorghum for biofuels in Mozambique, the regulatory framework that exists in India and Brazil is not yet in place (Orr et al., 2013). These asymmetries will result in divergence between ICRISAT's regions. As conditions in SSA improve over time, spillovers will become more likely. Consequently, while Africa needs 'profitable' product lines, they will take longer to have impact. This suggests the need to assess the potential for spillovers by region.

8. Conclusion

To repeat, the objective of this paper is not to provide a book of recipes on how to make smallholder agriculture more profitable and resilient, but to synthesize our knowledge on these subjects for planning purposes. From this knowledge base we can identify 10 key principles that can serve as a guide for going forward.

1. Clearly identify the demand drivers for each crop in each region. We need accurate information by crop and region on the size of the market, consumer preferences, and how income and urbanization will change consumer demand.

2. Clearly identify the threats to resilience in each region. Resilience operates at different levels. Besides information by crop and region on the main sources of yield loss, we also need to know how much these shocks actually affect smallholders at the household level. Building the resilience of farming systems to shocks (eg, through insurance or improving synergies between crops and livestock) is as important as reducing vulnerability to crop losses.

3. Recognize smallholder diversity. Although the majority of farms are below 2 ha, smallholders differ in their degree of orientation to markets or to home consumption. This has implications for the type of technology they need, with market-oriented smallholders favoring profitability, and subsistence-oriented smallholders favoring resilience. We need better ways of conceptualizing diversity and distinguishing between these two groups of farmers.

4. Improve our knowledge of smallholder transitions. Many questions about the 'IMOD transition' from subsistence to market-oriented farming remain open. ICRISAT's Village Level Studies can help identify the drivers for this transition, how it can be promoted, and the impacts of commercialization on women.

5. Recognize that there is no one road to success. ICRISAT's experience shows that success can take various forms. Some success stories have increased resilience, others profitability, while some managed to increase both at the same time.

6. Recognize the tension between commodity and systems approaches. The two CGIAR Research Programs led by ICRISAT envisage two different types of product lines targeted at two different types of smallholders. This is expected to make new technology more appropriate for farmers' needs. However, product lines for market-oriented farmers will still need to be resilient to shocks affecting the yields. Product lines for subsistence farmers should focus not just on reducing vulnerability to yield loss but on improving resilience at the household level. While this 'twin-track approach' may be useful in setting objectives for plant breeding programs, it has some limitations. ICRISAT's 'success stories' show that it is possible to develop 'win-win' technologies that improve both resilience and profitability, often because farmers spot opportunities to combine both objectives. Similarly, a focus on individual product lines differs from the approach taken by crop management scientists, where the focus is on identifying combinations of technologies that will increase the resilience and profitability of the system as a whole, rather than of specific components.

7. Drill down to determine how distinctions between product lines and subsistence- and market-oriented smallholders work in practice. These distinctions have received a mixed reception from ICRISAT scientists. We need to test them in specific contexts, improve them, and if necessary replace them as the CRPs evolve.

8. Develop resilience and profitability profiles for product lines. Research needs to provide farmers with information not just about mean yields, but about yield variability and profitability. Similarly, product lines for subsistence-oriented farmers must be tested under farmers' levels of management.

9. Different types of product lines require different development partners. Product lines targeted at increasing profitability for market-oriented farmers will attract development partners from the private sector, and delivery is expected to become self-sustaining. However, the delivery of product lines for subsistence-oriented farmers will be led primarily by the public sector. ICRISAT's role in this process is to facilitate impact pathways.

10. Spillovers from 'profitability' product lines from SA to SSA may be long term. ICRISAT's three regions are moving at different speeds. In SA, higher market demand and a better-developed private sector mean that we can expect significant spillovers from product lines that involve hybrid seed and higher levels of management. By contrast, markets and the private sector in SSA are less well-developed. Spillovers that require significant private sector investment may be difficult to achieve in the short term, although with convergence over the longer term.

References

Abate T, Alene AA, Bergvinson D, Shiferaw B, Silim S, Orr A, and **Asfaw S.** 2012. Tropical Grain Legumes in Africa and South Asia: Knowledge and Opportunities. Nairobi: International Crops Research Institute for the Semi-Arid Tropics.

African Development Bank. 2011. The Middle of the Pyramid: Dynamics of the Middle Class in Africa. Market Brief, April 20th. Mimeo, 24 pp.

Alinovi L, D'Errico M, Mane E and **Romano D.** 2010. Livelihood Strategies and Household Resilience to Food Insecurity: an Empirical Analysis to Kenya. Paper prepared for Conference on 'Promoting Resilience through Social Protection in Sub-Saharan Africa', Dakar, Senegal, 28-30 June. Mimeo, 52 pp.

Bantilan MCS, Kumara Charyulu D, Gaur PM, Shyam Moses D and **Davis J.** 2014. Short Duration Chickpea Technology: Enabling Legumes Revolution in Andhra Pradesh, India. Research Report No.23, ICRISAT Research Program on Markets, Institutions and Policies, ICRISAT, Patancheru, India.

Brooks S. 2013. Investing in Food Security? Philanthrocapitalism, Biotechnology and Development. Science and Technology Policy Research. Working Paper Series No. 12. University of Sussex, UK.

Byerlee D and **Haggblade S.** 2013. African Food Systems to 2030: Toward Inclusive Business Models. Center on Food Security and the Environment. Stanford Symposium Series on Global Food Policy and Food Security in the 21st Century.

Chandy L and **Gertz G.** 2011. Poverty in Numbers: The Changing State of World Poverty From 2005 to 2015. Policy Brief 2011-1. Washington, DC: The Brookings Institution.

Cooper P, Rao KPC, Singh P, Dimes J, Traore PS, Rao K, Dixit P and **Twomlow SK.** 2009. Farming With Current and Future Climate Risk: Advancing a 'Hypothesis of Hope' for Rainfed Agriculture in the Semi-Arid Tropics, Journal of SAT Agricultural Research, 7: 1-19.

Conway G and **Waage J.** 2010. Science and Innovation for Development. UK Collaborative on Development Sciences (UKCDS). Chapter 5: Combating Hunger. http://r4d.dfid.gov.uk/Output/182144/

DFID (no date). Learning from the Renewable Natural Resources Strategy: from research to innovation systems. http://r4d.dfid.gov.uk/pdf/ThematicSummaries/Brief6_From_research_to_innovation_systems.pdf

German L , Mowo J, Amede T and **Masuki K (eds).** 2012. Integrated Natural Resource Management in the Highlands of Eastern Africa: from Concept to Practice. London: Earthscan.

Harris D and **Orr A.** 2014. Is Rainfed Agriculture Really A Pathway From Poverty? Agricultural Systems, 123:84-96.

Hazell P and **Rahman A (eds).** 2013. New Directions for Smallholder Agriculture. Oxford: Oxford University Press.

Kharas H. 2010. The Emerging Middle Class in Developing Countries. OECD Development Centre. Working Paper No. 285.

ICRISAT. 2012. The Jewels of ICRISAT. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 68 pp. ISBN 978-92-9066-549-6

ICRISAT and **ICARDA.** 2012**.** CGIAR Research Program on Dryland Cereals. A Global Alliance for Improving Food Security, Nutrition and Economic Growth for the World's Most Vulnerable Poor. 15 August 2012.

ICRISAT, CIAT, ICARDA and **IITA.** 2012**.** CGIAR Research Program on Grain Legumes. Leveraging Legumes to Combat Poverty, Hunger, Malnutrition and Environmental Degradation. 15 August 2012.

McKinsey Global Institute. 2010. India's Urban Awakening: Building Inclusive Cities, Sustaining Economic Growth. http://www.mckinsey.com/insights/urbanization/urban_awakening_in_india

Minot M. 2014. Price Volatility in Sub-Saharan Africa: Has It Really Increased? *Food Policy*, 45: 45-56.

Nagayets O. 2005. Small Farms: Current Status and Key Trends. Prepared for the Future of Small Farms Research Workshop, Wye College, June 26-29 2005. Mimeo, 14 pp.

Orr A, Tsusaka T, Mgonja M and **Audi P.** 2013. Sorghum Scoping Study, Mozambique. Mimeo, 48 pp.

Pant GB. 2003. Long-term Climate Variability and Change Over Monsoon Asia. Journal of Indian Geophysical Union, 7 (3), pp. 125-134.

Rao KPC, Oyoo A and **Ndegwa WD.** 2012. Climate Variability and Change: Perceptions, Experiences and Realities, Climate Exchange: 240-242.

Parthasarthy Rao P, Basavaraj G, Ahmed W and **Bhagavatula S.** 2010. An Analysis of Availability and Utilization of Sorghum Grain in India. SAT eJournal, vol.8, December: 1-8.

van Ginkel T, Sayer J, Sinclair F, Aw-Hassan A, Bossio D, Craufurd P, El Mourid M, Haddad N, Hoisington D, Johnson N, Velarde CL, Mares V, Mude A, Nefzaoui A, Noble A, Rao KPC, Serraj R, Tarawali S, Vodouhe R, and **Ortiz R. (2013).** An integrated agro-ecosystem and livelihood systems approach for the poor and vulnerable in dry areas. Food Security, 5 (6): 751-767.

van Mourik T, Weltzien E and **Traore S.** 2013**.** Development and evaluation of integrated *Striga* and soil fertility management of pearl millet in Mali using cluster-based farmer field schools. Mimeo.

van Rooyen AF, Homann Kee-Tui S and **Masikati P.** 2013. Resilience Thinking in Agricultural Development: In Search of Effective Conceptual Models. Unpublished.

Timmer CP. 2009. A World Without Agriculture? The Historical Paradox of Agricultural Development. American Enterprise Institute for Policy Research. No. 1, May 2009. http://www.aei.org/outlook/foreign-and-defense-policy/international-organizations/economic-development/a-world-without-agriculture-outlook/

United Nations. 2012. World Population Prospects: The 2012 Revision. Department of Economic and Social Affairs. http://esa.un.org/unpd/wpp/Demographic-Profiles/index.shtm

Walker B, Carpenter S, Anderies J, Abel N, Cumming G, Janssen M, Lebel L, **Norberg J, Peterson GD** and **Pritchard R.** 2002. Resilience Management in Social-ecological Systems: a Working Hypothesis for a Participatory Approach, Conservation Ecology 6 (1): 14.

Appendix 1a

ICRISAT 'success stories', by profitability and resilience.

Description	Resilience (1-4)	Profitability (1-4)	Resilience	Profitability
DC - Improved pearl millet varieties (Nigeria, WCA)	4	1	High	Low
GL - Drought-tolerant improved Groundnut varieties (Karnataka, Tamil Nadu, SA)	4	2	High	Low
DC - Pearl Millet cultivars (SA)	4	2	High	Low
GL - Drought-tolerant improved Groundnut varieties (Nigeria WCA)	3	3	High	High
DS - Crop-livestock (Zimbabwe, ESA)	4	3	High	High
DC - Postrainy season Sorghum (Maharashtra, SA)	4	3	High	High
DC - Guinea-race sorghum hybrids (Mali, WCA)	3	3	High	High
GL - Short duration Pigeonpea (Maharashtra, SA)	3	3	High	High
GL - Pigeonpea Orissa (SA)	3	3	High	High
MIP - Collective action - Social capital in Maharashtra Groundnut (SA)	3	3	High	High
ICRISAT - Seed Systems of Sub-Saharan Africa (WCA, ESA)	3	3	High	High
GL - Early maturing chickpea with market traits (Ethiopia, ESA)	3	3	High	High
DS - Community Based Integrated Watershed Management (SA)	3	3	High	High
DS - Fertilizer micro-dosing (Burkina Faso, WCA, Zimbabwe, ESA)	2	3	Low	High
GL - Pigeonpea in eastern and southern Africa (Tanzania, ESA)	2	3	Low	High
DC - Extra-early pearl millet hybrids (SA)	2	3	Low	High
GL - Aflatoxin-kit for groundnuts (Malawi, ESA)	2	4	Low	High
DC - Sweet sorghum (SA)	1	4	Low	High
GL - Hybrid pigeonpea (SA)	1	4	Low	High
GL - Early-maturing chickpea (Karnataka, Andhra Pradesh, SA)	1	3	Low	High

Appendix 1b

ICRISAT 'success stories', by profitability and resilience – reasoning.

	Reasoning			
	Resilience		Profitability	
Description	Reasons	Score	Reasons	Score
DC - Improved pearl millet varieties (Nigeria, WCA)	Greater emphasis on improving yield for food security	4	Less emphasis on alternative end uses	1
GL - Drought-tolerant improved Groundnut varieties (Karnataka, Tamil Nadu, SA)	Drought tolerance for reduced yield losses	4	Slight increases in yield potential	2
DC - Pearl Millet cultivars (SA)	Personal communication	4	Personal communication	2
GL - Drought-tolerant improved Groundnut varieties (Nigeria WCA)	Drought tolerance a major resilience target	3	Spread of improved varieties for higher yields	3
DS - Crop-livestock (Zimbabwe, ESA)	Resilience through integration of various income sources which benefit each other	4	Support of markets for income increases	3
DC - Postrainy season Sorghum (Maharashtra, SA)	Post rainy season sorghum is mainly a staple food that is little marketed	4	Less scope for industrial uses because rainfed production leads to supply and price fluctuations	3
DC - Guinea-race sorghum hybrids (Mali, WCA)	Food security target based on WCA focus	3	Mainly enabling WCA to benefit from higher yields	3
GL - Short duration Pigeonpea (Maharashtra, SA)	Early maturity reduces yield loss from drought	3	High market demand for pigeonpea dal	3
GL - Pigeonpea Orissa (SA)	Early maturity reduces yield loss from drought	3	High market demand for pigeonpea dal	3
MIP - Collective action - Social capital in Maharashtra Groundnut (SA)	Collective input supply increases yields of staple food crops	3	Collective marketing increases cash income	3
ICRISAT - Seed Systems of Sub-Saharan Africa (WCA, ESA)	Resilience target through seed funds and high geographical spread	3	Enabling wide access to higher yields / improved varieties	3
GL - Early maturing chickpea with market traits (Ethiopia, ESA)	Early maturity reduces yield loss from drought	3	Market traits for profitability	3

Continued

Continued

ICRISAT 'success stories', by profitability and resilience – reasoning.

	Reasoning			
	Resilience		Profitability	
Description	Reasons	Score	Reasons	Score
DS - Community Based Integrated Watershed management (SA)	Resilience/ Sustainability targets with water loss reduction and soil conservation	3	Enabling farmers to grow more cash crops and increase their incomes	3
DS - Fertilizer micro-dosing (Burkina Faso, WCA, Zimbabwe, ESA)	Healthier plants are more resistant to droughts	2	Clear focus on yield increase by using fertilizer	3
GL - Pigeonpea in eastern and southern Africa (Tanzania, ESA)	Enabled through disease resistance	2	Marketable product fitting in a niche High yielding	3
GL - Aflatoxin-kit for groundnuts (Malawi, ESA)	Aspect of human health and nutrition	2	Main focus is on international trade and thus profits	4
DC - Sweet sorghum (SA)	Purely for biofuels	1	Purely profitable crop	4
GL - Hybrid pigeonpea (SA)	Only yield as selection criteria mentioned	1	Yield the major factor mentioned High cost has implications for profit maximizing farmers	4
DC - Extra-early pearl millet hybrids (SA)	Downy mildew resistance one of the targets	2	Hybrids for higher yields appears to be the focus	3
GL - Early-maturing chickpea (Karnataka, Andhra Pradesh, SA)	No clear resilience targets mentioned	1	Fitting a new seasonal niche	3

Appendix 2a

Product Lines for Dryland Cereals and Grain Legumes CRPs, by profitability and resilience.

Description	Resilience (1-4)	Profitability (1-4)	Resilience	Profitability
DC - Improved food security and incomes with productive, nutritious multipurpose pearl millet hybrid production technology for East Africa and South Asia	4	2	High	Low
GL - Insect-smart pigeonpea and chickpea	3	2	High	Low
GL - Heat-tolerant chickpea	3	1	High	Low
GL - Short-duration, drought tolerant and aflatoxin-free groundnut	2	3	Low	High
DC - Productive and nutritious finger millet production technologies for East and Southern Africa	2	3	Low	High
DC - Productive and nutritious pearl millet food and fodder production technologies	2	3	Low	High
DC - Multipurpose postrainy season sorghum hybrid production technology for improved food and fodder availability in the driest regions of South Asia	2	3	Low	High
GL - Herbicide-tolerant, machine-harvestable chickpea	1	4	Low	High
GL - Pigeonpea hybrid and management practices	1	4	Low	High
DC - Productive, nutritious, photoperiod sensitive sorghum production tools for multiple uses in West Africa	1	4	Low	High
GL - High nitrogen-fixing chickpea	1	3	Low	High
DC - Drought tolerant, highly productive multi-use sorghum variety for food and processing use in the dry lowlands of East Africa	1	3	Low	High
GL - Extra-early chickpea	1	3	Low	High

Appendix 2b

Product Lines for Dryland Cereals and Grain Legumes CRPs, by profitability and resilience - reasoning

Description from CRP Proposal documents	Reasoning			
	Resilience		Profitability	
	Reasons	Score	Reasons	Score
DC - Improved food security and incomes with productive, nutritious multipurpose pearl millet hybrid production technology for East Africa and South Asia	Focus on food security and nutrition in drylands	4	Pearl millet grain used as poultry and cattle feed in SA	2
GL - Insect-smart pigeonpea and chickpea	Small attention to IPM target is more richer farmers but the reduction of insect damage is a resilience target	3	Focus on genetic engineering and hybrids	2
GL - Heat-tolerant chickpea	Reduce potential yield reduction due to climate change Addresses only heat tolerance thus score 3	3	No mention of any productivity traits thus score 1	1
GL - Short-duration, drought tolerant and aflatoxin-free groundnut	Addressing negative effects from drought Score 2 as the focus is mainly on Aflatoxin reduction for trade and profitability	2	Reduction of Aflatoxin contamination for trade and profitability Partly drought tolerance is meant to reduce Aflatoxin Score 3	3
DC - Productive and nutritious finger millet production technologies for East and Southern Africa	Focus on food security and nutrition in drylands	2	Finger millet widely sold as porridge for weaning in ESA	3
DC - Productive and nutritious pearl millet food and fodder production technologies	Focus on food security and nutrition in drylands	2	Dual use (food and fodder) in SA	3

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Product Lines for Dryland Cereals and Grain Legumes CRPs, by profitability and resilience - reasoning

Description from CRP Proposal documents	Reasoning			
	Resilience		Profitability	
	Reasons	Score	Reasons	Score
DC - Multipurpose postrainy season sorghum hybrid production technology for improved food and fodder availability in the driest regions of South Asia	Emphasis on staple food crop in drylands	2	Greater emphasis on use for fodder for dairy industry	3
GL - Herbicide-tolerant, machine-harvestable chickpea	addressing more labor constraint	1	Addressing delays in harvesting and high labor rates Clear focus on profit increases	4
GL - Pigeonpea hybrid and management practices	Some component to address insect and disease resistance but main descriptor is the yield increase	1	Addressing mainly yield increase Requires investments and will thus target profitability more than resilience	4
DC - Productive, nutritious, photoperiod sensitive sorghum production tools for multiple uses in West Africa	Less emphasis on drought tolerance	1	Greater emphasis on alternative end uses (fodder, sorghum beer)	4
GL - High nitrogen-fixing chickpea	Minor attention to sustainability improvements due to N-fixing Score 1 as this is described more along the lines of a niche by-product	1	Clear focus is the increase in yield of the following crop closing the yield gap is a clear profitability focus	3
DC - Drought tolerant, highly productive multi-use sorghum variety for food and processing use in the dry lowlands of East Africa	Less emphasis on drought tolerance	1	Greater emphasis on alternative end uses (fodder, sorghum beer)	3
GL - Extra-early chickpea	Fills a niche in the wheat and rice systems No specific resilience target mentioned	1	Fill the gap and add income to the household	3