

# Pathways for the sustainable intensification of African smallholder agriculture

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Global food and fibre security is an international challenge given concerns over rising population, world food stocks, the food-biofuel debate, increasing water scarcity, the decline in natural forest cover, climate change and increasing energy costs. Livelihoods and prosperity are increasing in some parts of the world, driving increased dietary diversification and higher per-capita fibre and energy consumption. Conversely, other parts of the world find it harder to meet basic food and energy requirements. Looking forward, international agriculture must produce 64% to 81% more food by 2050 to feed the projected increases in population and consumption (Keating and Carberry, 2010). The international imperatives are to increase production of major food and tree crops in order to improve livelihoods of smallholder farming communities; keep pace with the projected increases in food demand; and mitigate agriculture's greenhouse gas emissions. Keating et al. (2010) ask the question of whether an eco-efficient agriculture can create both efficiencies in resource use and lower greenhouse gas intensities in order to meet these production and sustainability challenges.

Addressing global food insecurity is a central development objective for Australia's aid program. The Australian Government explicitly identifies R4D as a path to impact for lifting agricultural productivity in developing countries. Through the National Flagship for Sustainable Agriculture and its Research for Development Theme, CSIRO is directing Australian science to help deliver on Australian government priorities internationally.

The request here was to describe the thinking of CSIRO's Sustainable Agriculture Flagship on the pathways for the sustainable intensification of African smallholder agriculture. What follows is a description of how the Flagship views the challenge of research contributing to development outcomes in the agricultural domain – it draws from input into a recent review of this research in CSIRO. This reflection is somewhat broader than the specific topic of pathways for the sustainable intensification of African smallholder agriculture. However, we have produced several recent publications on intensification of smallholder agriculture (Keating and Carberry 2010a,b; Carberry et al., 2010; Keating et al., 2012a,b) and key propositions are contended again in what follows.

## Science Challenges

The Flagship intends to integrate, evaluate, communicate and publish a coherent research program targeted at improving the agricultural and forestry sectors in Africa, Asia and the Pacific. Its Research for Development Theme (~20% of Flagship research) is aligned to CSIRO's international strategy that recognises R4D as an important means whereby CSIRO can help to support Australia's national interests. The science challenge for the Theme is to align its R4D projects with the dual ambitions of achieving impacts within international smallholder farming communities alongside conducting and reporting quality scientific research. A specific challenge is to leverage a broader science perspective into Theme research, to develop capacity in social and economic sciences that will deliver innovative systems research in the context of livelihoods and value chain analysis.

The Flagship is advancing its R4D agenda on two fronts. Firstly, by entering the international community's dialogue on how sustainable livelihoods of smallholder farming communities can be improved. In this debate, the Flagship is evolving the concept of eco-efficiency, whereby research improves the efficiency with which desired outputs are produced with minimal generation of undesired negative effects.

Secondly, the R4D Theme invests in research projects that deliver:

- diagnosis of constraints at farm, regional and institutional scales
- generation of new technology options and stimulation of their uptake
- building of human capacity and science leadership within partner organisations
- insights into input and output markets leading to market-led innovations
- enhanced understanding of institutional environments and policy settings which involve farm households, small agricultural businesses, and the non-government and government sectors

## Flagship Strategy

The theme goal is to address the global challenges of food, fibre and carbon security through international research partnerships which both increase the capacity of participants and identify pathways to develop and improve sustainable livelihoods. To achieve this Goal, the Theme delivers outcomes along three impact pathways:

**Smallholder farmers producing for markets** will result from increases in the productivity and nutritional diversity of smallholder farming systems and from improved services from agricultural input/output providers. To achieve these outcomes, crop and livestock production need to be considered as enterprises and knowledge information systems need to be attuned to the requirements of service providers. The Theme will work with change agents, including leading farmers and service providers, to identify enterprise opportunities and demonstrate acceptable risks and returns from alternative system options.

**Improving the livelihoods of smallholder communities** is dependent on reducing their risks and delivering development opportunities both within and beyond agriculture. To achieve these outcomes advice to farmers needs to encompass economic and environmental risks and public and private support services for farmers needs to consider livelihood opportunities broader than farming. The Theme will work with Governments, NGOs and the private sector to evaluate risk-aware approaches and assist farming communities to consider natural, physical, human, social and financial dimensions to their livelihood strategies.

**Improving the net carbon balance of smallholder farming systems** is concomitant with the sustainable intensification of agricultural production systems whilst reducing their GHG emissions intensity. To achieve this outcome, smallholder farmers need to adopt practices to increase soil carbon and fertility and the production efficiency of livestock. Wood production from smallholder forest plantations must sustain site and soil resources and spare native forests. The Flagship will work with national Governments, international research and policy initiatives, NGOs and the private sector to establish the return on investment for conservation agriculture practices, to understand the trade-offs of soil carbon enhancing and emissions reducing practices and to elicit the policy impacts on forest sparing effects.

## Progress

CSIRO has a long-established inventory of R4D projects in the agricultural and plantation forestry domains. Our research into farming systems, forest systems, systems modelling and land and water management have long-standing successful research collaborations in many key developing countries and with international research agencies such as the CGIAR institutes. Where the Flagship has added value to this legacy is to present CSIRO as a coherent research program to our research partners both in Australia and internationally. Specific imperatives are:

### Eco-efficient agriculture: concepts, challenges and opportunities

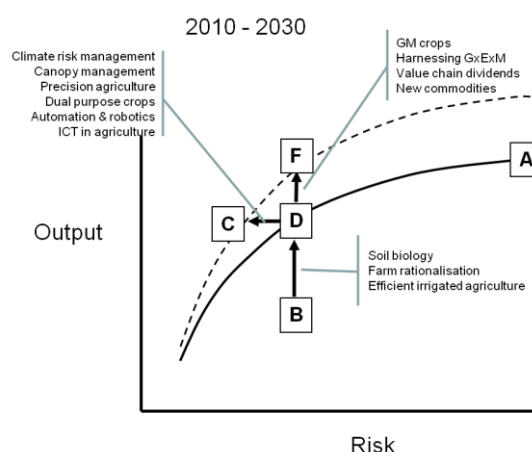
At the 2009 CGIAR Science Forum on Food Security held in The Netherlands, we presented an invited paper which explored the multi-dimensionality of eco-efficiency as it applies to agriculture across diverse spatial and temporal scales (Keating *et al.*, 2010). New thinking was introduced to this topic through the introduction of a framework which explores an efficiency frontier between agricultural outputs and inputs, investment or risk. This framework provided proposed pathways for agriculture to continue productivity growth.

The Theme has developed this high-level concept with a number of pathways identified for system improvement. Further publications have developed and used this framework to suggest how eco-efficient agriculture can lead to the needed production gains (Keating and Carberry 2010a,b; Carberry *et al.*, 2010; Keating *et al.*, 2012a,b).

As a consequence of this proactive involvement in the international dialogue on food security

and as a result of increased investment into engagement and communication activities, the Flagship is now a regular invitee to global meetings and into consortia establishing new research initiatives.

Figure 1: Return–risk framework and technologies identified as having potential to affect agriculture between 2010 and 2030 (from Carberry *et al.*, 2010a).



### Africa Food Security Initiative

In 2009, AusAID invited CSIRO to develop a four year \$30M collaborative program under an “Africa Food Security Initiative” (AFSI) and, in doing so, establish collaboration with two African research agencies:

- The Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricoles (CORAF)/West and Central African Council for Agricultural Research and Development (WECARD)
- Biosciences Eastern and Central Africa (BecA) hosted and managed by the International Livestock Research Institute (ILRI)

The program has subsequently developed six country-initiated projects in west-central Africa examining crop-tree-livestock farming systems, opportunities for strengthening seed systems, and integrated control of ticks and tick-borne diseases. Another seven projects are progressing in east-central Africa, on topics covering animal health and food nutrition. A fourteenth project aims to elicit and report learnings from the implementation of this R4D program. The overall aim of the AFSI program is to improve food security in Africa by fostering integrated agricultural research for development with African research agencies and

improving agricultural productivity and sustainability within the three themes of animal health, food quality (safety and nutrition) and farming systems.

The AFSI program is delivering coordinated, multi-disciplinary, program-level research aimed at development impacts. It has brought together a broad range of disciplines from across CSIRO's capability Divisions as well as from other partners within Australia and internationally (CGIAR, African National Agricultural Research System, Cornell University).

Alongside the research projects, CSIRO together with BecA have developed a new and innovative approach to capacity building for African science leadership. The Africa Biosciences Challenge Fund provides training and support to African scientists and students to progress their research in order to address Africa's underlying issues with food production, nutrition and animal health. The ABCF has attracted funding support from additional major donors (Bill & Melinda Gates Foundation, Swedish Government and Syngenta Foundation for Sustainable Agriculture).

### **Systems analysis and modelling as a path to impact**

*What innovation can Australia bring to the food security issue, especially in Sub-Saharan Africa where improving agricultural production and food access have been both intractable and well-resourced in research for decades past?*

Many of the Theme's projects share access to technical innovation in which Australia leads the world, but its exposure in developing countries has been minimal to date. Participatory systems analysis, based on simulation modelling, is the essential innovation required to address intervention options under high climate variability and investment risk. Today, systems simulation is endemic to research in the dryland farming systems of Australia. The Theme offers this same innovation to smallholder farming systems and their agents of change. This systems simulation research focus, coupled with active partnerships with farmers, agribusiness, and extension services provides the best avenue for research making a difference in food security in the short to medium term.

The origins of the renowned APSIM systems model can be traced to CSIRO R4D activities in Kenya in the 1980s. Almost 30 years later, Whitbread et al. (2010) summarised how Australian investment in farming systems simulation has led to the development of more sustainable smallholder farming systems in Africa. These same approaches are being applied within the current Africa Food Security Initiative whereby systems models such as APSIM and the Integrated Assessment Tool (IAT) for livestock systems (both developed and maintained by the Landscape Systems and Trends Theme) are central tools. These tools are key to the implementation of Innovation Platforms consisting of multiple actors within commodity value chains.

Developing in-country capacity in systems modelling and its application in promoting food security is a Theme priority.

### **Climate change and greenhouse gases (GHG) from agriculture**

Climate change will clearly challenge the food-security of smallholder farmers worldwide and intensification of their agricultural production systems must consider the consequent GHG load on the atmosphere. The Flagship proposes an eco-efficiency imperative for global agriculture, where more food and fibre are produced with more efficient use of natural resources and less impact on the environment (Keating et al., 2012a). Thus an identified impact pathway for the Theme is to build the net carbon balance of smallholder farming systems concomitant with sustainable intensification opportunities.

The Theme invests in R4D activities which support practices that increase soil carbon and fertility and improve the production efficiency of livestock. Much of the farming systems research in Sub-Saharan Africa is focused on increasing the nutrient supply to crops and livestock; the imperative is firstly to increase enterprise productivity, but carbon benefits are also quantified. Likewise, the portfolio of Theme projects assisting wood production in plantations and farm woodlot by smallholder foresters will improve their

livelihoods, husband soil carbon and nutrient resources of planted forests and likely help spare native forests – although quantifying such sparing effects is yet to be progressed.

The aspiration for the Theme is to quantify both production and environmental impacts of our R4D activities.

### Impact narratives

There is an active community of inquiry within international R4D where critiques and learnings from the many millions of dollars invested annually are reported. Despite CSIRO having an international reputation for research excellence across its full portfolio, it has not been a highly visible contributor in the R4D domain. The reality is that CSIRO has been poor at reflecting and publicising its R4D achievements and likely lacks the requisite skills in social and economic sciences to fully participate.

The Flagship is now actively resourcing increased support in this area and engaging the agricultural R4D community through involvement in the many food security round-tables and this has led to publication and representation opportunities. However, the intent to publish results and learnings needs to extend into individual projects. It is a Theme priority to encourage project-level publications contributing strong disciplinary science as well as informative learning narratives demonstrating our participatory approaches and impacts. The aspiration is to be recognised as world-leading in publishing learnings into the R4D literature, in helping set the international R4D agenda and in reporting impacts from R4D implementation

Two current initiatives have made progress in constructing impact narratives. Firstly, a component of the AFSI programme is a Learning Project aimed at eliciting and reporting learnings through the development of a common theoretical framework about successfully implementing R4D (Ison et al., 2012). Secondly, AusAID are supporting CSIRO to reflect on and thus deliver more effective application of science and evidence-based approaches to the development, implementation and evaluation of food security interventions. A Food Systems Innovation for Food Security project is contributing towards this objective by providing insights into how to improve design and implementation of food security research and development and initiating a program of building professional capacity of staff in AusAID, CSIRO & other partners.

### Looking to the Future

The international R4D theme contributes to the Flagship Goal of achieving a 50% increase in agricultural productivity and a 50% reduction in the intensity of carbon emissions. It is well positioned to integrate, evaluate and communicate a coherent CSIRO portfolio of research targeted at improving the livelihoods of the rural poor around the world. Its strengths are in R4D that proposes technical changes at the field to farm scale leading to improved agricultural productivity. This strength aligns well with the current Australian aid program's food security strategy that concentrates on the three pillars of 1) lifting agricultural productivity, 2) improving rural livelihoods and 3) building community resilience. The Theme focus on lifting agricultural productivity will thus continue to be strongly supported.

The Theme needs to accelerate its progress along its proposed impact pathways for boosting rural livelihoods and improving the net carbon balance of smallholder farming systems. The social and economic science capabilities within CSIRO and its collaborators need to be sought more extensively. Likewise, links will be made to the growing research capacity and tools being developed within the GHG and Carbon Theme for research into GHG mitigation and carbon storage.

However, an aggregated quantifiable metric of Theme impacts is not available against the sought-after goal of improved smallholder livelihoods. This deficiency is shared by most R4D initiatives and not easily remedied despite demands from funders and stakeholders. The Theme is addressing this challenge in two ways. Firstly, through collaboration with ACIAR and the CGIAR, methods for monitoring and evaluation of R4D are being explored in order to contribute to an improved basis for ex-post impact evaluation. This

collaboration will review the evidence of ex-post impact evaluation of R4D in agriculture systems and propose a mixed methods approach to an integrated monitoring and evaluation and impact assessment system that is compatible with a results-based program implementation culture and is implementable at reasonable cost. Secondly, through collaboration with our African research partners and AusAID to provide an integrated monitoring and evaluation system of measuring R4D impacts across 13 research projects and a major capacity building initiative across sub-Saharan Africa.

In future years, the Flagship wants to be recognised by the Australian and international R4D communities as a partner preferred for its quality science and its commitment to achieving quantifiable impacts.

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