Innovation for Sustainable Intensification in Africa

Calestous Juma, Ramadjita Tabo, Katy Wilson and Gordon Conway

A 2013 Montpellier Panel Briefing

This report should be cited as:

Juma, C., Tabo. R., Wilson, K. and Conway, G. 2013. *Innovation for Sustainable Intensification in Africa, The Montpellier Panel, Agriculture for Impact, London.*

Agriculture for Impact
15 Princes Gardens
South Kensington Campus
Imperial College London
SW7 1NA

www.ag4impact.org

Tel. +44 (0)207 594 1983

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Author Biographies

Calestous Juma

Calestous Juma, a national of Kenya, is an internationally-recognised authority on the role of innovation in economic development. He is Professor of the Practice of International Development and Director of the Science, Technology, and Globalization Project at Harvard Kennedy School. He directs the School's Agricultural Innovation Policy in Africa Project funded by the Bill & Melinda Gates Foundation. Juma has been elected to several scientific and engineering academies including the Royal Society of London, the US National Academy of Sciences, the World Academy of Sciences (TWAS) and the African Academy of Sciences. He co-chairs the African Union's High-Level Panel on Science, Technology and Innovation. Juma holds a DPhil in science and technology policy studies from the University of Sussex and has received numerous international awards and honorary degrees for his work on sustainable development. His latest book, The New Harvest: Agricultural Innovation in Africa was published in 2011 by Oxford University Press. Twitter @calestous

Ramadjita Tabo

Ramadjita Tabo, a Chadian citizen, is currently the Deputy Executive Director of the Forum for Agricultural Research in Africa (FARA). Prior to that he was the Assistant Director of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in West and Central Africa and a cropping systems agronomist based at ICRISAT-Niamey, Niger. He obtained his PhD in Agronomy and Plant Genetics from the University of Arizona in 1985. Dr Tabo has won several awards one of which is the 2007 Nobel Peace prize as a member of the Intergovernmental Panel on Climate Change (IPCC). His research activities included development and improvement of cereal based systems, evaluation and promotion of fertiliser microdosing technology and the "warrantage" or inventory credit system, enhancement of water and nutrient use efficiency, intensification of integrated crop-livestock systems in the dry savannas of West Africa, adaptation to climate variability and mitigation of land degradation and conservation of biodiversity.

Katy Wilson

Katy Wilson joined Imperial College London in August 2010 and worked with Gordon Conway on his new book "One Billion Hungry: Can we Feed the World?" She has previously worked at the Institute for International Research in New York and volunteered at Harnas Wildlife Foundation in Namibia. She has an MSc Environmental Technology from Imperial College London and is currently undertaking a PhD at the University of Cambridge.

Gordon Conway

Gordon Conway is a Professor of International Development at Imperial College, London and Director of Agriculture for Impact. From 2005-2009 he was Chief Scientific Adviser to the Department for International Development. Previously he was President of The Rockefeller Foundation and Vice-Chancellor of the University of Sussex. He was educated at the Universities of Wales (Bangor), Cambridge, West Indies (Trinidad) and California (Davis). His discipline is agricultural ecology. In the early 1960's, working in Sabah, North Borneo, he became one of the pioneers of sustainable agriculture. He was elected a Fellow of the Royal Society in 2004 and an Honorary Fellow of the Royal Academy of Engineering in 2007. He was made a Knight Commander of the Order of Saint Michael and Saint George in 2005. He was recently President of the Royal Geographical Society. He has authored The Doubly Green Revolution: Food for all in the 21st century (Penguin and University Press, Cornell) and his most recent book, One Billion Hungry: Can we Feed the World?, was published in October 2012.

An Agenda

We believe that innovation for sustainable intensification is essential if food and nutrition security is to be achieved in Africa. It is a significant challenge. Inevitably in a briefing paper of this nature we raise more questions than we answer.

Taken together, we believe the **issues** and ***questions*** below provide the basis for an agenda for further research, dialogue and policy making in the coming years:

1. We have focused on innovations that are relatively successful.

- ***How do we avoid unsustainable intensification?***

2. The culture and institutions for innovation in Africa are evolving in the right direction.

- ***But what further changes are needed?***

3. Appropriate policies in support of innovation are being developed in a number of African countries.

- ***How are they working and how do we accelerate this process?***

4. We know that innovation can come from a variety of sources – international organisations, the private sector, National Agricultural Research Systems (NARS), Non-Governmental Organisations (NGOs) and farmers themselves.

- ***But which of these and/or their combinations are most likely to deliver not only multiple benefits but resilience and sustainability?***

5. We know that multiple benefits can be built up on the basis of an initial innovation.

- ***Is this the best way to proceed or is it better to have multiple benefits as objectives right from the beginning of projects or programmes?***

6. We have examples of reducing costly and damaging inputs but often these may be at the expense of yield performance.

- ***What principles and practices will prevent this?***

7. Some innovations are clearly resilient, but often this arises from innovations breaking down and having to be redesigned. Other innovations will increase natural capital or reduce greenhouse gas emissions but often this appears to be serendipitous.

- ***How can we ensure these objectives are built in from the beginning and have no significant yield penalty?***

8. We have plenty of evidence that farmers are great innovators.

- ***But how can their innovations be brought to scale, to the community, district and nation?***

9. Going to scale involves an appropriate enabling environment and the participation of many stakeholders.

- ***How can this be achieved?***

10. Finally engaging in a participatory learning agenda involving African and donor governments, the private sector, NGOs and farmers themselves is a priority.

- ***How do we initiate and facilitate this?***

What is Innovation for Sustainable Intensification?

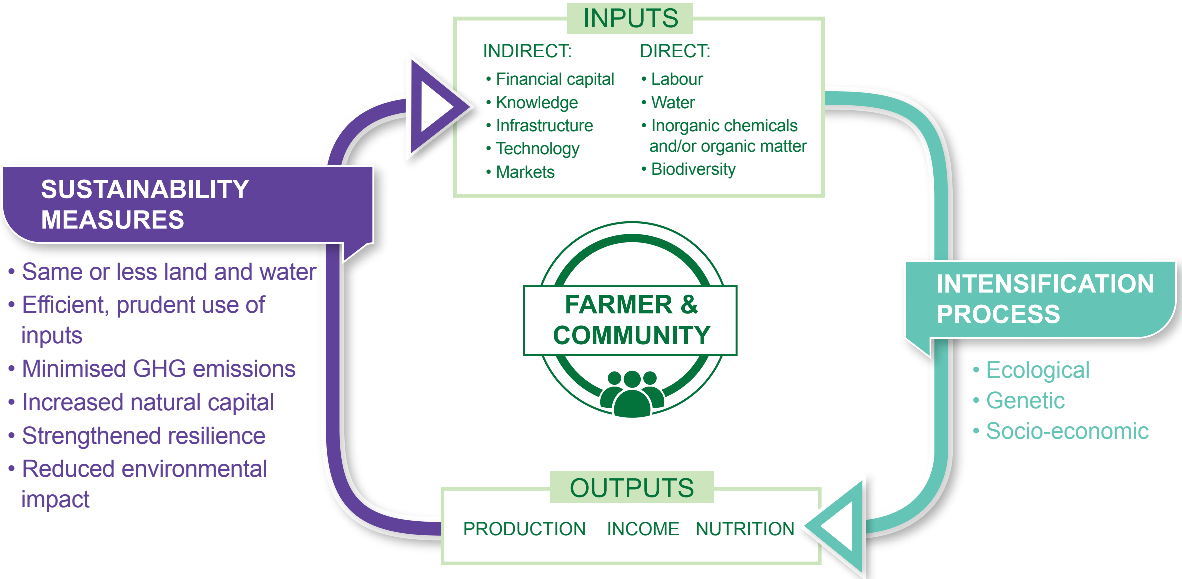

Figure 1 Theoretical model of sustainable intensification

A new paradigm for African agriculture is needed, one that can help address food and nutrition insecurity as well as spur growth, reduce poverty, create wealth, and protect the continent's natural resources.[1]

Sustainable Intensification (SI) offers a robust solution. It is about producing more outputs with more prudent use of all inputs – on a durable basis – while reducing environmental damage and building resilience, natural capital and the flow of environmental services.[2]

Innovation is at the heart of sustainable intensification, helping African smallholder farmers produce more with less impact on the environment while also improving agriculture's sustainability. Much can be achieved by utilising existing knowledge whether derived from other regions or from indigenous sources but because of the nature and scale of the challenges we face we also require innovation. As a 2013 report from the Chicago Council on Global Affairs states, 'the science of the past will not meet the demands of the future.'[3]

Innovation Takes Many Forms

Fundamentally innovation is about doing things in new and different ways (Box 1).

The following briefing paper is intended to:

- highlight the **importance of innovation** in African agriculture,
- provide a context for **innovation for sustainable intensification** that emphasises the need to pursue multiple benefits through multiple partnerships and multiple approaches, at multiple scales,
- offer some **practical current examples** of such innovation emphasising how the innovation came about and the roles of different actors.

In this paper we do not offer a blueprint, but rather an agenda for further work.

Box 1 What do we mean by innovation?

Science is the process of generating knowledge based on evidence.[4] It implicitly includes both natural sciences (biology, chemistry, physics, mathematics and related disciplines) and social sciences (economics, social science, politics and law).

Technology is the application of that scientific knowledge.

In colloquial terms we tend to use invention and innovation interchangeably. But there is a difference in emphasis. Invention is a novel object, process or technique. Innovation is the process by which inventions are produced – it may involve new ideas, new technologies, or novel applications of existing technologies, new processes or institutions, or more generally, new ways of doing things in a place or by people where they have not been used before.

Modern innovation is usually stimulated by innovation systems and pathways.

Why do we Need to Innovate?

Africa faces a series of challenges to achieving food and nutrition security for all:

- Repeated food price spikes are hitting the poorest hardest.
- Chronic malnutrition still affects 230 million people (one in four) in sub-Saharan Africa (SSA) as well as 40 percent of children under the age of five who will experience stunted mental and physical development and in extreme cases blindness or death.[5]
- Food production needs to increase by 60 to 100 percent by 2050, according to the FAO, if the world is to feed itself. On present trends SSA will only produce 13 percent of its food needs by then.[6]
- Intensification is expected to produce 80 percent of the required increase in food production, according to the UN.[7]

Food production remains well below its potential in Africa. Africa has a quarter of the world's arable land, but only generates 10 percent of global agricultural output.[8] In addition, more than 75 percent of total arable land in SSA is degraded with nearly 3.3 percent of agricultural GDP lost annually because of soil and nutrient loss. Climate change is also expected to reduce cereal production levels by up to three percent, contributing to decreased food availability in the region by 500 calories per person and increasing the number of malnourished children from 33 to 52 million.[9] Tackling hunger, malnutrition and poverty while at the same time protecting and improving the environmental base on which millions of peoples' livelihood depends, in the face of severe resource constraints and global warming will require human ingenuity, creativity and innovation.

The Benefits of Innovation

Science and innovation have long informed agriculture. From the application of ecological knowledge to increase the resilience of agricultural systems to the revolution in biotechnology made possible by the discovery of DNA, science, both fundamental and applied, can bring about transformations in the way we produce and access food.[10] And we know that agricultural productivity increases and poverty significantly declines as a result of investment in research and development (Box 2).

Increasing funding for agricultural research and ensuring the benefits are captured by smallholder farmers in Africa is critical but the systems which generate innovation, if they are to achieve sustainable intensification, will need to change.

Box 2 The returns to research and development (R&D)

- The average rate of return to investments in African agricultural R&D between 1970 and 2004 was 33 percent.[11]
- Investments in African R&D were associated with growth in agricultural productivity of 2.1 percent annually in the 1990s.
- Agricultural research currently reduces the number of poor by 2.3 million or 0.8 percent annually.[12]
- A doubling of investment in public agricultural research in SSA would increase growth in agricultural output from 0.5 to 1.1 percent and reduce poverty by 282 million people.[13]

How do we Innovate for Sustainable Intensification?

Innovation at the time of the Green Revolution was relatively straightforward – breeding of new short strawed varieties of wheat and rice able to take up more nitrogen and other nutrients, and partition more dry matter into the reproductive organs rather than the vegetative ones, resulting in higher harvest index. It could be largely conducted in a single research institution.

Today the challenges we face and solutions we need are more complex, by an order of magnitude. We will need to go beyond sector silos in academia, business and government, and think more strategically and holistically about how we can cope with inter-connected issues that require integrated approaches and solutions. We need to re-think our research and innovation systems to facilitate multidisciplinary, collaborative research at a range of scales (Box 3).

Box 3 Multiple dimensions to innovation for sustainable intensification

Success will require:

Focussing on **multiple benefits** - not only higher yields and production and more nutritious foods, but also more selective use of inputs, reduced environmental impact, greater resilience, minimised emissions of greenhouse gases and improvements in natural capital.

Engaging with **multiple partners** - to ensure all benefits are considered and to utilise different approaches. Partners will include both the public and the private sectors, Civil Society Organisations (CSOs) and NGOs. Gender equity and balance is also crucial.

Utilising **multiple approaches** - often concurrently in an integrated fashion. One is the application of agricultural ecological processes (ecological intensification), another is the utilisation of modern plant and livestock breeding (genetic intensification) and a third is socio-economic intensification, that provides an enabling environment for technological and institutional innovation and technology adoption.

Working on **multiple scales** - from the individual field, to the farm, to the community, to the watershed and to whole landscapes, to ensure multiple benefits are fully realised.

Conducting research and innovation simultaneously in these different dimensions is not going to be easy and will require changes in the culture and institutions of research and innovation.

Changing Cultures and Institutions

Systems of innovation are changing rapidly and in directions that may provide an appropriate basis for innovation for sustainable intensification:

Separate to diverse: Innovation systems increasingly involve a diverse array of players and institutions. The players and stakeholders may come from companies, universities, government, and civil society, and comprise scientists and technologists, policy makers and managers as well as financial investors. Systems may also operate internationally, regionally, nationally or locally.

Linear to holistic: Innovation systems are slowly evolving from a linear transfer of technology approach, to a more holistic and integrated system, characterised by greater collaboration across disciplines and institutions, grassroots participation and a focus on development and poverty reduction.[14]

Isolated to global: Innovation is becoming increasingly global with groups from different countries bringing specific expertise to the innovation process. Scientists from around the world now collaborate with each other in order to access the best expertise, resources and partnerships.[15] In the 20th century the flow of innovation was largely one directional being driven by basic research in the developed countries, for example in the identification of genetic traits, and then applied in other geographic domains, often with mixed results. More recently, global innovation has been more directed by need and by the findings of translational research. The rise of emerging countries such as China, India and Brazil has made this flow of innovation into Africa much more multi-dimensional as they provide practical innovations, based on their own experiences and lessons learnt.

Developed to developing: Perhaps most importantly, science and research in Africa are gaining support from African countries, which are developing their own innovation systems, following the examples of Asia, and especially eastern Asia.

African Innovation Systems

In 2007 the African Union adopted Africa's Science and Technology Consolidated Plan of Action (CPA) while Pillar IV of the Comprehensive Africa Agriculture Development Programme (CAADP) aims to develop Africa's research and development capabilities and investments from governments, donors and international research institutes.[16] The last two decades have seen African countries form ministries and national agencies of science, technology and innovation. In the last year, six African countries elected an engineer as president.[17]

Despite recent progress, Africa's science, technology and innovation productivity remains very low, at less than two percent of global output. Only South Africa has an investment rate approaching anywhere near the one percent of GDP on research and development recommended by the African Union. Most African governments allocate 0.3 percent or less of their GNP to research and development compared to the three percent the majority of industrialised countries allocate.[18] This raises the question;

How can African countries accelerate the process of developing policies supportive of innovation for sustainable intensification so that they are translated into clear gains for research and development?

Most African countries have National Agricultural Research Systems (NARS), but many need to be improved, strengthened and realigned. Agricultural research systems in sub-Saharan Africa are presently fragmented into almost 400 distinct research agencies in 48 countries.[19] Comparatively ineffective NARS are characterised by such things as their small size, high level of fragmentation, lack of holistic approach to research, poor incentives, high staff turnover, lack of financial independence and weak links with farmers and industry.[20]

Building Skills for Innovation

Building Africa's capacity to develop innovative and appropriate technologies for sustainable intensification is the fundamental challenge.[21] Improvements are needed in the full spectrum of formal and informal agricultural education institutions.[22] Crucial are innovative home grown researchers able to address local challenges and in particular the needs of sustainable intensification. But gross enrolment in tertiary education in many African countries is low with only Mauritius, Cape Verde, Liberia and Nigeria exceeding 10 percent. Improving African tertiary education can significantly aid Africa's technological catch-up.[23] However, emphasis will need to be placed on higher technical training while strengthening linkages with the productive sector.

Fundamentally scientific training institutions and higher education require sustained funding and considerable reform to make this happen. This entails improving education and training opportunities through revised, updated and flexible curricula, improved facilities, partnering with industry and more aligned and strategic funding for universities. It also means providing sufficient incentives to retain home-grown talented scientists.

Probably the most challenging task is the separation between agricultural research, teaching and extension activities. While research is mostly carried out in national research institutes which do not teach, formal education is done in universities with limited research activities. One way to bring agricultural research closer to the farmers is to build a new generation of agricultural universities that combine research, teaching, extension and direct farmer engagement. This can be done by strengthening research in existing universities and upgrading research institutes by adding teaching missions to their mandate.

One example that illustrates the latter approach is efforts by Tanzania to create new research-oriented universities under the Ministry of Communication, Science and Technology (MCST). The ministry houses the Mandela Institute of African Science and Technology in Arusha. MCST is working to strengthen development-oriented research in its Mbeya University of Science and Technology and Dar es Salaam Institute of Technology. The two started as technical institutes and were later upgraded to full universities operating under MCST. This approach could be used to upgrade many agricultural institutes into a new generation of research universities operating under agriculture ministries to champion sustainable intensification with direct engagement with farmers.[24] These culture shifts in the way in which research, education and farmers work together should support greater integration of skills and expertise – but what further institutional reforms are needed?

In the rest of this report we examine more closely the challenges of working in the different dimensions of innovation for sustainable intensification, illustrated with examples.

Multiple Benefits

Developing innovations that achieve two or more benefits is going to be relatively straightforward. Many researchers are working on this challenge and have achieved excellent results (see the 2013 Montpellier Panel Report for details[25]).

Innovation	Yield increases	Other benefits
StrigAway Imazapyr Resistant (IR) maize	Yields **38-82 percent** higher than traditional maize varieties.[26]	• Damage caused to crops by herbicide is minimised. • Growth of the weed Striga controlled. • Labour requirements reduced.
Conservation agriculture	**286 interventions in 57 developing countrie**s saw an average increase in crop yield of **79 percent**.[27]	• Better and more productive soil structure. • 0.35 tons of carbon per hectare per year potential average carbon sequestered. • In some areas 71 percent decline in pesticide use. • Water use efficiency gains in rainfed areas. [28]
Microdosing	**2,000 paired-plot trials** in Zimbabwe showed a **30-50 percent increase** in grain yields.[29] **25,000 smallholder** farmers in West Africa increased millet and sorghum yields by 4**4-120 percent.**[30]	• Household incomes in West Africa increased by 50-130 percent when microdosing was combined with "warrantage" or inventory credit system.[31] • Lower, more selective, precise and targeted use of fertiliser: approximately 30 kilograms of fertiliser for every hectare which equates to one-tenth of the amount typically used on wheat, and one-twentieth of the amount used on corn in the USA. Increased nutrient use efficiency and drought tolerance. [32]
Orange-fleshed sweet potato (OFSP)	The Tainung variety in Kenya yields **three times more** than traditional varieties, is drought tolerant and **quicker to mature**.[33]	• 125g of OFSP provides primary school children with over twice the recommended daily allowance of vitamin A.[34] • For over 24,000 households in Uganda and Mozambique between 2007 and 2009, vitamin A intake by women and children doubled.[35]
Water Efficient Maize for Africa (WEMA)	Looking to increase yields **20-35 percent** under moderate drought compared to conventional varieties. New drought tolerant genes will increase yields **12-24 percent** in high drought conditions. [36]	• Building in resistance to pests such as stem borers.

Innovation	Yield increases	Other benefits
Kenya Maize Development Program (KMDP)	From 2002-2010 maize yields quadrupled from **720kg to 2880kg per 0.4 hectares**. [37] Farmers produced an additional 133,380 MT of maize in the 2009–2010 season, compared to the beginning of the project.	• Increased annual household incomes by $533 or $1.46 per day. • 105,000 farmers completed ACDI/ VOCA's training course in Farming as a Business.[38]
Purdue Improved Cowpea Storage (PICS)	Yields unaffected but post-harvest **losses significantly reduced**.	• Harvests can be stored up to a year. • Farmers can sell their cowpeas when prices are up to four times higher. • Cowpeas are safer without the use of harmful pesticides to control weevils.[39]
Zaï systems	In Burkina Faso, grain yield increased by 120 percent, equivalent to around **80,000 tons of extra grain** per year. [40]	• Improves infiltration in the soil, limits water run-off, enhances drought tolerance and protects seeds and soil from erosion.[41]
Farmer Field Schools (FFS)	In Kenya, crop production increased **80 percent** as a result of participation in FFS.	• Participants increased their incomes by 61 percent. • In Tanzania, agricultural incomes of participants increased by over 100 percent.[42] • Can be beneficial to typically marginalised groups.
Ethiopia Commodity Exchange	Since starting in 2008 the value of trade has risen from **2.7 billion birr** (approximately $143 million) to **20 billion birr** ($1.05 billion).	• Market prices are transparent, quality grades are standardized and contracts are enforced.[43]
Faidherbia	Maize under Faidherbia albida yielded an average of **five tons per hectare** (t/ha) compared to two t/ha outside the canopy.[44]	• Source of fodder and firewood. • Helps retain soil cover for enhanced fertility and protection from erosion.[45] • Nutrient levels were 42, 25 and 31 percent higher with Faidherbia canopies than without for total nitrogen, potassium, and organic carbon respectively.[46]

As we can see from the examples in Table 1, benefits, either to yield, nutrition, income or the environment, can be achieved additional to those intended or targeted. The difficulty lies in achieving the combination of benefits that meet all the requirements of sustainable intensification. Inevitably there are trade-offs. Fewer inputs often mean lower yields. Higher yields may increase greenhouse gas emissions and be at the expense of resilience. Natural capital may suffer whatever the other benefits are. The challenge is to try and find innovations that satisfy multiple benefits from the outset and that place the farmer at the centre of these intersecting circles, where the trade-offs are minimal (Figure 2).

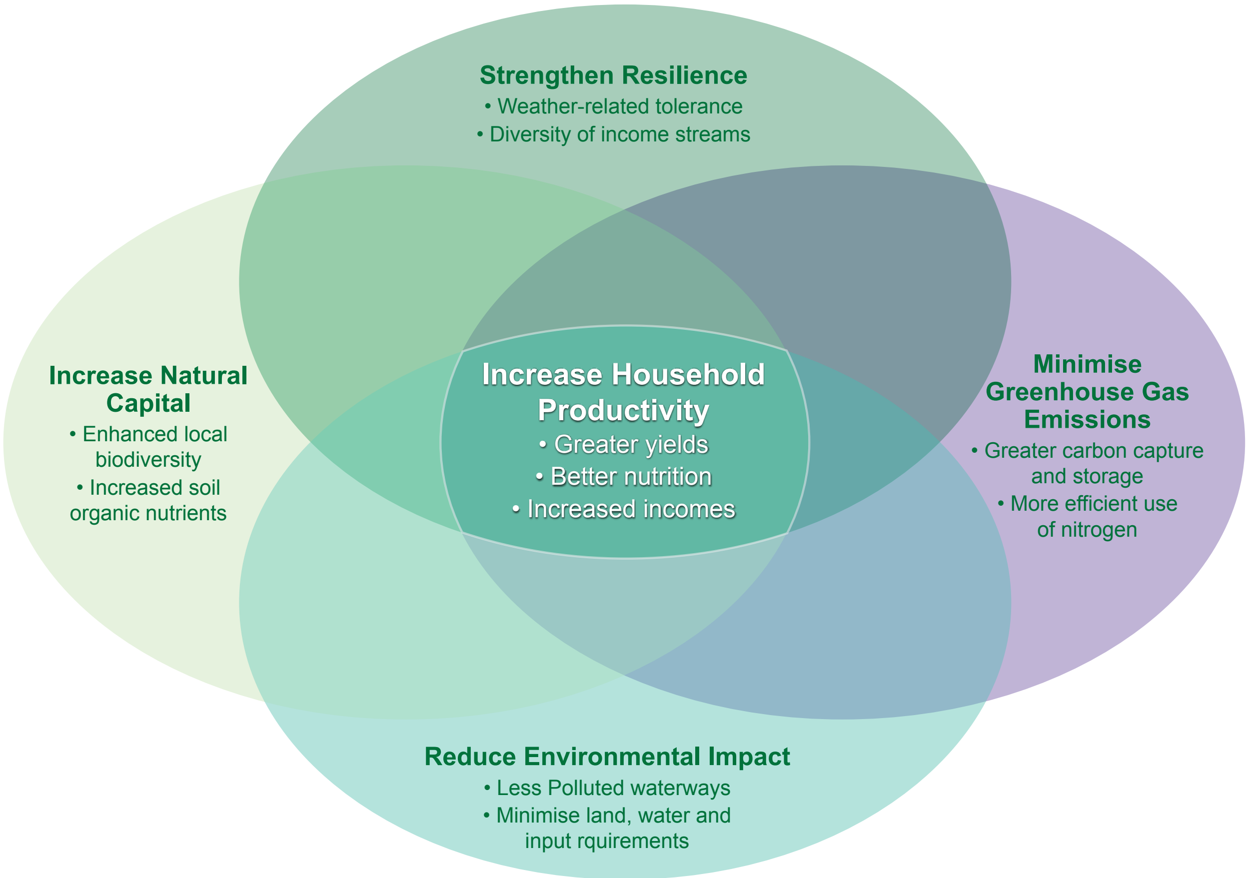

Figure 2 Innovating for multiple benefits

Achieving multiple benefits has traditionally occurred by seeking an extra benefit after an initial goal has been achieved. For example, high yields may be achieved through using a pesticide but this may not prove resilient if the pest develops resistance or it may reduce biodiversity through its impact on the environment. Part of the answer lies in ensuring the potential benefits, trade-offs and costs are identified from the outset. Since this entails bringing together different kinds of experiences and skills, it is likely to require teams of innovators drawn from different partners.

Multiple Partners

In Africa there are five sets of potential partners (Box 4).

Box 4 The key partners in agricultural innovation

- **International Agricultural Research Centres (IARCs)**, such as those of the Consortium for the CGIAR (formerly the Consultative Group on International Agricultural Research) as well as the International Centre of Insect Physiology and Ecology (ICIPE) and the World Vegetable Center. Fundamental to the success of these centres has been their ability to conduct and coordinate research at scale and to partner with national scientific and development centres to adapt research to local contexts.[47]
- **National Agricultural Research Systems (NARS)**, which are often innovative in their own right but also play a key role in adapting international research, shaping national strategies and building up domestic capacity and competences.
- **Non-Governmental Organisations (NGOs)**, which can be highly innovative, usually in terms of socio-economic intensification. Often this is at a village or community level, but some NGOs work on a larger scale playing an important role in bridging links between international and national organisations with farmers on the ground, and also facilitating productive links with the private sector especially with markets. Furthermore, they complement the efforts of the national extension services in promoting innovations for use by smallholdear farmers.[48]
- **Universities**, which can be major sources of innovation as well as innovators, working in a laboratory and the field. Some universities are outstanding in innovation others have little to contribute.
- **The Private Sector**, which, in developed countries, provides the largest share of R&D on agriculture focusing on the translational and applied components of the R&D portfolio as well as on the more commercially viable crops.49 However there is increasing interest in the private sector (both large and small) in providing innovations for smallholder agriculture in Africa.

These partners are already collaborating in an increasingly sophisticated fashion. As an example, CGIAR, since the early 2000s, has been undergoing a process of reform to bring together their separate research organisations into a collaborative and coherent whole. Their aim has been to become more responsive to global development challenges, more relevant to poor people's needs and more dynamic in their partnerships with NARS, the private sector and civil society. As of 2009, for example, CGIAR has worked to bring its 15 centres around the world into a consortium to work on 16 cross cutting research programmes, such as dryland systems, humid tropics, aquatic agriculture and climate change. Financed from a central donor fund, they aim to address agricultural issues in a more holistic fashion engaging with a wide range of external partners to help develop, manage and execute these projects. This reform also enhances the economies of scale through more joint and prudent use of both financial and human resources, avoidance of duplication, and with greater accountability to donors and clients.[50]

Some of the most effective partnerships for innovation combine the private and public sectors. The African Agricultural Technology Foundation (AATF), an African not-for-profit organisation based in Nairobi but operating throughout SSA, works to assist in partnerships between the two sectors. It is largely funded from public sources (for example, African governments, the US and UK governments and the Bill & Melinda Gates Foundation) and facilitates access to appropriate, mostly proprietary, agricultural technologies, provided free or at little cost for sustainable use by African smallholder farmers (t5).

A Striga control innovation was a response to a widespread weed problem in Africa where other, albeit partial, solutions are already being pursued. In this case the innovation was initially a product of the private sector but was facilitated by a public-private partnership. The technology is now in farmers' hands in eastern Africa. How resilient the technology is remains to be seen. The partnerships need to be extended to embrace other agroecological zones and genetic approaches.

While such partnerships can be difficult, requiring time, on-going learning, adaptability, and clear communication, they can bring together the demand-driven goals of the private sector, the social welfare goals of the public sector and the expertise of research organisations, civil society and other actors to deliver existing technology to developing countries and jumpstart the innovation process.[52]

Box 5 The control of Striga[51]

Striga (witchweed) is a devastating parasitic weed that causes yield losses ranging from 20 to 80 percent and annual damage in Africa worth around $1 billion, affecting the livelihoods of more than 100 million people. Various approaches are being tried, for example breeding crops for resistance to the weed or interplanting a legume, Desmodium, which suppresses the weed. Striga is also killed by herbicides but these often damage the crop. One such is imazapyr (IR), a very effective herbicide produced and marketed by the German based chemical company BASF.

BASF through tissue culture was able to select for maize with a mutant gene that conferred resistance to the herbicide. This was made available to one of the CGIAR institutes, the International Maize and Wheat Improvement Centre (CIMMYT). Their breeders in collaboration with the Weizmann Institute of Science, Israel and the Kenya Agricultural Research Institute (KARI) with funding from the Rockefeller Foundation were able to incorporate the IR-gene into African maize varieties and adapt them for agroecological regions in Africa where Striga is endemic.

The herbicide-resistant maize, known as StrigAway is coated with low doses of the herbicide, about 30g imazapyr per hectare – a minuscule amount. As the StrigAway maize germinates, it absorbs some of the herbicide used in coating it. The germinating maize stimulates Striga to germinate and as it attaches to the maize root, it is killed before it can cause any damage.

StrigAway hybrid seed is now commercially available to farmers in Kenya and Tanzania. The use of IR-Maize technology to control Striga leads to yields 38 to 82 percent higher than those currently obtained from traditional maize varieties.

There are several challenges to such partnerships:

1. **Protecting Intellectual Property rights.** Germplasm may be donated to the project but this can be a challenge when that germplasm has been developed over years of research and at considerable cost.
2. **Liability and regulatory structures.** Regulatory frameworks and the ability to develop and enact them can be missing in developing country partners. They are essential to minimise the risks for both the investors and the end user. Partnerships can help develop strong regulatory frameworks within developing countries.
3. **Neutral organising bodies.** As all partners will have their own mandates, a neutral party, often an NGO, can help organise and manage expectations.
4. **Stakeholder consultation.** If a new technology is to be adopted consultation with stakeholders and end users is critical. Public-private-community partnerships can help ensure approaches address local needs.
5. **Partnerships** developed in response to a specific problem or opportunity must now take a broader view to encompass the gamut of sustainable intensification goals.[53]

Regional Organisations

One approach to bringing different disciplines, skills and experiences together is to create regional networks, which can pool resources and facilitate knowledge exchange and collaboration.

An example of a FARA initiative is the Sub-Saharan Africa Challenge Programme (SSA-CP), a grouping of 32 multi-stakeholder innovation platforms. Implemented by FARA for the CGIAR and backed by funding of $26 million for the period 2006-2010/12, it aims to test and validate a more holistic and integrated approach to agricultural innovation. The Programme is being implemented at three Pilot Learning Sites covering 8 countries in ASARECA, West and CORAF/WECARD and Southern Africa Development Community (SADC-FANR) sub-regions. Early lessons show that communities with access to innovation platforms achieved greater poverty reduction than those communities without or with conventional extension approaches.[56]

Box 6 FARA and regional R&D

The Forum for Agricultural Research in Africa (FARA) has a mandate from the African Union Commission (AUC) to serve as its technical arm for agricultural research for development and has been designated by the AU NEPAD Planning and Coordination Agency as the lead institution for implementation of CAADP Pillar IV on agricultural research, technology dissemination and adoption. FARA derives additional strength from its broad-based stakeholders and its constituent sub-regional research organisations (SROs) and other key CAADP Pillar IV institutions.

FARA developed the Framework for African Agricultural Productivity (FAAP) which it uses as a road map to success. 54The FAAP aims to achieve evolution and reform of agricultural institutions and services; an increase in the scale of Africa's investment; and an aligned and coordinated support to agricultural research for development. The FAAP advocates for integrating agricultural research, advisory services, education and training aspects of Pillar IV in CAADP country and regional agriculture and food security investment plans.

The following FAAP principles provide the critical elements that guide effective implementation of CAADP Pillar IV at country and regional levels.[55]

- Empowerment of end users to ensure their meaningful participation in CAADP country processes; in particular, setting priorities and work programmes for research, extension, and training to ensure their relevance.
- Planned subsidiarity to devolve responsibility for implementation of agricultural research, extension, and training activities to the lowest appropriate level of aggregation (local, national and regional).
- Pluralism in the delivery of agricultural research, extension, and training services so that diverse skills and strengths of a broad range of service providers (e.g. universities, NGOs, public and the private sectors) can contribute to publicly supported agricultural productivity operations.
- Use of evidence-based approaches in the CAADP process with emphasis on data analysis, including economic factors and market orientation in policy development, priority setting and strategic planning for agricultural research, extension, and training.
- Integration of agricultural research with extension services, the private sector, training, capacity building, and education programmes to respond in a holistic manner to the needs and opportunities for innovation in the sector.
- Explicit incorporation of sustainability criteria in evaluation of public investments in agricultural productivity and innovation programmes (fiscal, economic, social and environmental).
- Systematic utilisation of improved management information systems, in particular for planning, financial management, reporting and monitoring and evaluation.
- Introduction of cost sharing with end users, according to their capacity to pay, to increase their stake in the efficiency of service provision and to improve financial sustainability.
- Integration of gender considerations at all levels, including farmers and farmer organisations, the private sector, public institutions, researchers and extension staff.
- Applying the principles of FAAP to Pillar IV implementation at country and regional levels will ensure that investments in the CAADP programmes lead to increased agricultural productivity and therefore contribute to the CAADP 6 percent annual growth of agriculture.

Understanding how different institutions and their regional groupings contribute to the process and outcomes of innovation is critical. Only through facilitating partnerships between these stakeholders will multiple approaches be taken to achieve multiple benefits at scale.

Multiple Approaches

As the Striga control example demonstrates, innovation for sustainable intensification can be approached in a number of ways. As we argued in the 2013 Montpellier Panel Report these approaches can be broadly grouped in three categories:

Agroecology - based on the application of ecological principles and practices

Genetics - applying the tools of modern cellular and molecular biology

Socio-economics - utilising social, economic and institutional interventions

Each of these can produce multiple benefits including greater resilience and sustainability, improved national capital and reduced greenhouse gas emissions, but they do it in different ways and can be used in combination to maximise the number of benefits. Below we provide examples of innovations across the three categories detailing the process of their development and the key partners involved.

Agroecology

Ecological innovation depends on identifying appropriate ecological principles and practices. These include the processes of competition between crop plants and between crops and weeds, herbivory of crops by pests, predation of pests by their natural enemies and the decay of organic matter.

Conservation Farming

One example of the incorporation of organic matter to improve soil structure and fertility is the practice of conservation farming (Box 7). This is an instance where the innovators are difficult to identify. They include CGIAR institutes, NARS, NGOs and countless farmers themselves. There is now an FAO Community of Practice for Conservation Agriculture website that keeps practitioners from around the world up to date with developments.[57]

Box 7 Conservation agriculture

Conservation agriculture is a system of crop farming that was developed in response to the Dust Bowl of the 1930s in the US Great Plains that resulted from excessive tillage. Farmers began experimenting with mulching to control weeds without tilling the soil.

With the development of selective herbicides, the practice began to spread across North and South America and, to a lesser degree, in Europe. Farmers in Iowa, for example, growing maize (corn) on their deep, highly organic long grass prairie soil do not cultivate their land, but do apply herbicides to control the weeds, which increases environmental contamination and reduces resilience and sustainability.

Conservation agriculture is based on three principles, designed to enhance biodiversity above and below ground:

Minimum or no mechanical soil disturbance throughout the entire crop rotation,

Permanent organic soil cover,

Diversified crop rotations in case of annual crops or plant associations in case of perennial crops.[58]

These elements are now being applied in many parts of Africa, by NARS and by NGOs. In these circumstances weeding is still a challenge but is being tackled relatively successfully by hand weeding, without the use of herbicides.

In general, yields under conservation agriculture are significantly higher than under conventional farming in large part due to improved soil and water conservation (Table 1).

Microdosing

While conservation agriculture has an excellent effect on soil structure and function it may not provide sufficient nutrients especially on poor soils or degraded lands. Under these conditions, the challenge is to apply inorganic fertilisers but in amounts that are not too costly and are not damaging to the environment. One such approach is known as microdosing (Box 8). Here the innovation is led by a CGIAR institute, although it involves partnerships with other institutes, with NARS and with private fertiliser companies.

Box 8 Microdosing

Throughout the 1980s and 1990s, a CGIAR institute, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was developing earlier maturing varieties of sorghum and pearl millet, both to improve productivity and reduce the risks of drought in southern Africa. Although farmers liked the new varieties there were limited gains in crop yields and productivity. The soils had inherently low fertility and farmers were reluctant to risk investments in fertiliser, particularly at the recommended rates that are far beyond the capabilities of all but the wealthiest of households. In southern Zimbabwe less than five percent of farmers commonly used fertiliser.

In 1999, ICRISAT began a series of workshops with CIMMYT using simulation models that showed that doses of fertiliser of only nine kg/ha could be very productive. This was confirmed by on-farm trials (funded by DFID and the European Commission) where farmers applied the fertiliser using a beer bottle cap, 4.5 g of ammonium nitrate for every three plants.

Subsequently ICRISAT in collaboration with other IARCs, NARS and employing farmers as experimenters established the viability of the approach of using microdoses of fertiliser on each hill of planted seeds. In maize fields microdosing involves the use of a soda bottle cap to apply fertiliser to holes before seeds are planted. This precise technique equates to using only four kg/ha of phosphorus, the key limiting nutrient, significantly less than used in Europe and North America, but still very effective.

By correcting soil nutrient deficiencies with tiny doses, root systems develop and capture more water.59 ICRISAT is now experimenting with small tablets of fertiliser and fertiliser companies have initiated an associated set of programmes for small pack fertiliser sales and are promoting the microdosing technology.

Microdosing has contributed an estimated 70,000 tons of additional grain, valued at almost US$12 million, to the food security of poor farmers in drought-prone regions of Africa.


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Genetics

Farmers have, for thousands of years, sought to shape the genotype and, as a result, the physical characteristics of crop varieties and livestock breeds. Today, alongside conventional breeding, biotechnology is a powerful and rapidly advancing technology that allows scientists to develop greater yielding, more nutritious and resilient crops.

Genes for Vitamin A

Lack of vitamin A in the diets of children under the age of five renders them prone to a form of blindness and makes them less resistant to the effects of diarrhoea, a leading cause of death in the developing world. Often vitamin A is absent in many staple foods, such as the sweet potato that is commonly grown throughout Africa. In Mozambique a programme of conventional plant breeding has resulted in new varieties of sweet potato rich in vitamin A.

Here innovation is led by an African scientist working with a NARS. The success has been a product of first class applied breeding, coupled with an effective distribution programme of the planting material and a very lively publicity campaign to inform farmers of the benefits of the new sweet potatoes.

Box 9 Breeding for vitamin A in sweet potatoes

In Mozambique sweet potatoes grow well on marginal land and can be left in the soil and harvested when other crops are not available. Traditionally white-fleshed varieties, rich in carbohydrates but lacking in beta-carotene, the precursor of vitamin A, are grown.

In the 1990s a team of scientists began a programme of breeding for beta-carotene rich sweet potatoes. It was led by Dr Maria Andrade who was employed by the International Potato Centre (CIP) in Peru but based at the Mozambiquan NARS known as the National Institute for Agronomic Investigation (INIA).

First they introduced orange-fleshed varieties from the USA that were rich in beta-carotene and then they crossed them with local varieties. Subsequently the team found a way of accelerating the breeding programme by rapidly multiplying breeding lines for assessment at numerous sites at the same time and by developing molecular markers to speed up the process of identifying beneficial traits.60 This halved the length of time needed to produce new varieties from eight to four years. By 2011, 15 new drought tolerant varieties were released capable of producing up to 15 t/ha.


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Distribution of the varieties is accomplished through private farmers who multiply the material and sell them on to small farmers. Adoption rates are high, particularly among women. The material is now being distributed to NARS in other African countries who are crossing the orange-fleshed varieties with their local varieties.

Drought Tolerance

Another example of a genetic approach is the development of Water Efficient Maize for Africa (WEMA), specifically designed to cope with the increasing drought conditions brought about by climate change in many parts of Africa.

Maize is the most widely grown staple crop in Africa – more than 300 million Africans depend on it as their main food source but it is severely affected by drought, weeds, pests and diseases. Drought in particular can lead to unpredictable and low yields, and at worst, complete crop failure. (Box 10).

In this instance leadership has come from a public-private partnership, facilitated by AATF, described earlier, who persuaded the life science company Monsanto to donate some of their drought tolerant genetic material for use by African plant breeders free of royalties. The material is now being bred into African hybrids by NARS and is about to enter national trials before being passed on to private seed companies.

In a second phase of the project a new genetic trait is being introduced into these varieties. The trait can confer tolerance to stress of various kinds, including cold, heat, and lack of moisture. The product of the gene helps to repair misfolded proteins caused by stress and so the plant recovers more quickly. This so-called chaperone gene is found in bacterial RNA and has been transferred to maize by Monsanto and donated royalty free under the AATF programme. Plants with the gene show a 12 to 24 percent increase in growth in high- drought situations compared with plants without the gene. Field trials are now being carried out in Africa.


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Box 10 Water Efficient Maize for Africa (WEMA)

Launched in 2008, WEMA, led by AATF, is developing new drought-tolerant maize varieties initially through conventional breeding speeded up by marker-assisted selection. Drought tolerance can be achieved through the combination of a variety of traits: deeper root systems, reduced leaf area and greater retention of water in the cells during drought periods.

Germplasm with traits such as these has been donated by Monsanto for further breeding by CIMMYT. The project is a partnership between AATF, Monsanto, and NARS and is funded by the Bill & Melinda Gates Foundation, Howard G. Buffett Foundation and USAID.[61]

Target countries include Kenya, Mozambique, South Africa, Uganda and Tanzania, where NARS are crossing this material into local varieties. Maize varieties being developed aim to increase yields by 20 to 35 percent under moderate drought conditions in comparison to current varieties. The improvements could produce an estimated two million additional tons of food enough to feed 14 to 21 million people. The project is now being expanded to include the development of maize varieties resistant to stem borers.

Socio-Economics

Social, economic and institutional interventions are crucial to innovation for sustainable intensification because they ensure that higher yields and production result in real benefits to farmers and they provide much of the enabling environment in which innovation can flourish and be resilient and sustainable.

It has been increasingly recognised in recent years that flourishing, efficient and fair markets, both for inputs and produce, are crucial to intensification, In a recent Agriculture for Impact publication '8 views for the G8,' the authors comment that 'We have seen firsthand the power that providing enterprise skills and market access can have in empowering smallholder farmers to boost their production, improve their nutrition and increase their incomes – when managed effectively and coupled with appropriate safety nets.'[62]

A very high proportion of African smallholder farmers have no or very weak links to markets. For this to improve this paper argues that farmers need five key interventions, each requiring innovation in social, economic and institutional arenas (Box 11).

Box 11 Practical and policy interventions to improve farmer links to markets[63]

1. Facilitate access to high-quality seed, fertiliser and other inputs, agribusiness finance and credit tailored to smallholder farmers, storage materials that are practical and low-cost, and professional advice.
2. Build the institutional capacity of farmers to allow them to self-organise at sufficient scale and complexity and thus benefit from collectively accessing credit, input and output markets.
3. Deliver market information on quality standards, prices and risks as well as support and advice to assist fledgling small and medium enterprises (SMEs) and farmer enterprises to increase in size, impact and competitiveness.
4. Increase public sector investment in rural infrastructure, research and extension to improve physical access to inputs, services and markets and virtual access to information, for example on agroclimatic risks. National agricultural research and extension services, traditionally used to disseminate information to farmers, are also underfunded.
5. Provide a stable policy environment to avoid unpredictable policy shifts, nontransparent regulation enforcement, weak contract enforcement mechanisms, restrictive policy environments and discordant regional policies which hinder trade across countries.

Innovative Markets

As with other approaches, public-private partnerships can be instrumental in generating appropriate market innovations (Box 12). One example is being developed by a long established NGO, ACDI/VOCA, with public funding from USAID and involving a wide array of private sector players.

Interventions to supply farmers with the resources they need to be productive, innovative and to sustainably intensify are critical. But there are innumerable potential points for innovation along the value chain from field to fork – better methods of harvesting and storage, processing and quality control, improved links to markets, and selling strategies. By way of example we will focus here on food waste and its prevention.

Box 12 Kenya Maize Development Programme

ACDI/VOCA has a strong background in working with agribusiness. Their experience is that scale limitations can make food production a poverty trap for many smallholders. Their approach is to apply a push/pull strategy to support smallholders' entry into increasingly profitable value chains. "Push" interventions directly address socioeconomic constraints to market engagement while "pull" strategies foster increased profits through such things as higher-value crop mixes.

The Kenya Maize Development Programme (KMDP), implemented by ACDI/VOCA, works closely with the Cereal Growers Association of Kenya, Farm Input Promotions Africa Ltd and the Kenya Agricultural Commodity Exchange. In collaboration with the Ministry of Agriculture, KMDP established a network of 160,000 private sector-sponsored demonstration plots and helped mobile phone companies see the business case for disseminating market price information, weather alerts and extension messages via SMS for the price of a local call.

KMDP facilitated linkages between farmer organisations and agribusinesses through agricultural fairs and promotional events, and stimulated incentives for farmer organisations to provide improved services to members. From 2002 to 2011 KMDP quadrupled smallholder farmer maize yields from 720 kg to 2,880 kg per 0.4 hectares while reducing harmful environmental practices. The increase in marketable surplus resulted in increased earnings of $208 million for 370,000 smallholder farmers, a third of them women.[64]

Reduced Waste

According to the UN, a third of food in the world gets wasted and an estimated 14 percent of the world's CO2 emissions are caused by food waste. In Sub-Saharan Africa, where food goes to waste primarily at the post-harvest stage, losses are estimated to be worth US$4 billion per year, equivalent to feeding some 48 million people. Inefficient processing and drying, poor storage and insufficient infrastructure are key factors in food waste in Africa. Innovations along the supply chain which support farmers and investments in infrastructure and transportation could help to reduce the amount of food loss and waste (Box 13).[65]

The following innovation is an example of an invention pioneered at a US university that, with sufficient funding from a major Foundation, has been able to ensure implementation and acceptability through a wide range of local government, NGO and private sector partners.

Agroecological, genetic and socio-economic innovation will all be required to achieve the numerous goals of sustainable intensification. It is unlikely a single technology will achieve all the goals of sustainable intensification. Rather we will need all forms of innovation in various combinations. For example, growing drought tolerant, pest resistant maize varieties, under the shade of nutrient boosting Faidherbia trees, used with microdosing to help retain soil nutrients, and with zaï to conserve water. Additionally farmers can be linked to knowledge sources and banking services through their phones and to markets through partnerships with public, private and civil society actors. Thus in combining innovations, be they ecological, genetic or socio-economic, we can begin to imagine the reality of sustainable intensification. But for it to have a significant impact the innovations, single or combined, have to be taken to scale.

Box 13 Small-scale storage innovation[66]

Fifty percent of cowpeas in Africa, an important nutrient-rich food source in parts of West and Central Africa, are lost each year to pest damage once stored after harvest.

Larry Murdock, a professor of entomology, at Purdue University in the US has been researching pest-management techniques in Africa since 1987. Recently he has developed a technology, under the Purdue Improved Cowpea Storage (PICS) project, that uses ordinary materials manufactured in Africa to almost completely control the insects in stored grain without the use of chemicals.

Under the system, farmers place their cowpeas in a polyethylene bag and seal it. That bag is surrounded by another, identical bag and sealed, and the double-bagged crop is held within a third, woven polypropylene bag. The woven bag gives strength to the unit and allows the bag to be handled without bursting the inner polyethylene bags. The inner bags deprive the insects of oxygen and the water insects make with that oxygen. The insects eventually die due to desiccation.

The PICS project, which began in 2007, found that hermetic storage of the cowpea, known in the US as the black-eyed pea, was practical and profitable for African farmers and ensured a supply of the nutritious legume for many months after harvest. Without the storage, farmers have to sell their cowpeas immediately after harvest when the price is at its lowest or treat them with sometimes dangerous and costly insecticides.

Critical to the innovation's success is the creation of a supply chain of local manufacturers making and marketing the bag. The project is being implemented in 10 different countries in West and Central Africa, including Nigeria, Niger, Burkina Faso, Ghana, Mali, Senegal, Cameroon, Benin, Togo and Chad. The plans are to disseminate the triple-layer sack technology in 28,000 villages in West and Central Africa.


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The project, funded by the Bill & Melinda Gates Foundation is a joint collaborative effort involving various partners including the CGIAR, various NARS, international and local development NGOs, government agencies, local NGOs, private entrepreneurs, and farmers.

At Purdue University, four departments are involved: Agricultural Economics, Entomology, Food Science, and Youth Development and Agricultural Education.

Multiple Scales

In some respects taking innovation for sustainable intensification to scale is the most difficult challenge of all. Needless to say it is crucial if the world is to be fed and if the world's environment and its natural capital is to be protected and enhanced, and if global warming is to be kept in check.

It is common to find innovation in a field or on a farm, but far too often neighbours do not adopt the innovation and there is little going to scale even at the community or district level let alone nationally or regionally.

Farmer Innovation

Farmers are by nature resourceful and adaptable, and local innovation can make a significant contribution to agricultural development. In a survey of 505 farmers in western and central Kenya and the Usambora Mountains in Tanzania between 1998 and 2000, farmers listed 1614 innovations they had initiated in the previous 12 months.[67]

Many of these innovations address the needs of sustainable intensification. They are often generated through necessity, the need to tackle a pest or disease problem, declining yields or water shortages and result in more efficient use of inputs and significant contributions to natural capital.

Farmers are also an essential partner, playing a critical role in the new paradigm of sustainable intensification, just as they did in the western agricultural revolutions of the 18th and 19th centuries, not only as collaborators to, and beneficiaries of, the research agenda but as innovators themselves. Engagement with smallholder farmers is key to improving agricultural productivity while maintaining relevance and cultural acceptability.

The Zaï System

Box 14 The zaï system[69]

The technique, known as zaï in the local language of northern Burkina Faso originated in Mali among farmers in the Djenné Circle and was adopted and improved in northern Burkina Faso by farmers after the drought of the 1980's.

Farmers apply the zaï technique to recover crusted land. A zaï is a planting pit with a diameter of 20 to 40 cm and a depth of 10 to 20 cm - the dimensions vary according to the type of soil. Pits are dug during the dry season from November until May and the number of zaï pits per hectare varies from 12,000 to 25,000. After digging the pits, organic matter is added at an average, recommended rate of 0.6 kg/pit and, after the first rainfall, the matter is covered with a thin layer of soil and seeds, typically millet or sorghum, placed in the middle of the pit.

The excavated earth is ridged around the demi-circle to improve the water retention capacity of the pit. Zaï fulfils three functions: soil and water conservation and erosion control for encrusted soils. It serves to: (i) capture rain and surface/ run-off water; (ii) protect seeds and organic matter against being washed away; (iii) concentrate nutrient and water availability at the beginning of the rainy season; and (iv) increase yields.

The system conforms in many respects to the requirements of sustainable intensification. Yields are higher. For example, in Burkina Faso, grain yield has increased by 120 percent equivalent to around 80,000 tons of extra grain per year.70 If fertilisers are used, the labour in the first year is quite high, but thereafter farmers may reuse the holes or dig more between the existing ones. A key benefit is the building up of natural capital by improving soil structure. There may also be a reduction in CO_2 emissions.[71]

Dissemination of the innovation has been supported by the World Bank programme on Indigenous Knowledge for Development with the Association pour la Vulgarisation et l'Appui aux Producteurs Agro-écologistes au Sahel (AVAPAS) providing day-to-day guidance to farmers. Other local development actors (administration, extension workers, local authorities, community leaders) have supported the initiative to ensure sustainability.

As is widely recognised, inappropriate farming practices can lead to soil erosion, a loss of soil fertility and poor water retention, resulting in low, unreliable yields.[68] In the dry, sun-baked, encrusted soils of north-western Burkina Faso farmers have developed the zaï system as a novel method for conserving water (Box 14).

This appears to be a long-standing traditional method of soil and water conservation developed probably long ago. It was, however, seen to be of relevance to the drought stricken lands of Burkina Faso and transferred there with World Bank funding and considerable engagement by farmers, community leaders, NGOs and extension agents.

The Role of Extension

The conventional method of transferring knowledge and experience amongst farmers and so facilitating the scaling of innovations has been the extension service, typically a government institution under the Ministry of Agriculture. However, such services were seen as costly and there was a widespread belief that the private sector could provide the service more efficiently. As a consequence, funding for extension services declined in the 1990s following structural adjustment programmes, and private sector and NGOs assumed a greater role in providing extension services.[72]

In addition, extension services have seen significant modifications in the way in which they are provided. Early approaches favoured a top-down model where farmers were passive recipients of the 'knowledge' transferred by extension agents. Over time, extension training has broadened in scope and is more relevant to the needs of sustainable intensification, covering issues such as nutrition as well as more typical topics such as integrated pest management (Box 15). It has also been built on participatory models, which treat farmers as more dynamic participants and sources of knowledge, or even as the trainers themselves.[73]

The innovation of Farmer Field Schools owes much to a skilled, experienced and highly energetic entrepreneur who has secured considerable support for this work initially in Southeast Asia and more recently in Africa with NARS and some NGOs playing key roles in their development.

Box 15 Farmer Field Schools[74]

Farmer Field Schools (FFS) are a way for communities to try out a new technique or technology (e.g. new seeds, inputs or farming methods) and adapt it to their situations. The FFS approach came about as a means of engaging farmers in participatory training activities to learn about integrated pest management (IPM). Developed in the Philippines by a leading FAO innovator, Peter Kenmore, it grew over a decade of experimentation starting in the 1970s. It proved very popular among smallholder farmers in South and Southeast Asia, where an estimated two million farmers were trained in the 1990s alone.

As arenas for participatory training and learning, FFS enable local farmers to learn about techniques relevant to the problems they face. In Africa, this approach was first implemented in Ghana in 1995 and there are currently 12 African countries where programmes are running or being piloted with costs per farmer between $9 and $35.

In a study of the participation and effects of FFS in Kenya, Uganda and Tanzania, females constituted 50 percent of participants and participation in the schools increased income by 61 percent.[75] In Kenya, crop production increased by 80 percent as a result, and in Tanzania agricultural incomes increased over 100 percent.[76] FFS were shown to be especially beneficial to women, people with low literacy levels and farmers with medium sized land holdings.

The teachers and facilitators of FFS are often local farmers, who have attended schools and then gone on to organise their own FFS to pass on their learning. Farmer to farmer learning is an effective means of disseminating knowledge and technology, whereby farmer teachers provide demonstration plots of a new innovation working on their land to promote wider acceptance.

Reaching Farmers

The challenge of reaching farmers over often large and remote areas has also generated interest in the potential of new technologies to help foster linkages.

Information and Communications Technologies (ICTs) are important for getting innovation to scale and helping deliver knowledge to rural smallholder farmers over a wide area. The use of mobile phones and the internet has enabled farmers to have on-demand access to tailored information, to avoid lengthy gaps between contacts with an extension agent, and to help break geographical and gender boundaries. Apart from information delivery, ICT is also being used to provide crucial services such as banking which, while being an innovation in its own right, similarly brings innovation to farmers at a large scale. The continent's mobile banking revolution started in Kenya in 2007 where the principle innovator has been the private sector (Box 16).

Since 2000 sub-Saharan Africa's mobile market has grown by 44 percent a year on average and is now the world's fastest growing, and the applications for mobile technology seem endless.[80]

New applications of ICT can enable ideas and innovations to spread rapidly while helping farmers to save and invest in their farms. Mobile banking has been so successful because it has been designed with the end user, people who are disconnected from formal institutions, in mind. In many developing countries, only between one- and two-fifths of the rural population are significant participants in formal agricultural markets despite markets being critical for accessing technologies, along with other inputs, and selling harvests.[81]

Box 16 Mobile banking[77]

Mobile banking in Africa began when Safaricom launched M-Pesa, a service that aimed to facilitate rural women repaying micro-loans. Its application as a tool for sending, receiving and saving money was far greater, and the M-Pesa model has now spread to Rwanda, South Africa, Tanzania and Uganda. Mobile banking now exists in 33 African countries and more people in Africa use their mobile phone to bank than in any other region in the world. 70 percent of the world's registered 81.8 million mobile money customers are in sub-Saharan Africa and more Africans have access to a mobile phone than to clean drinking water.[78]

The success of mobile banking lies in its ability to link rural and often remote people with formal banking institutions to which they would otherwise not have access. In Nigeria, as of 2013, over 110 million active mobile lines exist compared to less than 25 million bank accounts. Remote banking is also cheaper by around 19 percent.[79]

National Markets

The biggest challenge in going to scale is to bring not only market information to smallholders but to help them connect to national markets, since this will significantly increase their returns. Local markets are now springing up in many parts of rural Africa. The challenge is to link them to national markets so that farmers even in remote places can get good prices. ICT has a major role to play here as do Farmer Organisations, which through collective action can strengthen smallholder farmers' positions in markets and policy, but an especially innovative initiative has been the creation of national commodity exchanges (Box 17).

This innovation owes much to the energy and entrepreneurship of an Ethiopian diaspora resident in the US who returned to her homeland to develop the first commodity exchange of its kind in Africa. As a pilot project of IFPRI it attracted multi-donor support but most significantly the full support of the Ethiopian government.

Box 17 The Ethiopian Commodity Exchange (ECX)[82]

The ECX was established in April 2008 as a national marketplace through which all actors in the value chain— farmers, traders, processors, and retailers— can come together to trade domestic and major export earning commodities (coffee, sesame, haricot beans, teff, wheat, and maize). The first of its kind in Africa, its inception was led by a member of the Ethiopian diaspora, Eleni Gabre-Madhin, who started it as a senior researcher of IFPRI, and then led the ECX organization.

The ECX provides market data, clearly defined rules of trading and dispute settlement procedures, a central trading system with remote electronic trading centers, storage and warehouse delivery centers, product grade certification and quality assurance, and clearing banks. These lower the costs and risks associated with traditional trading.

As of 2013 it has over 300 members and 12,000 clients and it reaches some 2.4 million smallholders. It has traded over $5 billion of commodity value and the grading, handling, storing, trading, and delivery of 5.7 million bags of produce a year.

Combining Benefits at Scale

So far we have discussed benefits that accrue to smallholder farmers, in the short and medium term. But sustainable innovation is also about benefits to the larger community, in the medium to long term. How we bring these about is still not clear (Box 18).

Conservation agriculture also has much broader benefits for resilience, natural capital and climate change across the wider landscape, creating a more stable and sustainable farming system.

For example:

- **Soil loss** does not exceed rates of soil formation;
- **Soil fertility** and soil structure are maintained or enhanced;
- **Biodiversity** is maintained or enhanced;
- **Downstream effects** of run-off or leaching do not impair water quality;
- **Rainfall** is managed to avoid excessive runoff;
- **Emissions** of greenhouse gases are reduced;
- **Food production** levels are maintained or enhanced.[83]

Box 18 Conservation agriculture

We have described the basic benefits of conservation farming above (Box 7). But it is clear that it is appropriate in many different circumstances and for a variety of benefits.

For example, experiments in western Zambia, conducted by partnerships between local government bodies and the NGO Concern Worldwide, are investigating the use of conservation agriculture as a replacement for the traditional long fallow system of the region. Traditionally, the woodland is felled and burned before being ploughed and sown to maize. Crops are grown for only a couple of years, and the land then takes several decades to return to a state where it can be felled and burned again. The alternative, conservation agriculture, produces higher yields and despite the need to hoe weeds, the labour is much less than in the conventional systems. In addition to building carbon in the cropped soil, such a system should allow tree or shrub cover to remain unburned more or less permanently, so increasing carbon sequestration and maintaining soil carbon levels, and thus creating a more stable and sustainable farming system.

As with all innovations there are trade-offs. Conservation agriculture may not be suitable for every environment and yield and labour-saving benefits may not be realised for some time, making it less attractive to farmers who require immediate gains. To reduce trade-offs we must take a more holistic view, say combining conservation agriculture, where appropriate, with crops bred to be higher-yielding, with integrated pest management and with programmes to facilitate smallholder farmer access to herbicides.

Reducing trade-offs and mobilising resources in order to go to scale will require an appropriate enabling environment and the participation of many stakeholders. It will, as with innovation in general, no doubt be a learning process that warrants greater investigation into the means by which we can take innovations to scale and in identifying the policies that support this.

Conclusion

We believe that innovation for sustainable intensification is going to be essential if food and nutrition security is to be achieved in Africa. It is a significant challenge. Inevitably in a briefing paper of this nature we raise more questions than we answer.

Most important it is clear that we will need partnerships and research organisations to embrace the goal of sustainable intensification; we will need fair and efficient markets; we will need systems of education that produce the African innovators of tomorrow; for farmer innovation to be embedded in formal processes, and most importantly we need new technologies to address a wide range of food and nutrition security and environmental challenges in a variety of contexts.

But for this to happen we have to develop appropriate cultures and institutions for innovation. In turn we will need supportive government policies and leadership – creating enabling environments fit for the purpose of innovation for sustainable intensification.

We believe the questions raised in this paper provide the basis of an agenda for research, dialogue and policy making as we go forward.

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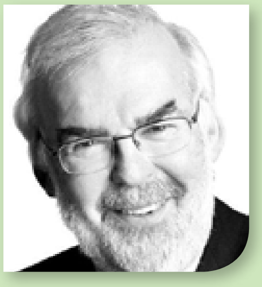
About the Montpellier Panel

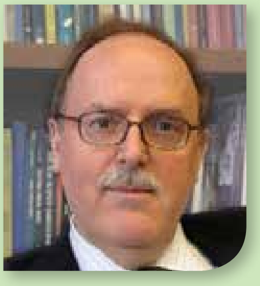
All Panel members serve in a personal capacity.

Gordon Conway (Chair)
Professor of International Development, Agriculture for Impact, Imperial College London

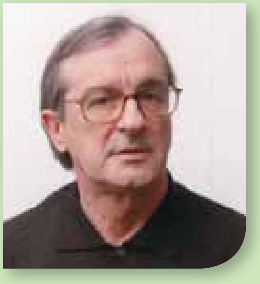
Camilla Toulmin (Deputy Chair)
Director, International Institute for Environment and Development (IIED)



Tom Arnold
Chair of the Convention of the Irish Constitution and former Chief Executive, Concern Worldwide

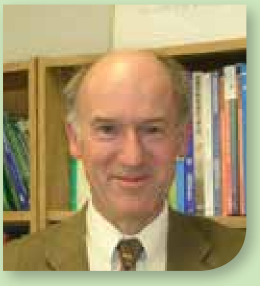


Joachim von Braun
Director, Department of Economic and Technological Change, Center for Development Research, University of Bonn

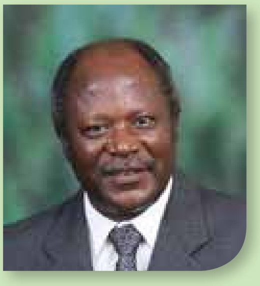


Henri Carsalade
Chair of the ICARDA Board of Trustees and President of Agropolis Foundation

Louise Fresco
Professor, University of Amsterdam



Peter Hazell
Visiting Professor, Imperial College London

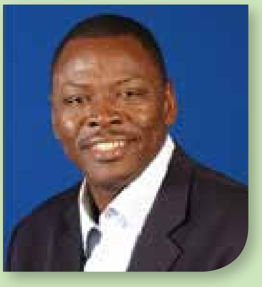


Namanga Ngongi
Former President, Alliance for a Green Revolution in Africa (AGRA)

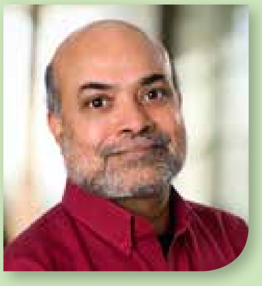
David Radcliffe
Senior Advisor, Agricultural Research for Development

DG Development and Cooperation, European Commission

Lindiwe Majele Sibanda
Chief Executive, Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN)



Ramadjita Tabo
Deputy Executive Director, Forum for Agricultural Research in Africa (FARA)



Prabhu Pingali
Deputy Director, Agricultural Development, Bill & Melinda Gates Foundation (Observer)

Imperial College London

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