Sustainable Intensification:
A New Paradigm for African Agriculture

A 2013 Montpellier Panel Report

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Our Vision

In a world where natural resources are in short supply at the same time as almost one in four people in Africa suffer from chronic hunger, the Montpellier Panel believes that a new paradigm to tackle food insecurity is urgently needed.

Sustainable Intensification offers a practical pathway towards the goal of producing more food with less impact on the environment, intensifying food production while ensuring the natural resource base on which agriculture depends is sustained, and indeed improved, for future generations.

In sub-Saharan Africa (SSA) a rapidly growing population and increasing food demand, alongside scarcities in resources such as land, water and soil fertility, are compounded by stagnant yields for some crops and alarmingly high rates of hunger and malnutrition. Many of the farming systems in Africa are far from their productive potential while accelerated economic growth in Africa now offers demand-side opportunities for agriculture.

Intensification of production can take many forms. The current model has served us well for a hundred years or more, including its underpinning of the Green Revolution of the 1960s and 1970s that kept food production in pace with population growth. But the context has radically changed. Our current food crisis – recurrent food prices spikes, the existence of about a billion chronically hungry and the need to feed a growing, more prosperous population in the face of threats from climate change – is not a transient affair. Moreover, conventional intensification is not a viable solution if it comes at the expense of the environmental and social resources on which it depends. We need radical measures and new paradigms.

One such paradigm is Sustainable Intensification. This pathway strives to utilise the existing land to produce greater yields, better nutrition and higher net incomes while reducing over reliance on pesticides and fertilisers and lowering emissions of harmful greenhouse gases. It also has to do this in a way that is both efficient and resilient and contributes to the stock of natural environmental capital.

None of the components of this paradigm are new. They comprise techniques of ecological and genetic intensification, within enabling environments created by processes of socio-economic intensification. What is new in this report is the way in which they are combined as a framework to find appropriate solutions to Africa's food and nutrition crisis.

Recommendations

This report presents examples of sustainable intensification in action. These actions now require being multiplied, combined and scaled up and out.

We recommend that Governments in the developed countries and in Africa – in partnerships with the private sector, Civil Society Organisations (CSOs) and NGOs – recognise and act on the paradigm of sustainable intensification through:

- Adoption of policies and plans that combine intensification with sustainable solutions and a focus on the food security needs of people
- Increased financial support for global and domestic research and innovation to develop and identify suitable technologies and processes
- Scaling up and out of appropriate and effective technologies and processes
- Increased investment in rural agricultural market systems and linkages that support the spread and demand for Sustainable Intensification
- Greater emphasis on ensuring that inputs and credit are accessible and that rights to land and water are secure for African smallholder farmers
- Building on and sharing the expertise of African smallholder farmers in the practice of Sustainable Intensification.

Why Do We Need Intensification?

Sub-Saharan Africa (SSA) faces many challenges, not least a high prevalence of chronically hungry people, and the urgent need to feed a rapidly growing population. Demand is increasing while supply is insufficient or even declining (Table 1).

Table 1: Overview of demand- and supply-related food challenges for sub-Saharan Africa

Demand Challenges	Supply Challenges
• **Over 200 million people**, nearly 23%, of the African population, are now classed as hungry. [1] • Despite declines up to 2007, **hunger levels** have been rising **2%** per year since then.[2] • **40% of children** under the age of five in SSA are stunted due to malnutrition. • SSA has a population of around **875 million**, with an average annual growth rate of 2.5%.[4] • The population in SSA will **almost double** by 2050, to close to two billion people. [5] • Between now and 2100 **three out of every four** people added to the planet will live in SSA. [6] • **50% of the population** will live in cities by 2030.[7] • **Declines** in total fertility rates in SSA are occurring later and slower than in Asia and Latin America.[8] • Incomes are rising with GDP per capita in SSA expected to reach **$5,600 by 2060**, and diets already beginning to change.[9]	• On present trends, African food production systems will only be able to meet **13%** of the continent's **food needs** by 2050.[10] • More than **95 million** ha of arable land, or **75%** of the total in SSA, has degraded or highly degraded soil, and farmers lose eight million tons of soil nutrients each year, estimated to be worth $4 billion.[11] • Nearly **3.3%** of agricultural GDP in SSA is lost annually because of **soil and nutrient loss**.[12] • Cereal yields have increased by over **200%** in Asia and Latin America but only by **90%** in Africa, between 1961 and 2011.[13] • In SSA only **4%** of cultivated land is irrigated.[14] • In SSA only about **seven million ha** of new land have been brought into production between 2005 and 2010.[15] • Between 1991 and 2009 per capita arable land **fell by about 76m² per year**.[16] • Under moderate climate change with no adaptation, total agricultural production will **reduce by 1.5%** in 2050.[17]

Lack of Land and Water

Before 1960 greater food supplies were obtained by taking more land into production. Since 1960 raising yields per unit area has been far more important. The harvested areas for major food crops have remained more or less constant, with oil crops (soybeans and oil palm) being the only exception (Fig. 1). If considerably more new arable land is easily available, we would expect this to have come into production, given the rising demands for food.

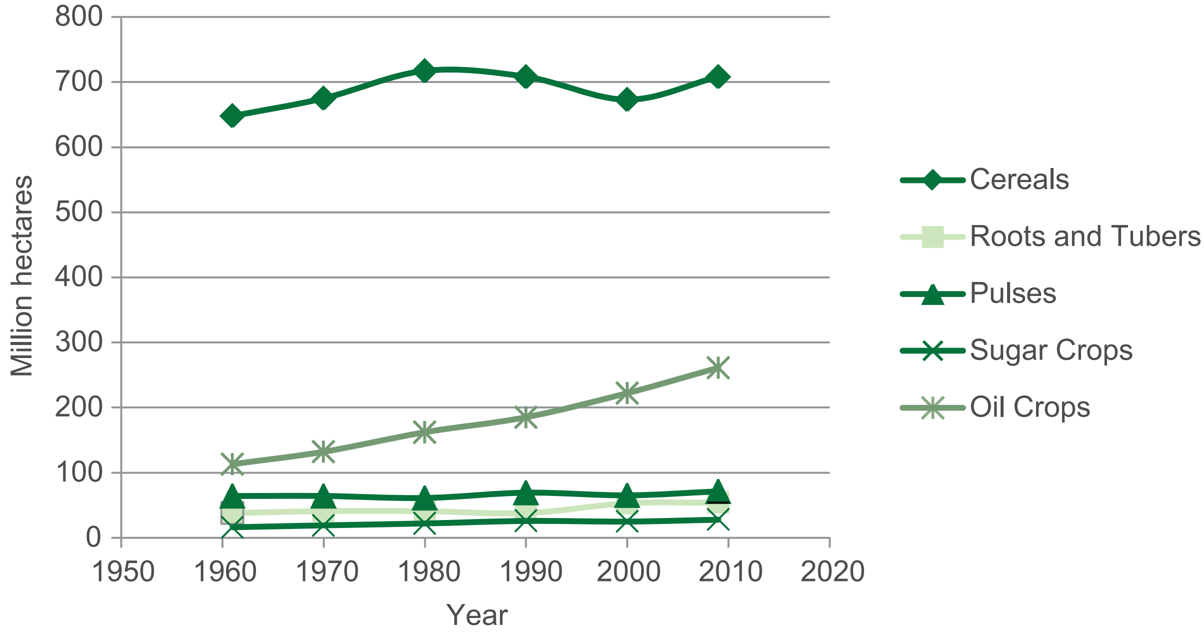

Figure 1 Trends in harvested food crops[18]

Globally, there has been a growth in harvested arable land since the food price spikes, with 27 million hectares added in the five years since 2005/6, yet an increase of only seven million hectares has occurred in SSA. Therefore, it seems that FAO's figure of 1.2 billion hectares of land available for cultivation in SSA is a considerable overestimate.

More land could be brought into cultivation by clearing the tropical rainforests, but this would be at the expense of biodiversity and cultural value, and greatly increase greenhouse gas emissions. There is much degraded arable land and some long fallow land in SSA, but the pristine arable lands are only extensive in some countries and for various reasons, including issues of tenure, they are not easily brought into production.

Africa could continue to rely on greater and more costly food imports from countries that still have plentiful land or other production potential but this could prove unsustainable in the face of crises and instability elsewhere in the world. More intra-regional trade within Africa can provide new market opportunities and increased access to food, but it is primarily through domestic agricultural growth that the majority of poor people will either be able to feed themselves or acquire the purchasing power they need to buy more food. Vast areas of African land are producing at levels well below their potential.

Part of the challenge is a decline in land quality. Land degradation affects about 65% of Africa's land and around six million hectares of productive land are lost each year. Inappropriate land use and poor management result in desertification, salinisation and soil and water erosion, creating a spiralling decline in the productivity of the land in terms of both food and other natural resources and services. The effects are often felt most by the rural poor.

Water scarcity is equally critical. Demographic pressures, industrial development, urbanisation and pollution are all putting unprecedented pressure on water supplies, particularly in semi-arid and arid regions. In SSA only 4% of cultivated land is irrigated, the lowest in the world. Three countries (Sudan, South Africa, and Madagascar) account for two-thirds of the irrigable area developed. Yet, potentially over 20 million hectares of land could be brought under irrigation.

For these and other reasons (e.g. the decline in public funding of research, the lack of readily available inputs and poor extension services), there has been stagnation in crop production and yields in Africa since the 1960s, especially contrasted to other regions such as China and Southern Asia (Fig. 2).

Many will argue that chronic food insecurity cannot be solved through a productionist agenda, and this is partly true. Distribution and access to healthy foods, as well as reducing waste and inequalities in the system, are critical. But for the 80% of the chronically hungry who are smallholder farmers, increasing their access to food must involve generating greater yields and increased incomes from their land. Moreover, while large farms will play an increasing role, these smallholders will have to be the primary source of food for the growing urban populations for some years to come. Thus we must help to increase their agricultural productivity and production while initiating more systemic changes. This is the agenda of intensification.

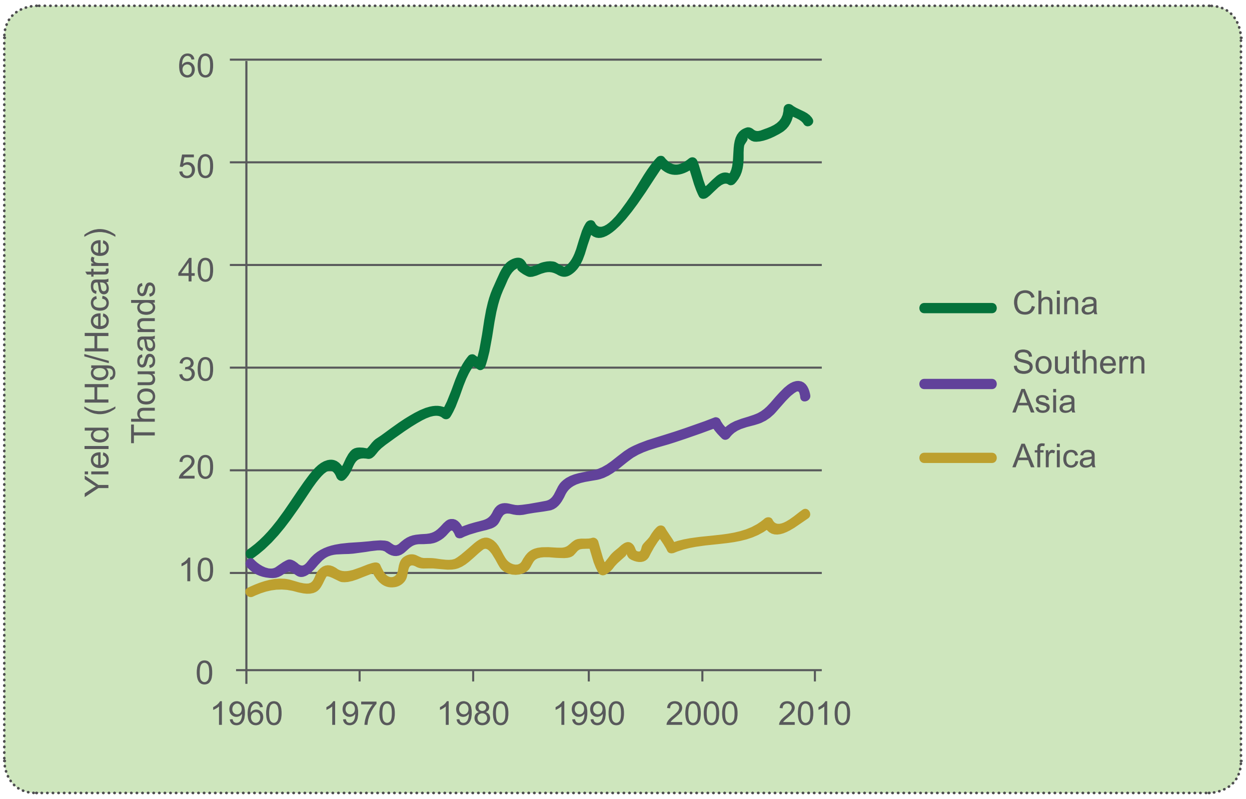

Figure 2 Cereal yields (hg/ha) in China, Africa and Southern Asia between 1961 and 2010 Figure 1 Trends in harvested food crops[18]

What is Intensification?

In simple terms intensification can be defined as producing more units of output per units of all inputs and through new combinations of inputs and related innovations. It involves improving physical input-output relations and increasing the overall efficiency of production. Conventionally, intensification has aimed to raise production, yields and/or income per unit of land, through greater investment of capital or labour and higher use of inputs such as fertiliser or pesticides, but intensification can take many forms dependent on climate and land, household resource endowment and socio-economic states, individual choice and market demands.

The Outputs

Defined in this way, intensification results in greater amounts of output, whether of food produced, the income generated or the nutrition received by consumers of the farm's produce (Table 2).

Table 2 Definitions and sources of three outputs of agricultural intensification

Production	Income	Nutrition
Definition *Total amount or yields of food per unit input*	**Definition** *Amount of net income generated per unit input*	**Definition** *Human consumption of nutrients per unit input*
Resulting from: • Improved high yielding, drought, pest and disease tolerant crop varieties or livestock breeds • Better crop cultivation or livestock husbandry: - More effective inputs of water, nutrients or means of control of pests, diseases and weeds - Exploiting synergies between crops and livestock[26]	Resulting from: • Access to fair and efficient output markets • Greater market and price information • Shifts from low value to high value crops or livestock • Diversification of income-generating activities, including: - Adjustment of the farm or household enterprise - Exploiting new market opportunities[27] - Increasing non-farm income	Resulting from: • New varieties of staple crops or breeds of livestock with improved nutritive value • Diversification of production towards higher overall nutritive value

Increases in land productivity will have to meet almost three quarters (73%) of the future growth in global food demand by 2030, either from yield increases or increases in cropping intensity. The remaining 27% will come from expansion of the area under cultivation – mainly for maize – in the limited number of countries that still have room for this.[28] This means closing the gap between actual and potential yields, a gap that is widest in SSA.[29] Although global yields, at least for some major grain crops, are continuing to increase, in SSA average farm yields are well below potential, for instance, with average maize yields at 1.3 tons/ha.[30]

Increasing income for farmers is also essential to purchase food, education, medicine and other goods and services essential for their livelihoods and development. Farmers need to improve their access to healthy and nutritious foods. A key element in the fight against child malnutrition (40% of children under five in SSA are stunted due to malnutrition) is the cultivation of a wide range of nutritious foods, including staples fortified with such micronutrients as vitamin A, zinc and iron.

We know that smallholder farmers are capable of producing high levels of these outputs, given access to good-quality, certified seed, to appropriate fertilisers and to markets (Box 1).

Box 1 One Acre Fund

The One Acre Fund, established in 2006 in Western Kenya by Andrew Youn, uses a market-based system to enable one-acre subsistence farmers, a group they refer to as the 'forgotten poor', to escape poverty. The model is built around five core principles:

1. Empowerment of local farmer groups, bringing them together to increase their negotiating power;
2. Farm education provided by field officers;
3. Capital, the provision of certified and environmentally-sensitive seeds as well as fertiliser;
4. Market facilitation, training on post-harvest handling and storage; and
5. Crop insurance.[31]

As of autumn 2012, the One Acre Fund has facilitated a tripling of raw harvest material per planted acre and a doubling of farm income per planted acre, after repayment.[33]

The Inputs

As with the outputs, the inputs used in the intensification process vary according to the farming system and the local social, economic and environmental conditions (Table 3).

Table 3 Examples of the direct and indirect inputs to agricultural intensification

Direct inputs *Use of which can directly alter the outputs from the farm[1]*	• **Labour**, in either human or mechanised form • **Water**, either through irrigation or rainfall • **Inorganic chemicals and/or organic matter**, such as fertilisers, manure, crop residue and pesticides • **Biodiversity**, be it a new variety of crop or breed of livestock.
Indirect inputs *Use of which are often required to facilitate or modify the use of direct inputs*	• **Financial capital**, for investment in inputs and other changes to the farming system • **Knowledge**, of new methods of working and of local conditions • **Infrastructure**, to enable access to input and output markets • **Technology**, which generates and supports new forms and ways of using direct inputs • **Markets**, as an outlet for increased outputs.

Greater intensification can derive from increasing the use of inputs, introducing a new input to the system or using an existing input in a new way. Examples include using a new and improved rainwater harvesting technique to increase access to water, planting new high-yielding seed varieties or employing more farm labourers. All these changes require both access to technologies and information as well as the fundamental science that generates new inputs or novel ways of employing them.

What Makes Intensification Sustainable?

Perhaps surprisingly, this new paradigm has proven rather controversial. 'Sustainability', tends to mean all things to all people. But at its heart **Sustainable Intensification** is about producing more outputs with more efficient use of all inputs – on a durable basis – while reducing environmental damage and building resilience, natural capital and the flow of environmental services.[33] It is also about conserving natural landscapes not only because of the ecosystem services they provide, but also their present and future cultural value (Box 2).

These objectives are not particularly controversial, but it is the means that excite vigorous debate. This report aims to provide a balanced view in the hope that it will be of use to policy makers, investors, practitioners and, especially, to smallholder farmers in SSA who are struggling to feed themselves and those dependent on them, now and for generations to come.

Box 2 Sustainable Intensification

Increased production, income, nutrition or other returns

On the same amount of, or less, land and water,

With efficient and prudent use of inputs,

Minimising greenhouse gas emissions,

While increasing natural capital and the flow of environmental services,

Strengthening resilience and

Reducing environmental impact,

Through innovative technologies and processes (Fig. 3).

Adapted from Pretty (2009)[34]

Sustainable Intensification aims to have a smaller environmental footprint by minimising the use of fertilisers and pesticides, generating lower emissions of such greenhouse gases as carbon dioxide, methane and nitrous oxide and, at the same time, contributing to the delivery and maintenance of a range of public goods, such as clean water, carbon sequestration, flood protection, groundwater recharge and landscape amenity value. [35]

Defined in this way Sustainable Intensification is an ambitious objective but is achievable if we focus on being:

- ***Prudent***, in the use of inputs, particularly those which are scarce, are expensive and/or encourage natural resource degradation and environmental problems;
- ***Efficient***, in seeking returns and in reducing waste and unnecessary use of scarce inorganic and natural inputs;
- ***Resilient***, to future shocks and stresses that may threaten natural and farming systems;
- ***Equitable***, in that the inputs and outputs of intensification are accessible and affordable amongst beneficiaries at the household, village, regional or national level to ensure the potential to sustainably intensify is an opportunity for all.

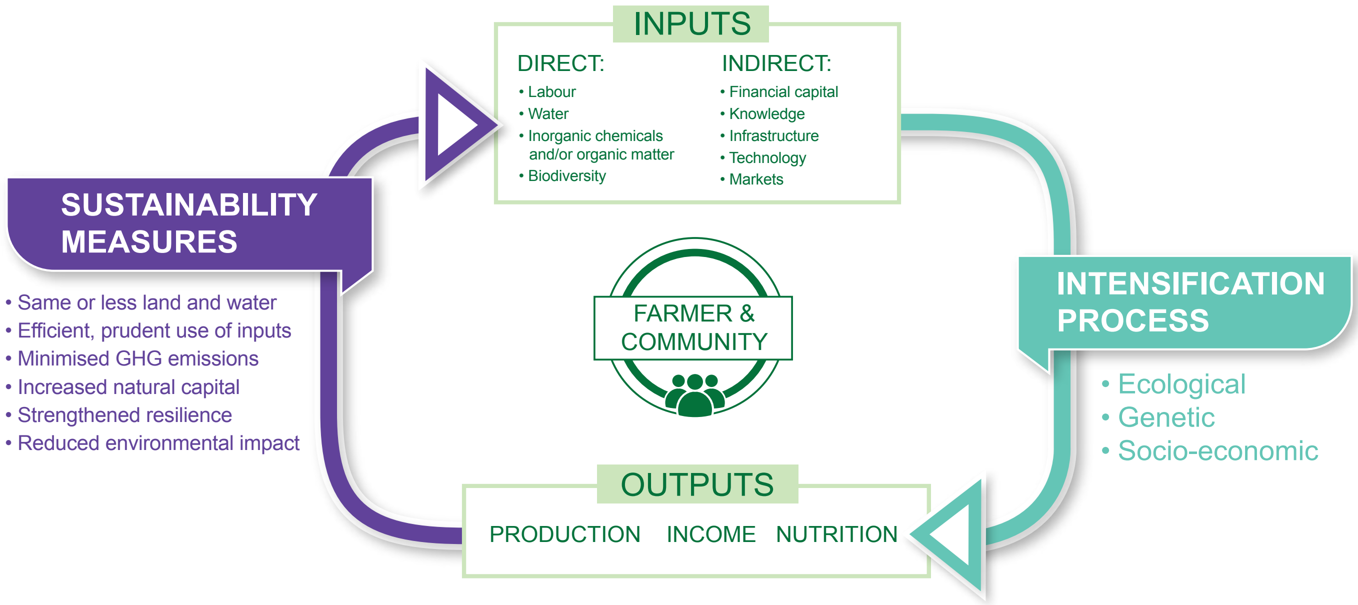

Figure 3 Theoretical model of Sustainable Intensification

A common objection to Sustainable Intensification is that it is simply a cover for more industrial agriculture. The sections that follow hope to demonstrate that while it can be applied to the large-scale, intensive agriculture of, say, North America, it can equally be appropriate for smallholder farmers trying to increase their production.

Making Farming Precise

Today, farmers in the industrialised world are striving to ensure their inputs are much more precisely targeted. Their goal is to optimise returns on inputs while preserving resources. They are increasingly relying on new technologies like satellite imagery, information technology and geospatial tools. For example, they may analyse and plot in detail the nutrient levels in different parts of their fields and then use tractors equipped with satellite positioning systems to apply different fertiliser mixes in accordance with soil needs in specific locations.

Such **precision farming** is not appropriate for the smallholder farmers who predominate in SSA, but the same principles may apply.

Applying Fertilisers

African smallholders are equally keen to ensure they use appropriate amounts of inorganic fertiliser in a cost effective manner. Fertilisers are increasingly costly (Box 3), are often inefficiently used, and when overused can cause severe pollution.

Without nutrients, crops will not produce high yields. Fertiliser application is often inefficient, with the amount of fertiliser taken up by plants only a small fraction of the amount applied to a field.[39] Between 1960 and 2000 the efficiency of N use for global cereal production decreased from 80% to 30%.[40]

Box 3 Fertiliser prices

Fertiliser is thought to be responsible for 60% of yield increases seen globally in the past 50 years. Fertiliser prices have increased steadily since 2002, but then peaked following the 2007/8 food price crisis. Subsequent to this food price spike the price of potash increased tenfold to almost $1000 a tonne.[36]

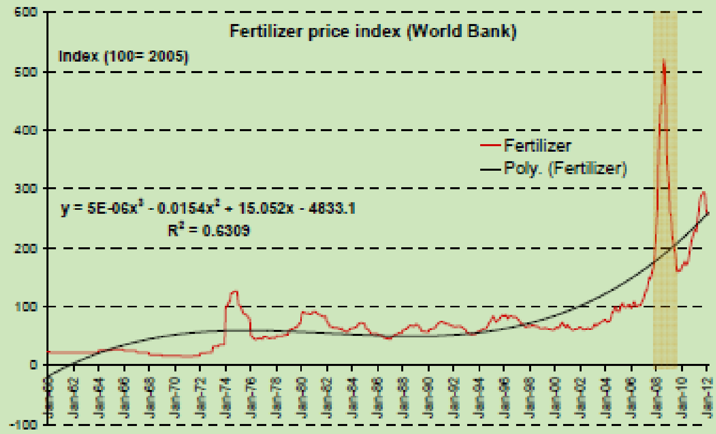

Figure 4 World fertiliser price index

Africa accounts for less than 1% of the global fertiliser market and the cost of fertiliser can vary significantly between and within countries.[37] For example, the price a farmer will pay per ton of fertiliser in Kenya (about $330) is very different to what an Angolan farmer would pay ($830).[38] The cost to move fertilisers from ports to central areas is high, further limiting access for many African farmers.

The low level of nutrient usage in Africa is causing widespread soil nutrient mining. African fertiliser usage is currently estimated at eight kg/ha compared to the global average of 93kg/ha and 100-200kg/ha in Green Revolution countries of Asia.[41] At the same time, in the early 2000s, over 80% of countries in Africa were losing more than 30 kg/ha/year of nutrients, and 40% of countries were losing over 40 kg/ha/year.[42]

African farmers need to use more inorganic fertiliser, but they also need to strike the right balance between managing soil organic matter, fertility and moisture content and the use of such fertilisers. One highly efficient and intrinsically sustainable approach is the technique of microdosing developed to both minimise the application of and over reliance on inorganic fertiliser and to improve nutrient use efficiency and protection against drought (Box 4).

Box 4 Microdosing in Niger, Mali and Burkina Faso [43]

Each microdose consists of a six-gram mix of phosphorus and nitrogen fertiliser, which just fills the cap of a soda bottle—an item that is easy to obtain. The cap of fertiliser is then poured into each hole before the seed is 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. For example, millet yields increase by over 50% and crops are better able to absorb water.

Applying Herbicides

The same principle can be applied to use of herbicides that, far too often, are sprayed relatively indiscriminately, killing not only weeds but other wild plants and sometimes damaging the crops themselves. Applying precision farming techniques simultaneously addresses the challenge of combating serious weed problems in Africa – such as Striga (or witchweed), which sucks nutrients from the roots of maize, sorghum, millet, cowpea and other crops – while minimising any unintended or undesirable environmental impacts (Box 5).

Box 5 Control of Striga

This devastating weed is readily controlled by a herbicide, imazapyr, but this tends to damage or kill the crop. Recently, a mutant gene in maize has been discovered through tissue culture research, which confers resistance to the herbicide and is being bred into local maize varieties.


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The resistant maize seed is dipped into the herbicide before being planted. When the parasitic weeds germinate, they attach to the maize roots and suck out the systemic herbicide as well as the nutrients. The Striga is killed, while allowing the maize to grow with little or no impact from the herbicide and minimal impacts on the surrounding environment.

Water Conservation

A wheat grain may contain up to 25% water; a potato 80%. For rice, a gram of grain can require as much as 1,400 grams of water for its production.[44] As with nutrients, water has to be available for crop uptake in the right amounts and at the right time, as water stress during growth results in major yield reductions for most crops.

In Asia and elsewhere there is often an abundance of water, yet it is badly managed – resulting in waterlogging, salinisation, non-sustainable drawdown of aquifers and pollution. In some parts of SSA there is also plenty of water available and the challenge is to increase the amount of irrigation (currently on less than 4% of total arable land in Africa) but do it in such a way that does not repeat some of the mistakes elsewhere in the world.

In other parts of SSA water is very scarce; some 200 million sub-Saharan Africans face serious water shortages.[45] There the challenge is to design and implement cheap and efficient small-scale water harvesting, collecting rainwater as it runs off the land for later use.

Water harvesting from short slopes is relatively straightforward and cheap. An example is the *zai* (or water pockets) technique pioneered by farmers for the dry, sun-baked, encrusted soils of northwest Burkina Faso (Box 6).

Box 6 The zai system

Farmers first dig medium-sized holes (or zais) in rows across the fields during the dry season. Each zai is allowed to fill with leaves and farmers add manure, which during the dry months attracts termites; these create an extensive network of underground tunnels beneath the holes and bring up nutrients from the deeper soils.

The rainwater is captured in the zais which are sown with sorghum or millet seed. Water loss through drainage is limited by the manure and deep infiltration is made possible by the termite tunnels. Thus, even in the drought-prone environment of the Sahel, sufficient water capture is ensured.

Farmers have consistently reported greatly increased yields using this technique. In Burkina Faso, grain yield has increased 120% equating to around 80,000 tons of extra grain per year.[46] The labour in the first year is quite high, but after that farmers may reuse the holes or dig more between the existing ones.

A key factor in the spread of zai adoption was the student-teacher system led by the innovators of the technique to train farmers.[47]

In these and other examples, the interconnectedness of water, soil and nutrient conservation is critical. The most successful systems are those that provide water, nutrients and a supportive soil structure in a synergistic fashion.

What Practical Approaches Can Help Deliver Sustainable Intensification?

Precision farming focuses on one aspect of Sustainable Intensification, namely the precise and prudent use of inputs. More generally Sustainable Intensification is a product of the application of technological and socio-economic approaches to the task. There are two main technological approaches – one is the application of agricultural ecological processes (ecological intensification), the other is to utilise modern plant and livestock breeding (genetic intensification). Concurrent to these approaches is socio-economic intensification, which provides an enabling environment to support technology adoption and develop markets for the products of Sustainable Intensification (Fig. 5).

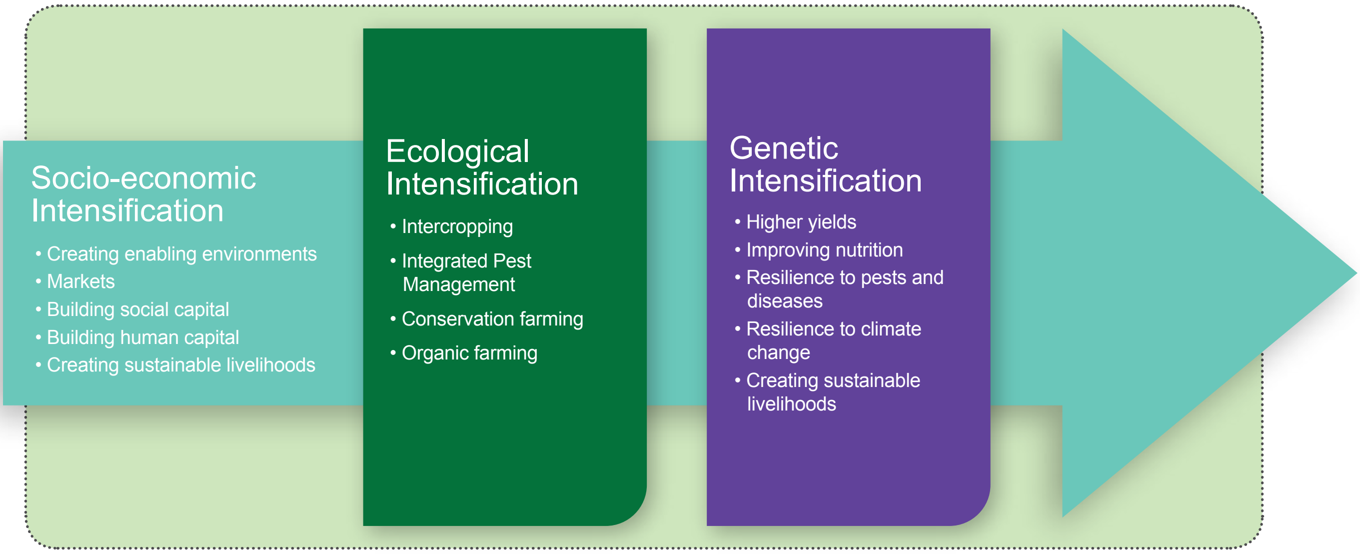


Figure 5 The practical approaches to Sustainable Intensification

Ecological Intensification

Ecology has informed and underpinned agriculture since the first steps in domestication and cultivation. Agricultural systems created by farmers are modified natural ecosystems – known as agroecosystems.[48] Each farmer's field is crafted from the natural environment. The great diversity of the original wildlife is reduced to a limited set of crop, pest and weed species, but inside the field boundary many of the basic ecological processes remain the same and can be used intensively to create sustainable forms of crop and livestock production. These include: (1) competition between crop plants and between crops and weeds, (2) herbivory of crop plants by pests, (3) predation of the pests by their natural enemies and (4) decay of organic matter.

Such **ecological intensification** is illustrated by highly productive intercropping that relies on reducing competition and increasing mutual benefits between crops, by Integrated Pest Management (IPM) that depends on natural enemies replacing pesticides and by conservation farming using no-till to encourage the build up of organic matter in the soil.

Intercropping

A form of intensification that is potentially highly sustainable is to utilise the mutually beneficial ecological relationships that arise when two or more crops are grown in association, either as mixtures or rotations. This is especially true and beneficial where one is a nitrogen-fixing legume.

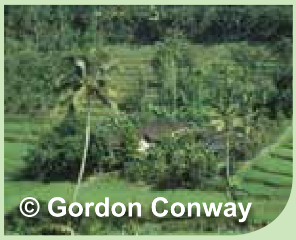
There are numerous examples of such intercropping:

- ***Mixed cropping:*** interspersion of different crops on the same piece of land, either at random or more commonly in alternate rows usually designed to minimise competition but maximise the potential for both crops to make use of the available nutrients, such as N supplied by a legume.
- ***Rotations:*** the growing of two or more crops in sequence on the same piece of land.
- ***Agroforestry:*** *a form of intercropping in which annual herbaceous crops are grown interspersed with perennial trees or shrubs. The deeper-rooted trees can often exploit water and nutrients not available to the crops. The trees may also provide shade and mulch, creating a micro-environment, while the ground cover of crops reduces weeds and prevents erosion.*
- ***Sylvo-pasture:*** similar to agroforestry, but combining trees with grassland and other fodder species on which livestock graze. The mixture of shrubs, grass and crops often supports mixed livestock.
- ***Green manuring:*** the growing of legumes and other plants to fix N and then incorporating them in the soil for the following crop. Commonly used green manures are *Sesbania* and the fern *Azolla,* which contains N-fixing, blue-green algae.

Despite these examples, only in a few cases has intercropping been practiced at scale. Two exceptions are examples of agroforestry – the traditional home garden and the planting of the legume tree *Faidherbia albida* (Box 7).

Box 7 Two examples of agroforestry

Home gardens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Home gardens or kitchen gardens are characterised by their great diversity of useful plants and small livestock in a small area, cultivated in intricate relationships with one another. They are often a sustainable source of a variety of nutritious foods for family consumption.

While most often seen across southern and South East Asia, successful home garden training programmes have been instituted in Niger, Somalia, Ghana and Kenya under the leadership of the FAO's Nutrition and Consumer Protection Division alongside national agricultural extension, research and training institutes and NGOs.[49] For example, Farm Africa and its partners are working to develop cropping of, and markets for, African indigenous vegetables (AIVs) in Tanzania and Kenya as important sources of nutrients and income.[50]

Faidherbia[51]


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This leguminous tree has the curious habit of shedding its leaves in the wet season, thereby providing nutrients to the soil below and allowing for light to pass through. As a consequence it is possible to plant and grow maize under the trees. Yields can be over three tons/ha even without fertilisers, depending on the nitrogen fixed by the trees. The trees also contribute two tons or more per hectare of carbon to the soil and mature trees can store over 30 tons of carbon per hectare.

Integrated Pest Management

Pesticides tend to be expensive, can be hazardous and are often inefficient at controlling pests, due in part to the risk of resistance and because they also kill the natural enemies of pests. Integrated Pest Management was initiated in the 1950s with the aim of replacing broad-spectrum pesticides with targeted, safer, selective compounds, combined with use of agronomic and biological means of control.

One of the most effective agronomic approaches is the "push-pull" system, which has built on ecological studies to create a polyculture agriculture that protects maize, millet and sorghum from two devastating pests: the stem borer insect and *Striga* weed (Box 8).

In Africa, a programme of IPM training through Farmer Field Schools (FFS) began in Ghana in 1996 under the FAO in partnership with civil society. In subsequent phases of the project, training has expanded to Senegal, Mali, Burkina Faso, Benin, Guinea, Niger and Mauritania, where some 155,000 farmers have been targeted. As a result, all crops in the West Africa programme have experienced median increases of yields of around 23% and a decrease in pesticide use of 75%.[53]

Box 8 The push-pull system of pest and weed control[52]

Push-pull entails mixing plants that repel insect pests ("push") and planting diversionary trap plants around a crop that attract away the pests ("pull").

It is based on intercropping of the main cereal crop with the forage legume Desmodium. This plant both emits volatile chemicals that repel stem borer moths ("push") and attracts a natural enemy of moths, parasitic wasps ("pull").

Figure 6 Push-pull system of pest and weed control

In addition, Desmodium secretes chemicals from its roots that cause "suicidal" germination of Striga seeds before they can attach to the maize roots. To ensure further protection, farmers can plant a "trap crop," such as Napier grass, around the edge of the field, which attracts the moths, pulling them away from the main crop.

The system was developed by collaboration between the International Centre of Insect Physiology and Ecology (ICIPE) and the Kenyan Agricultural Research Institute (KARI), both in Kenya, and Rothamsted Research in the United Kingdom.

As of 2010, 25,000 smallholders in East Africa are using push-pull systems. It allows them not only to control pests but also to increase soil fertility, protect against erosion, reduce pesticide use and gain income from the Desmodium crop.

Conservation Farming

Over the years, especially in temperate climates, it has been common practice for farmers to till the soil in fields before seeds are sown in order to loosen and aerate the soil and to destroy weeds. Such tillage, either with a hoe or using an animal- or mechanically-powered plough, breaks up heavy clay soils. But for many soils prone to erosion or drought, as are common in SSA, tilling can harm soil structure and increase water loss.

Conservation farming experiments, ongoing today, were first conducted in the United States but are now widespread, often in a very different form in SSA (Box 9). They include various systems of reduced or no tillage. The advantages are the saving of labour used for ploughing, protection of vulnerable soils from erosion by keeping topsoil from being blown or washed away, and improvement of soil fertility by keeping soil structure intact and by allowing more beneficial insects to thrive. It also keeps carbon and organic matter in the soil, leading to a higher microbial content and carbon sequestration, thus reducing carbon emissions from agriculture.


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Box 9 Conservation farming in Zambia[54]

Experiments in western Zambia, conducted by partnerships between local government bodies and the NGO Concern Worldwide, are investigating the use of conservation farming as a replacement for the traditional long fallow system of the region. There 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 farming, is not to plough and instead sow the seed in small "pockets" in the soil to which have been added two cupfuls of manure and a bottle cap of fertiliser. After harvest, the soil is covered with the stems and leaves of the maize and next year's seed is sown several months later in the same holes. Despite the need to hoe weeds, the labour is much less than under conventional systems.

Yields are also high, at some four to five tons of maize when growing new drought-tolerant hybrids, for example. 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, thus creating a more stable and sustainable farming system.

Organic Farming

Organic agriculture is a highly sustainable form of crop and livestock production which brings together many of the technologies described above. Among the benefits are an increase in soil quality and soil biota by returning organic matter to the soil, utilisation of key nutrients (N, P and K) from manures, leguminous crops and other renewable sources, pest control through biological means (and limited use of naturally occurring pesticides) and weed control by mechanical or hand labour.

Perhaps most significant, organic cropping has lower energy requirements by not requiring synthetic inputs (although mechanical weeding, if used, will increase energy requirements). In general, it will result in lower emissions of greenhouse gases, especially nitrous oxide.

Yet a critical question remains whether the yields produced through organic agriculture can be intensified sufficiently and at scale in order to ensure food security for the population at large. Comparative studies in developing countries are not thorough enough to answer the question conclusively, but there is extensive data from developed countries to question this potential. For instance, long-term wheat experiments in the United Kingdom show comparable yields are obtained only with very heavy applications of manure, well above the amounts permitted under organic farming.[55]

Careful analysis of a wide range of other experiments suggests the typical ratio of organic to conventional wheat yields is 0.65 (i.e. organic cultivation yields 30 to 40% less), and this seems to be the approximate ratio for other crops.[56] However, this ratio could be an underestimate for developing countries. In drought-affected areas and under subsistence conditions, conversion to organic farming may well improve yields where the soils have been degraded over time, providing that a sufficient supply of manure and compost are available at the local level, as well as access to extension services.

In summary, while ecological intensification shows considerable promise, at least in terms of sustainability and resilience, it may not provide the higher yields required by intensification. Such technologies are rarely taken to scale, partly due to the often considerable labour and skills they require. Thus, while the practice of agricultural ecology is central to improving sustainability, as important is the process of crop and livestock breeding.


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Genetic Intensification

For thousands of years, humans have been harnessing the power of genetic inheritance to improve food security, increasing both yields as well as the nutritive qualities of crop varieties and livestock breeds.

Through conventional breeding, beneficial genes have been preserved and brought into association with other complementary genes from close or distant relatives. The earliest bread wheats resulted from natural hybridisation of two species of wild wheat and wild grass followed by intensive human selection. This concentration of beneficial genes in varieties and breeds can be thought of as a process of genetic intensification.

Since the cellular and molecular revolution of the last century, conventional breeding has been augmented by forms of biotechnology – cell and tissue culture, marker-assisted selection and genetic engineering – to further intensify the process (Box 10).

Box 10 Forms of crop and livestock breeding

- Conventional Breeding focuses on selecting and crossing crop varieties and livestock breeds that possess desirable traits, using painstaking, mostly manual methods, and often depending on the serendipitous discovery of new and beneficial mutations. It is as much a craft as a science, and it can be a slow and imprecise process.
- Cell and Tissue Culture involves the development of whole plants from a single cell or cluster of cells in an artificial growth medium external to the organism. It has become a powerful tool in the production of wide crosses, whereby wild relatives, often hosting desirable traits such as disease resistance, are crossed with domestic varieties.
- Marker-Assisted Selection (MAS) is a process whereby DNA sequences within an organism are analysed with the aim of detecting the presence and structure of genes responsible for particular traits. It greatly speeds up conventional breeding.
- Genetic Modification (GM), or recombinant DNA, involves the direct transfer of genes from one organism to another. Sections of DNA code are located, cleaved and reattached using a variety of naturally occurring enzymes. It has several advantages: (1) combinations are predetermined and the transfer process is exact, producing precise rather than randomly determined offspring; (2) the process is much quicker; (3) the sources of genetic material are much larger and less restricted by geographic or biological boundaries.

Examples of the use of genetic intensification to increase crop yields, enable nitrogen uptake and fixation, improve nutrition and enhance resilience to pests and diseases and climate change demonstrate how modern breeding can contribute to Sustainable Intensification.Some of the priorities for modern breeding are:

- increased productivity,
- improved nutritive value,
- crops and livestock that are resilient to pests and disease attack,
- crops and livestock that are resilient to the effects of climate change, and
- greater efficiency in taking up nutrients from the soil, and fixing nitrogen from the atmosphere.

Achieving these targets is a tall order but the potential benefits are considerable. This is why building desirable characteristics – high yields coupled with stability and resilience – into the seed is so attractive. The seed, in a sense, can be a ‘package of desirable and appropriate technologies.’ It is in this respect that the new genetics, in the form of biotechnology, becomes so relevant.

Higher Yields

Yields of major crops in SSA are frequently low, achieving far less than their potential. For example, rice yields can be as high as 11 tons/ha with Asian varieties typically yielding around five tons/ha.[57] However, these Asian varieties are often poorly adapted to African environments. African varieties, while better adapted, yield poorly (about one ton/ha).

To address this challenge, one solution has been to cross the Asian rice species (*Oryza sativa*) with the African species (*O. glaberrima*) in order to capture the yield benefits of the former and the adaptive benefits of the latter (Box 11).

Box 11 New Rice for Africa (NERICA)[58]

- Making crosses between Asian and African rice species is possible through conventional breeding, but the process is easier if the resulting embryo is grown in a culture medium.
- Like the African species, these new rice hybrids grow well in drought-prone and upland conditions, as well as being resistant to local pests and diseases, and tolerant of poor nutrient conditions and mineral toxicity. They also show early vigorous growth and crowd out weeds.
- Later in their development, characteristics of the Asian rice species appear: they produce more erect leaves and full panicles of grain and are ready to harvest 30 to 50 days earlier than current varieties.
- While early efforts to apply this embryo rescue technique did not work well, collaboration with Chinese scientists provided a new tissue culture method involving the use of coconut oil, which proved highly successful in producing the so-called New Rice for Africa (NERICA).
- Because of the higher yields of the new varieties Uganda was able to reduce its rice imports by half and farmers' incomes increased.

Livestock has also benefitted from improved yields and sustainability through conventional hybrid breeding of the taurine cattle (*Bos taurus)* of the temperate climates of Europe, North Asia and West Africa with the humped zebu cattle (*Bos indicus)* of the hot arid and semiarid regions of Africa and Asia.

Although these two species can naturally cross, years of selection for different characteristics have made them quite different today. While the taurine cows have been selected for milk production, the zebu cattle have been selected for a high degree of heat tolerance, resistance to many tropical diseases and the ability to survive long periods of feed and water shortages. However, the zebus have a low milk yield, are late maturing and usually do not let down milk unless stimulated by the sucking of the calf.

A number of sophisticated cross-breeding schemes have now been introduced with considerable success. For example, in the Kilifi plantation near Mombasa in Kenya, a rotational crossing scheme alternating with bulls from the two breeds has resulted in Sahiwal x British Ayrshire crosses producing 3,000kg of milk per year, mainly from pasture.

Improving Nutrition

The diets of poor people are often dominated by the intake of basic staple foods (e.g. maize, rice, wheat, cassava, millet and sorghum) which are usually deficient in micronutrients – such as vitamin A, iron and zinc – necessary to combat malnutrition.

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While home gardens, as described earlier, can provide more nutritious foods, rich in micro-nutrients, another promising approach is biofortification – the breeding of crops with enhanced nutritional value. An early example of biofortification has been the breeding of quality protein maize. Another success story is the development of orange-fleshed sweet potatoes, also using conventional breeding (Box 12).

But, in some instances, conventional breeding will not work. In rice, for example, beta-carotene is not present in the grain endosperm so scientists are introducing new versions of the key *psy* maize gene to rice varieties, raising the beta-carotene levels to 31 μg/g. This new 'Golden Rice' has already been developed into locally appropriate varieties in the Philippines and India and is forecast to be available in other countries in the next two to four years.

Box 12 Orange-fleshed sweet potatoes in Mozambique

- A classic food security crop, the roots of sweet potatoes can be left in the soil and lifted when other crops are not available. Sweet potatoes grow well on marginal land but are white-fleshed in Mozambique, meaning they are rich in carbohydrates but lacking in beta-carotene, which our bodies convert into much needed vitamin A.
- To overcome this deficiency, beta-carotene rich, orange-fleshed varieties of sweet potato were introduced for breeding by the National Institute for Agronomic Investigation (INIA) in 1997. Three years later, nine new orange-fleshed varieties were released just in time to help with the recovery from devastating floods in southern Mozambique. By 2005 half a million households had received improved planting material.
- The same year, a severe drought in the country brought home the need to breed for drought tolerance as well. Using an accelerated conventional breeding programme Maria Andrade and her team halved the time needed to produce new varieties from eight to four years. By 2011, 15 new drought-resistant varieties were released, capable of producing up to 15 tons/ha.
- Adoption rates are high, including amongst women and children, with nearly a doubling of daily intake of beta-carotene and significant increases in serum retinol, the form in which vitamin A circulates in the blood.[59]

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Resilience to Pests and Diseases

Crop plants and livestock tend to be naturally resistant to the pests, diseases and weeds in the regions of the world where they originate. When transferred to other regions, they encounter new pests and pathogens that can be devastating. Breeding, both conventional and biotechnology, can greatly strengthen resistance, at least in the short term, until such point that the pest species adapts to overcome the resistance.

In 1950, a new race of wheat stem rust exploded in the United States and southern Canada and was carried by high winds into Mexico. This was only the first in what has become a series of epidemics; a more recent outbreak of another highly virulent strain of black stem rust, named UG99, appeared in Uganda in 1999 (Box 13).

Box 13 A new rust UG99 on wheat[60]

UG99 appeared in Uganda in 1999 and spread through the highlands of East Africa, with losses in Kenya as high as 80%. The new strain is resistant to all but 10 of the some 50 rust resistance genes. Since 1999 the rust has spread beyond East Africa to Ethiopia, Sudan, Yemen and Iran.

A small number of wheat cultivars are resistant to UG99 and some new crosses have been made. The new hybrids contain a number of genes, each of which has a low level of resistance but when combined are very effective. But the ability of the fungus to mutate and evolve means protracted resistance is unlikely.

One ray of hope is the discovery that rice is resistant to the entire taxon of rust fungi. If the mechanism of resistance can be identified and the genetic information translocated to wheat, a range of durable, resistant varieties could be created.

In recent years breeding for resilience to insect pest attacks has benefited from engineering based on the genes that code for toxins produced by *Bacillus thuringiensis (Bt), a* naturally occurring bacterium widespread in the soil. Since the toxins are crystalline cry proteins, the bacterium itself or extracts of the cry protein can be sprayed on crop leaves to kill insects feeding on the plants, especially caterpillars of moths such as cotton bollworms. Once ingested, the protein kills the insect. Since useful insects such as honey bees and natural parasites and predators do not feed on the sprayed plants, they are unaffected. Also, the toxins do not harm humans.

These features make the cry proteins ideal insecticides. The genes encoding for the proteins were first isolated in the early 1980s and have now been transferred to crops ranging from cotton to cowpea. Inevitably though, the use of cry proteins will lead to selection for resistance, as would the use of chemical insecticides, synthetic or natural. Fortunately, a number of different cry proteins can be produced by different *Bt* genes. One approach is to produce crops with at least two different *Bt* genes in the expectation that the insects cannot readily develop resistance to both toxins simultaneously. Another possibility is to use multiple toxic genes, each with a different mode of action. A promising companion to the *Bt* gene is a gene that encodes for a proteinase inhibitor contained in the tropical giant taro plant. This confers high resistance to insect attack.

Genetic Modification (GM) technologies have also been used against crop pathogens. One example is the current development of bananas resistant to banana wilt in Uganda, a programme entirely funded from public sources. The resistance genes have been obtained from sweet peppers and donated by the Academia Sinica. Funding for the work has come primarily from the Uganda government.

Resilience to Climate Change

The main threats from climate change arise from the stresses and shocks caused by higher temperatures and lack of rainfall. These include shorter growing seasons and more frequent and severe extreme events, such as flooding and heat waves. Towards each of these, and to their combinations, we need crops and livestock that are resilient.

Such an example is Water Efficient Maize for Africa (WEMA), a collaborative project aiming to develop and distribute maize varieties that yield 24 to 35% more than currently available varieties under moderate drought conditions (Box 14).

Breeding for drought tolerance has so far been difficult given the variety of effects that drought can have. Nevertheless, in recent years, a suite of genes that confer drought tolerance has been identified. One such gene is a so-called ‘chaperone’ gene. This can confer tolerance to various stresses, including cold, heat and lack of moisture. The product of the gene helps to repair mis-folded proteins caused by stress, allowing the plant to recover more quickly. Found in bacterial RNA, this resilience gene has been transferred to maize with excellent results in field trials. Plants with the gene show 12 to 24% increase in growth in high-drought situations compared with plants without the gene.

Box 14 Water Efficient Maize for Africa (WEMA)

Launched in 2008, the WEMA project, led by the African Agricultural Technology Foundation (AATF), is developing new drought-tolerant maize varieties through conventional breeding, marker-assisted selection and biotechnology. Target countries include Kenya, Mozambique, South Africa, Uganda and Tanzania, where some 15 new varieties will be marketed royalty-free to smallholder farmers.

Currently beginning its second phase (2013-2017), the project has expanded to include the development of maize varieties resistant to stem borers and the production, promotion and stewardship of new varieties.[61]

In Tanzania’s central plateau, where the arid climate has previously prevented maize from growing, farmers are now testing five maize varieties and initial reports indicate that they require little water and grow quickly. While most maize varieties require a period of 90 days to mature, one of WEMA’s varieties, Situka, only needs 75 days.

Farmers involved in the testing process are currently receiving seeds at no cost, but the aim is that they will be available commercially at a price of around $0.13 per kilo.[62]

Nitrogen Uptake and Fixation

Currently, crops are inefficient at absorbing and making use of nitrogen in the soil, whether from inorganic fertiliser or from crop residue or manure. Moreover, efficiency levels have been declining, with less than half of N applied to crops ending up in the harvested product.

Nitrogen utilisation can be improved through practices such as precision farming or the planting of nitrogen-fixing crops such as soybeans[63], but crops can also become more efficient at taking up and utilising nitrogen through genetic intensification. Some varieties are more efficient than others, but N-use efficiency is a complex trait with many components.

The most promising genetic approach is to utilise N-fixing bacteria that convert atmospheric ammonia to N using an enzyme, nitrogenase. The symbiotic forms of these bacteria, known as rhizobia, live in nodules on the roots, mostly of legumes such as peas, lupines, clover, and alfalfa. The crop plants furnish some of the products of their photosynthesis, and the bacteria reciprocate by supplying N.

Rhizobia already colonise the root zone of cereals, producing improvements in plant growth. This may have been the origin of root nodule symbiosis in legumes. To understand how to also enable nitrogen fixation in a similar fashion, the way forward may be to reconstruct their evolutionary process with legumes in order to duplicate this with wheat, rice, and other cereals. It will, however, take some time to identify the genes and engineer them into cereal varieties.

In summary, modern breeding can deliver new crop varieties and livestock breeds that not only are high yielders but also resilient to many different kinds of stress and shock. A combination of conventional approaches, tissue culture, marker-assisted selection and GM technology can be used to breed crops which can adapt to low levels of inputs, whether of water or nutrients, to a variety of pests and diseases and to the consequences of climate change, especially severe heat and drought. Breeders are now adept at combining these different attributes in single animals or seeds.


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In this way Sustainable Intensification can be made available to farmers, large and small, in a 'ready-to-use' fashion. The challenge is to ensure the new seeds and animals are accessible and affordable, are subject where appropriate to biosafety regulations, are provided with complementary inputs and supported by appropriate extension advice.

Socio-economic Intensification

Sustainable Intensification is not just about farming practices, technologies and husbandry. Adoption of new practices and technologies by farmers will only happen and persist if an appropriate enabling environment is supported that favours not only agricultural intensification but also its sustainability.

To this goal, socio-economic intensification is the process of developing innovative and sustainable institutions on the farm, in the community and across regions and nations as a whole. This encompasses improvements to the enabling environment and to social and human capital as well as to sustainable livelihoods.

African smallholders require equitable access to input and output markets and help with joining remunerative value chains. Without secure secure rights to land and they will not invest in improvements to their farms. Farmer associations, including cooperatives, outgrower and contract farmer groups, are essential if smallholders are able to exert their bargaining power.

Increasing productivity on current land will require significant investments in agricultural research and extension, in the road infrastructure that links farmers to markets and in the development of better rural services, including access to education and health care.

Creating Enabling Environments

A key component of an enabling environment is the creation of efficient, fair and transparent input and output markets and the connectivity that makes them work for smallholders (Fig. 7).

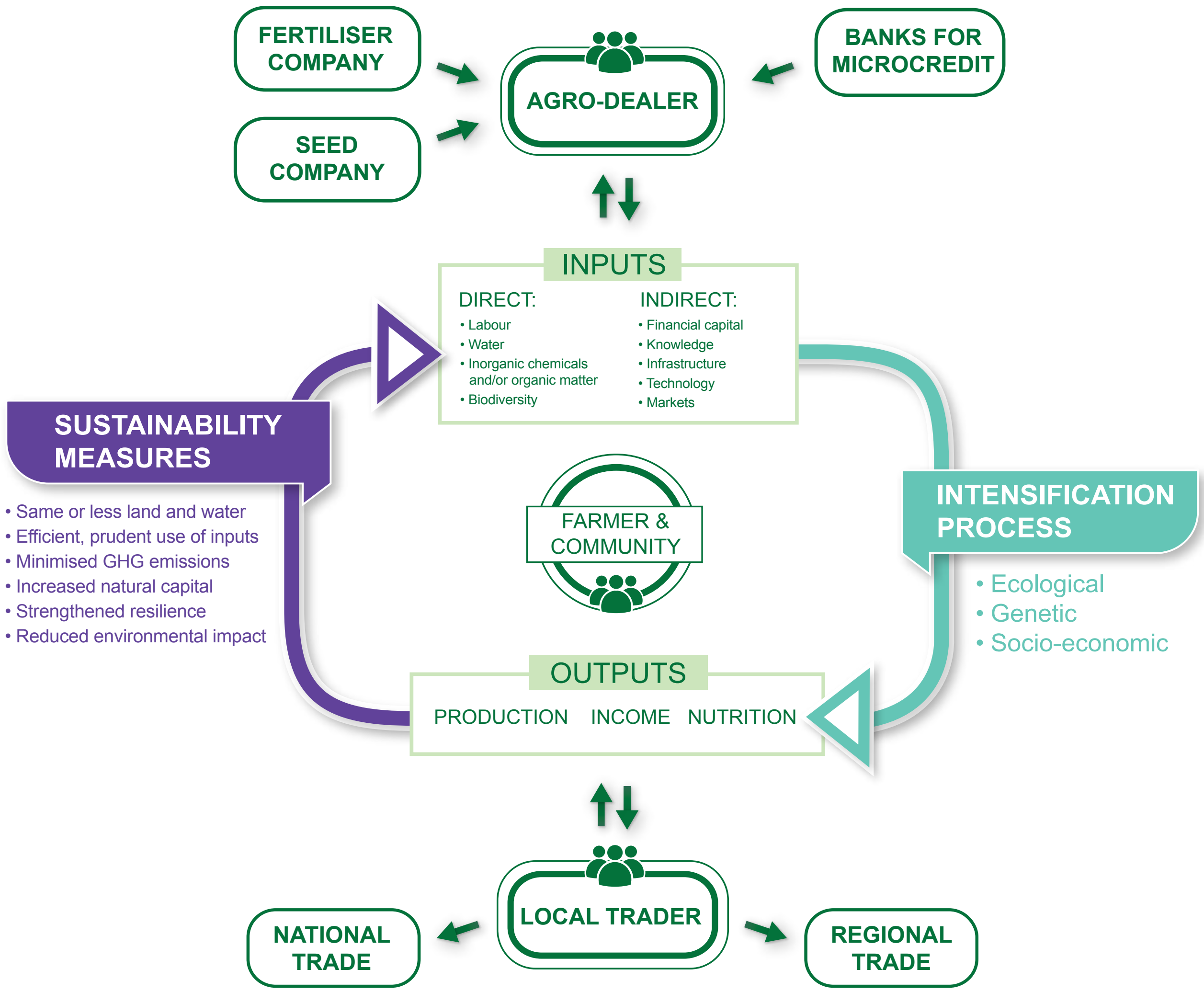

Figure 7 An enabling environment. Adapted from a model of the Alliance for a Green Revolution in Africa (AGRA).

A good example of the process of creating an appropriate enabling environment is a programme in northern Ghana supported by the Alliance for a Green Revolution in Africa (AGRA) (Box 15).

Box 15 An enabling environment for northern Ghana[64]

AGRA's strategy, produced in partnership with the Ghanaian Government, relies on strengthening local institutions and building working links both among them and with farmer organisations. Unlike many other development programmes, AGRA's support is essentially to facilitate and is neither top down nor dependent on the interventions of outside bodies and experts (although it does rely on supportive government policies and, in some circumstances, on advice from outside experts). It is this facilitatory approach that not only intensifies the relationships between the key actors but also makes the process sustainable.

Despite its relatively short operational history, the programme has seen significant progress in bringing in outside financial resources, in strengthening the capacity of locally based institutions, in creating agrodealers' networks and in establishing seed companies. Farmers themselves have also experienced significant increases in yields and in their cooperative bargaining power.

Markets

As part of this enabling environment, markets are key to reducing poverty; only through sustainable access to markets can poor farmers increase the income from their labour and lift themselves and their families out of poverty. Yet, most poor farmers are not linked to markets. Smallholders, in particular, often have little contact with the market and hence a poor understanding of, and ability to react to, market forces.

Markets in Africa are changing under the influence of a myriad of factors—urbanisation, population growth, increasing per capita incomes, changes in consumer preferences, the modernisation of food processing and retailing, as well as improvements in transport and communications infrastructure. Also, developing country farmers increasingly have become sources of commodities for large, multinational agri-food companies.

Agricultural produce markets have become highly differentiated, ranging from village markets selling locally produced, locally consumed staple crops to global markets selling packaged, off-season vegetables. This spectrum of markets offers new opportunities for smallholder farmers, yet it also poses heightened risks as well as new and difficult barriers to surmount.

One answer lies in creating village-level 'grain banks,' owned and run by a farmer association, for depositing their grain. The store is usually fumigated against pests, some grain is kept in case the owner needs it later in the year, and the rest is sold when prices seem right.

In such a system in Kenya, the marketing depends on having a countrywide network of small and large markets. This network is supported by the Kenya Agricultural Commodity Exchange (KACE), a private sector firm that provides farmers with prices and other market intelligence accessible to smallholders using a mobile phone short message service (SMS) system.

While efficient, fair and transparent *output markets* are crucial, smallholders also need efficient, fair, and transparent *input markets* where they can purchase the seed, fertilisers, machinery and other inputs they need, in appropriate quantities and at prices they can afford.

One approach pioneered initially by the Rockefeller Foundation and developed by AGRA is to facilitate the creation of village-level agrodealers (Box 16).

Box 16 Portrait of an agrodealer[65]

Flora Kahumbe owns two agrodealer shops at the south end of Lake Malawi. She was trained by the Rural Agricultural Market Development Trust (RUMARK) in the proper storage of seeds, fertiliser and chemical pesticides as well as their safe and appropriate application to achieve maximum effect.

More than just a shop owner, Flora is a private extension agent providing valuable knowledge to farmers on how to get the most out of the inputs they purchase. The Kenya Agrodealer Strengthening Programme (KASP) has built a network of agrodealers that covers 85 districts in Kenya's agricultural areas, accessed by 1.4 million farmers.

KASP also has been instrumental in improving agrodealers' access to finance through local microfinance institutions, and it advances agricultural policy by helping to create associations that advocate on behalf of small business agrodealers.

Building Social Capital

Social cohesion is critical for societies to prosper economically and for development to be sustainable. In essence, social capital defines the accumulated positive experiences of people working and inter-relating with each other, for example, farmers with each other, with people from other walks of life and with government officials. They build relationships based on trust and solidarity in order to achieve collective action and cooperation for the common good. This creates the confidence to invest in collective activities, knowing that others will also do so.

Farmer associations are examples of social capital created by smallholders to further their interests and their interactions with markets and other institutions in the wider world. With greater intensification of market linkages comes a heightened awareness of value chains and of the need to shift more of the value of produce to the hands of the farmers who produce it. Far too often for smallholders participating in the chain, the rewards are low and the risks are high. Often the situation is made worse by middle-men in market chains who transfer the risks to those with the least power, namely the smallholder farmers.

In this context farmer associations employ economies of scale to reduce risk and maximise collective incomes. Cooperatives are usually formal and registered; other collective groups are more informal. Examples include food, fodder or seed banks or other storage facilities managed by local communities; savings and credit groups; and even extended families.

For example, the development of farmer organisational structures in the Nakasongola district of Uganda has, in part, facilitated the adoption of disease-free cassava planting material and resulted in the transformation of the region from being food deficient to generating and selling a surplus.[66] Faso Jigi, a farmers' cooperative association in Mali, is another example which demonstrates some of these benefits (Box 17).

Box 17 Faso Jigi in Mali[67]

Faso Jigi was set up in 1995 with the aim of assisting smallholder producers of cereals and shallots in marketing their products by:

- Reducing transaction costs through economies of scale in storage and transportation,
- Disseminating market information to smallholders,
- Enabling access to technical advice,
- Making collective purchases of inputs,
- Advancing credit to smallholders against a commitment to deliver, and
- Creating an insurance fund.

Since its establishment, over 5,000 farmers in 134 cooperatives have become involved. Wholesalers prefer sourcing from Faso Jigi and are willing to pay higher prices because the association offers centralisation of stocks, better quality of storage facilities and accessibility.

But there are shortcomings; farmer associations can be exclusive, leaving out marginal groups such as widows, AIDS-affected households or ethnic minorities. They may also have to depend heavily on state support or on development agencies for their implementation and regulation.

Another, sometimes complementary, approach is through contract farming. This approach usually comprises a central processing or exporting agency purchasing the produce of a number of independent farmers, although the structure of the systems, the ways in which they operate and the overall objectives can vary. Such arrangements exploit economies of scale in both purchases and sales. Although evidence is scarce, contract farming can increase net revenue; for example, one study of contract farming in Kenya found that farmers received an average of 27% more net revenue per bird than independent farmers.[68]

Building Human Capital

At the core of sustainable socio-economic intensification is the development of the human capital of smallholder farmers.

The acquisition of skills, knowledge and experience occurs through both schooling and outside the formal education system. In low-income countries the social rate of return to primary schooling is very high (about 23%) and growth in knowledge can improve labour productivity and incomes. Given the proportion of the developing world engaged in the agricultural sector, estimated at over 65%, increasing human capital would be expected to bring about huge returns for both agricultural and economic growth. But this is heavily dependent on effective institutional arrangements as well as overcoming barriers such as those relating to ethnicity or gender.

Educating women is a crucial means of building human capital. While agriculture has been seen as essentially a male activity (and it is still common for agricultural extension workers to be male and to interact only with men), in recent years there has been growing recognition of women's critical importance in farm households.

Women account for half the production of food in developing countries. In SSA, where women and men customarily farm separate plots, this figure is as high as 75%, with the men concentrating their efforts on cash crops. African women are responsible for 90% of the work involved in processing food. Women's income also affects the food consumption of the household, since women typically spend a high proportion of their income on food and health care for children.

Women are thus a critical link between food production, consumption and future progress on food security: they are farmers, mothers, educators and innovators. Equal access to productive resources is thus essential. If women farmers had access to the same resources as their male counterparts, the number of undernourished people in the world could be reduced by 100 to 150 million.[69] Farmer Field Schools (FFS) – a form of adult, non-formal education and extension increasing farmer capacity and the spread of knowledge amongst communities – have shown to be especially beneficial for women. Participation in FFS in Kenya, Tanzania and Uganda has led to an average increase in income of about 60% with women constituting 50% of the participants.[70]

Lastly, the training of extension workers is also a potential driver of socio-economic intensification. Traditionally extension has been carried out by the public and private sectors, utilising a top-down 'Transfer of Technology' (ToT) model. More recently this service has been contracted out to NGOs and local community organisations. In Africa, many rural poor households are located in heterogeneous and complex areas and face numerous diverse risks, which require a more interactive extension system.

Indeed, the limited impact of traditional research and extension in Africa is thought to be partly due to the more simplistic and linear models that dominate.[71] In some cases programmes training farmers themselves to become informal extension agents have proved successful in building human capital, such as the example of Flora Kahumbe, an agro-dealer in Malawi, mentioned in Box 16, who was trained by RUMARK to be a private extension agent. Under the Malawi Agricultural Input and Output Development (MAIOD) programme and through the support of the Bill and Melinda Gates Foundation,[72] RUMARK has trained around 1500 such extension agents between 2001 and 2005.

Creating Sustainable Livelihoods

Sustainable Intensification is not only about farmers and their farms, but involves whole farm households. A recent survey of households in Rwanda has revealed the many challenges that households face if they are to escape poverty (Box 18).

Box 18 Household analysis in Rwanda[73]

The World Food Programme (WFP), in partnership with the Ministry of Agriculture and Animal Resources (MINAGRI) and the National Institute of Statistics of Rwanda (NISR), carries out a regular baseline survey of over 5000 households in Rwanda in order to "analyse trends of food insecurity and malnutrition over time, measuring their extent and depth and identifying their underlying causes".

The latest survey found that, in general, food production was increasing: markets were functioning relatively well and food movement within and outside the country was relatively free flowing due to a well-connected road network and market infrastructure.

But, a total of 21% of households are food insecure:

- A high percentage of these are in rural areas and where soils are less fertile and land is more susceptible to erosion.
- They are likely to farm small plots of land (less than 0.5ha) and rely on a small number of livelihood activities.
- The further households are located from a main road or market the more likely they are to be food insecure.
- They typically live in crowded housing and depend on low-income agriculture or casual labour.

Child malnutrition is also common:

- The prevalence of chronic malnutrition (stunting) in children between 6 months an 5 years is 'very high' at 43%.
- Stunted children are more likely to live in poor, crowded, rural households that are further away from key services.
- They often have young, lowly educated mothers who are stunted themselves.
- Children between one and two years who had consumed milk products were significantly less stunted than other children in the same age category.

The results of this survey suggest the following options for poor, food insecure households:

- Intensification and diversification of existing production patterns;
- Increasing farm size, where possible;
- Diversifying livelihoods through increased off-farm income, both agricultural and non-agricultural;
- Improving coverage and targeting of assistance and social protection safety nets;
- Upgrading household living conditions;
- Improving child malnutrition; and
- Complete exit from the agricultural sector.

These strategies are not mutually exclusive and can be used in concert within one household. While many African smallholders are already significantly diversified out of farming with off-farm income increasing food purchasing power, increasing the productivity of land holdings still offers the best prospects for escaping poverty and hunger for most smallholders, at least until such time as economic growth leads to much faster growth in off-farm jobs.

In Conclusion

In short, Sustainable Intensification can be relevant as a new paradigm for African smallholder farmers as long as suitable, sufficient resources and practices are supported and delivered at scale.

Often success can be achieved on a small scale – a plot or a farm – but often with only one or two of the economic, social and environmental objectives attained. The challenge lies in meeting all the objectives and in scaling up success to a regional or national production system.

African smallholders face many barriers to sustainably intensifying their incomes, their production and their nutrition, not least their physical access to the inputs of intensification, which may be limited for a variety of reasons. Land tenure must also be assured if smallholder farmers are to invest in Sustainable Intensification. Aside from security of rights to land, by women as well as men, intensification also requires a demand for the increased output, greater and more accessible financial investment (whether on a large scale or in the form of microcredit), available labour, better knowledge and skills and access to both input and output markets.

Although the concept of Sustainable Intensification is relatively simple, experience suggests it is difficult to achieve, especially in its entirety – namely, using a more sophisticated set of inputs of all kinds while increasing outputs. One such difficulty is the responsible and efficient use of inputs. For farms in the developed world this may mean a decrease in their application, but for many farmers in SSA, who use virtually none of these inputs, a prudent and precise increase in their use can intensify production without forfeiting resilience and sustainability.

The challenges are complex as are the technologies and processes required to find appropriate solutions. The paradigm of Sustainable Intensification shows the way forward. What is needed is research into appropriate innovations (technological and socio-economic), targeted financial investments and public-private partnerships, active participation in the process by smallholder famers and, above all, political leadership.

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(Footnotes)

1 Land as a direct input is excluded here as its increase in area is technically defined as extensification, a process constrained by land availability, described above.

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All Panel members serve in a personal capacity.

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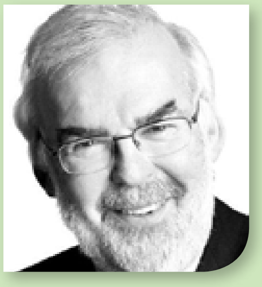
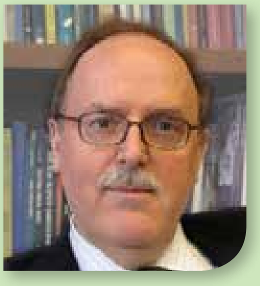


Tom Arnold
Chair of the Convention of the Irish Constitution and former Chief Executive, Concern Worldwide



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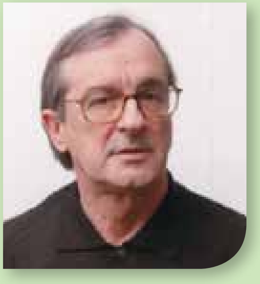

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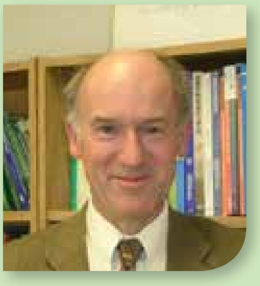

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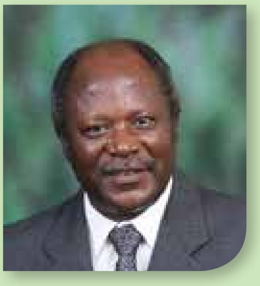

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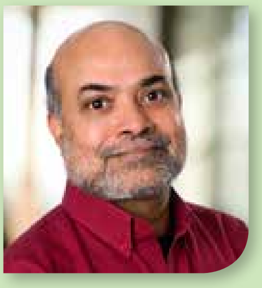

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