CAN SUSTAINABLE AGRICULTURE FEED AFRICA? NEW EVIDENCE ON PROGRESS, PROCESSES AND IMPACTS

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Abstract. Africa faces enormous food security challenges. Most commentators agree that, despite the complexities of food insecurity, there will have to be increases in food production from existing agricultural land. Most, too, are pessimistic about the future, judging likelihood of success on the basis of past performance of 'modern' agricultural development. Sustainable agriculture, though, offers new opportunities, by emphasising the productive values of natural, social and human capital, all assets that Africa either has in abundance or that can be regenerated at low financial cost.

This paper sets out an assets-based model of agricultural systems, together with a typology of eight improvements that are currently in use in sustainable agriculture projects. In the 45 projects/initiatives spread across 17 countries that are investigated, some 730,000 households have substantially improved food production and household food security. In 95% of the projects where yield increases were the aim, cereal yields have improved by 50–100%. Total farm food production has increased in all. The additional positive impacts on natural, social and human capital are also helping to build the assets base so as to sustain these improvements in the future.

This analysis indicates that sustainable agriculture can deliver large increases in food production in Africa. But spreading these to much larger numbers of farm households will not be easy. It will require substantial policy, institutional and professional reform.

Key words: natural capital, social capital, sustainable agriculture

1. The scale of the challenge

As the new millennium approaches, the world faces a massive food security and production challenge. Although the world population currently stands at 5.9 billion people, the UN Population Fund (1998) projects increases to 7.5 billion by 2020 and to 8.4 billion by 2050, by which time 84% of the world's population will be in those countries that currently make up the 'developing' world.

Today there are 828 million people lacking adequate access to food, of whom 25% are in sub-Saharan Africa (210 million), 31% each in E & SE Asia and in south Asia (258 and 254 million), 7.6% in Latin America and the Caribbean, and 5% in north Africa and near East (Pinstrup-Anderson and Cohen, 1999, this conference). Prospects for Africa do not appear to look good. As population grows and puts more pressure on natural resources, so it is expected that food insecurity will also grow. Within sub-Saharan Africa, some 39% of people are malnourished; and FAO (1996) indicates that Africa as a whole will see an increase in food insecurity to 2010 whilst the rest of the world see continuing progress (predicted to fall to 680 million by 2010). The number of hungry children in SSA will increase by 24% to 39 million by 2020 (over 1995 levels).

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Most commentators agree that food production will have to increase, and that this will have to come from existing farmland (cf IFPRI, 1995; FAO, 1995; Leach, 1995; Conway, 1997). Many predictions are gloomy, indicating that the gap between demand and production will grow. Again, African countries face some of the greatest challenges. Past approaches to agricultural development have not been sufficiently successful. Since the mid-1960s, per capita food production has fallen by about 20% – the only region in the world to experience such a fall. Agricultural productivity is low, economic stagnation widespread, political instability persistent, and environmental damage increasing.

Solving hunger is not simply a matter of developing new technologies. Most hungry people are poor, and they simply do not have the money to buy the food they need. Poor farmers also cannot afford expensive technologies. And if they cannot afford them, no amount of ‘modern’ technology developed by companies or research establishments seeking to make a financial return will make any difference for them. They will have to find solutions based on existing resources.

Yet Africa already has a great wealth of both natural resource assets and social capacity to solve these agricultural challenges. This paper analyses recent evidence on sustainable agriculture in Africa. Such sustainable agriculture offers new opportunities for substantial increases in food production in precisely those regions that have missed out in the past. But this time, instead of having to rely on costly external inputs (which of course can be effective, but only if farmers can afford them and national systems can deliver them), the improvements are based on improved configurations and use of natural, social and human capital assets.

2. An assets-based model for agricultural systems

Economic systems at all levels, from farms, livelihoods, communities and national economies, rely for their success on the value of services flowing from the total stock of natural, social, human, physical and financial capital (Coleman, 1990; Putnam, 1993; 1995; Costanza et al., 1997; Daily, 1997; Carney, 1998; Pretty, 1998; Pretty and Ward, 2000). These are:

1. Natural capital – nature’s free goods and services, and comprises food (both farmed and from the wild), wood and fibre; water regulation and supply; waste assimilation, decomposition and treatment; nutrient cycling and fixation; soil formation; biological control of pests; climate regulation; wildlife habitats; storm protection and flood control; carbon sequestration; pollination; and recreation and leisure.
2. Social capital – the cohesiveness of people in their societies, and comprises relations of trust that lubricate co-operation; the bundles of common rules, norms and sanctions for behaviour; reciprocity and exchanges; connectedness and social institutions.
3. Human capital – the status of individuals, and comprises the stock of health, nutrition, education, skills and knowledge of individuals; access to services that provide these, such as schools, medical services, adult training; the ways individuals and their knowledges interact with productive technologies; and the leadership quality of individuals.

4. Physical capital – local infrastructure, and comprises housing and other buildings; roads and bridges; energy supplies; communications; markets; and air, road, water and rail transportation.
5. Financial capital – stocks of money, and comprises savings; access to affordable credit; pensions; remittances; welfare payments; grants and subsidies.

These five assets are transformed by policies, processes and institutions to give desirable outcomes, such as jobs, welfare, economic growth, clean environment, sustainable use of natural resources, reduced crime, better health and schools, and so on. If achieved, these desirable outcomes then feed back to help build up the five capital assets. Where they are undesirable, such as pollution or deforestation, or increased crime or social breakdown, they reduce the asset base.

The basic principle is, therefore, that sustainable systems accumulate stocks of these five assets. They increase the capital base over time. But unsustainable systems deplete or run down capital, spending it as if it was income, so liquidating assets and leaving less for future generations.

The assets-based model described in Figure 1 shows how farms, rural livelihoods and communities take the five types of asset, both renewable and non-renewable, and transform these to produce food and other desirable outputs. These can be processed for home consumption, transformed through value-added processes for sale, or sold directly as raw

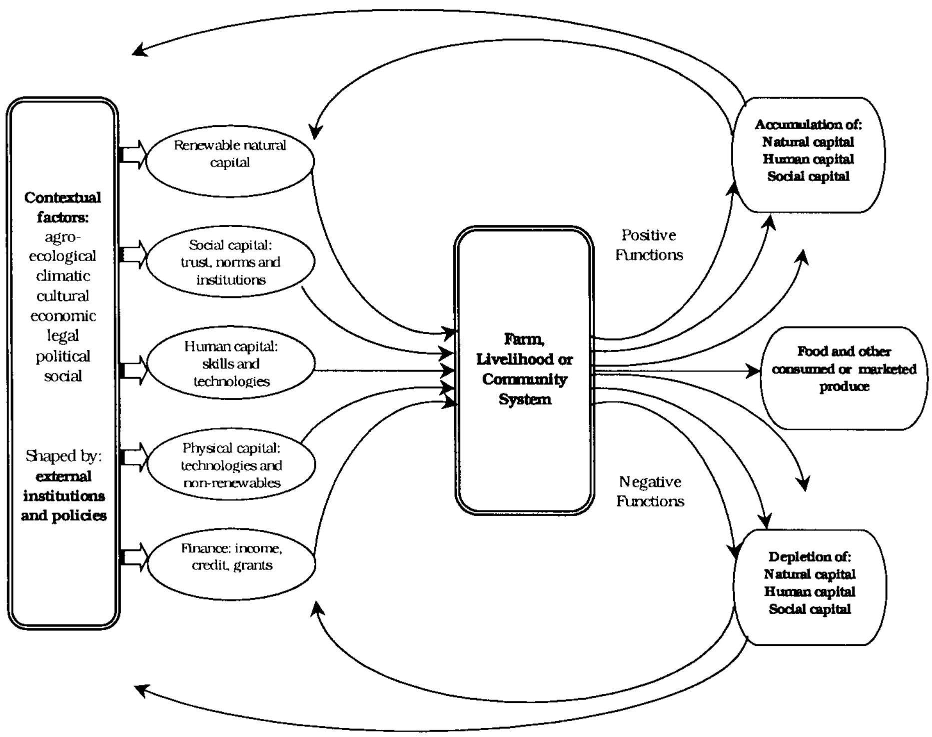

Figure 1. Assets-based model of agricultural systems.

product. The inputs are shown as:

i. Renewable natural capital – soil, water, air, biodiversity; and including regenerative technologies (e.g. legumes, natural enemies);
ii. Social capital – including both locally embedded and externally-induced social capital, and partnerships and linkages between external organisations, and renewable through a range of participatory processes;
iii. Human capital in the form of skills and knowledge – both technical (indigenous and externally-derived) and social (e.g. leadership)
iv. Physical capital, in the form of non-renewable technologies (e.g. hybrid seeds, machinery), fossil-fuel derived inputs (e.g. fertilisers, pesticides, antibiotics, fossil-fuels), and investments in roads and infrastructure (e.g. markets, storage facilities);
v. Financial capital in the form of credit, remittances, income from sales and grants.

Availability and access to these five assets is shaped by a wide range of contextual factors. These include unchanging ones (at least over the short-term), such as climate, agro-ecology, soils, culture; and dynamic economic, social, political and legal factors shaped by external institutions and policies. These contextual factors are an important entry point for shaping and influencing agricultural systems and their assets' base (such as national policies, markets, trade).

Agriculture, though, does more than just produce food. It has a profound impact on many other aspects of local, national and global economies and ecosystems. These impacts can be positive or negative. A fundamental principle of sustainable systems is that they do not deplete capital assets, whilst unsustainable ones deplete them (Goodland, 1998; Butler-Flora, 1998). More sustainable agricultural systems, therefore, tend to have a positive effect on natural, social and human capital whilst also producing food, fibre, oil, etc. A vital feedback loop occurs from outcomes to inputs: agricultural systems impact on the very assets on which they, together with many other sectors of economies, rely on for inputs.

For example, an agricultural system that depletes organic matter or erodes soil in order to produce food externalises costs that others must bear; but one that sequesters carbon in soils through organic matter accumulation both contributes to the global good by mediating climate change and the private good by enhancing soil health. Equally, a diverse agricultural system that protects and enhances on-farm wildlife for pest and disease control contributes to wider concerns about biodiversity and genetic conservation, whilst simplified systems that eliminate wildlife do not.

Agriculture is, therefore, fundamentally multi-functional. It delivers many unique non-food functions that cannot be produced by other economic sectors so efficiently. A key policy challenge is clearly to find ways to enhance food production, whilst seeking both to improve the positive functions and to eliminate the negative ones. This will not be easy, as past agricultural development has tended to ignore both the multi-functionality of agriculture and the external costs. Fortunately, there has emerged in recent years much evidence to illustrate that it is indeed possible to produce more food and more natural, social and human capital. Ironically, though, much of this has occurred without, or even despite, significant or intentional policy support.

3. Agricultural modernisation and transformation

The process of agricultural modernisation during the 20th century has produced three distinct types of agriculture: industrialised, Green Revolution, and all that remains – the pre-modern, 'traditional' or 'unimproved' (Chambers et al., 1989; Pretty, 1995). The first two types have been able to respond to modern technological packages, producing highly productive systems of agriculture. Their conditions were either like those where the technologies were generated, or else their environments could easily be homogenised to suit the technologies. These systems tend now to be endowed with access to roads and urban markets, modern crop varieties and livestock breeds, inputs, machinery, marketing infrastructure, transport, agroprocessing facilities, credit, and water supply.

Most agricultural systems in industrialised countries are high-external input systems, save for the relatively small number of organic farmers (Lampkin, 1999). In developing countries, modern high-input systems tend to be monocrop and/or monoanimal enterprises geared for sale, and so include lowland irrigated rice, wheat and cotton; plantations of bananas, pineapples, oil palm, sugar cane; market gardening near to urban centres; and intensive livestock rearing.

The third type of agriculture comprises all the remaining 'pre-modern', 'traditional' or 'unimproved' agricultural systems. Farming systems are complex and diverse, and cereal yields are low – typically only 500–1500 kg ha^{-1}. They are remote from markets and infrastructure; located on fragile or problem soils; and are unlikely to be visited by agricultural scientists and extension workers or studied in research institutions. The poorest countries, in particular the low income food deficit countries, have higher proportions of these agricultural systems. By the mid-1990s, some 30–35% of the world's population, about 1.9–2.1 billion people, were still directly supported by this third agriculture (Pretty, 1995).

Figure 2 illustrates the emphasis in the assets-based model for industrialised systems. They have become efficient transformers of technologies, non-renewable inputs and finance to produce very large amounts of food, but with substantial negative impact on capital assets (e.g. reduced natural capital, diminished labour).

This raises several questions about what constitutes success. Wheat yields in India and Pakistan grew from 1.2 to 2.5 and 1.8 t ha^{-1} respectively from 1970 to 1995, and in Mexico from 3 to 4.2 t ha^{-1}; rice yields in China grew from 3 to 5 t ha^{-1}, in India from 1.6 to 2.8 t ha^{-1}, and in the Philippines from 2.2 to 4 t ha^{-1}; and maize yields in Latin America as a whole grew from 1.5 to 2.5 t ha^{-1} (Conway, 1997). In Europe, per hectare yields of wheat, barley and other grains, potatoes and sugar beet have tripled over fifty years, while milk yields have more than doubled. And these are just averages – increases on many individual farms are far greater (Pretty, 1998).

But it is an illusion to suggest that these kinds of improvements have resulted only in benefits. Environmental and health problems associated with agriculture have long been documented (cf Balfour, 1943; Conway and Pretty, 1991), but it is only recently that the scale has come to be appreciated. One problem is that there is no single accounting measure which can be used to assess the multi-faceted nature of both benefits and costs.

In the 1970s and 1980s, energy was seen by many as that measure (Leach, 1976; 1985; FAO, 1976; Pimentel et al., 1989), and it is clear that sustainable systems of production are

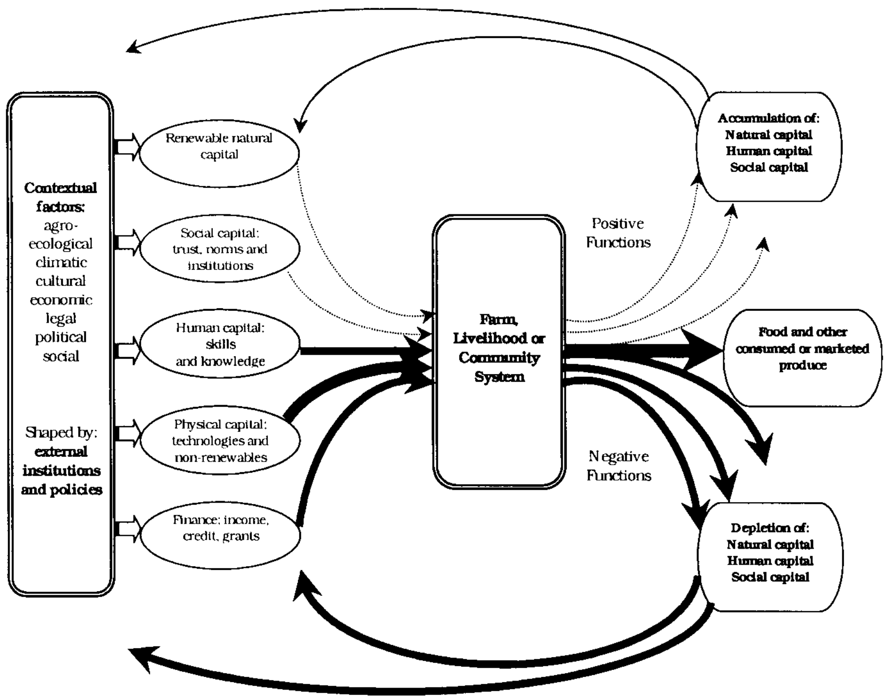

Figure 2. Assets-based model of agricultural systems – flows and outcomes in modernised systems.

much more energy efficient than modern high-input systems. Low-input or organic rice in Bangladesh, China, and Latin America can produce 1.5–2.6 kg of cereal per MJ of energy consumed, which is some 15–25 times more efficient than irrigated rice produced in Japan or the USA. On average, sustainable systems produce 1.44 kg of cereal per MJ compared with just 0.26 kg MJ^{-1} in conventional systems (Pretty, 1995). Energy balance remains a good, but not the only, indicator of sustainability.

In the 1980s and 1990s, the discipline of environmental economics increasingly sought to put monetary values on benefits and costs. This has helped greatly in understanding the scale of costs, so that clearer comparisons between more or less sustainable systems can be made (Pearce and Turner, 1990; EEA, 1996; 1998). There have been several recent studies on the external costs of modern agriculture in Germany, UK and the USA (Pimentel et al., 1992; 1995; Waibel and Fleischer, 1998; Fleischer and Waibel, 1998; Steiner et al., 1995; Pretty et al., 2000). The first to assess the costs of the environmental and health externalities arising from UK agriculture put annual external costs in the 1990s at GBP 2340 million (Pretty et al., 2000). The annual costs arising from all 11.28 million ha of arable land and permanent grassland (but not including rough grazings) amount to GBP 208 ha^{-1}.

The success of modern rice cultivation has also proven to be partly illusory. IRRI researchers investigated the health status of Filipino rice farmers exposed to pesticides, and found statistically significant increased eye, skin, lung and neurological disorders (Rola and Pingali, 1993; Pingali and Roger, 1995). Rola and Pingali calculated the health costs of these pesticide problems, and compared the economics of various pest control strategies. The so-called 'complete protection' strategy, with nine pesticide sprays per season, returned less per hectare than the other two control strategies, and cost the most in terms of ill-health. Any expected positive production benefits of applying pesticides were overwhelmed by the health costs.

4. The transition to sustainable agriculture

What then do we understand by sustainable agriculture? And how then can we encourage transitions in both 'pre-modern' and 'modernised' systems towards greater sustainability? Sustainable farming makes the best use of nature's goods and services whilst not damaging the environment (Altieri, 1995, 1999; Thrupp, 1996; Pretty, 1995, 1998). It does this by integrating natural processes such as nutrient cycling, nitrogen fixation, soil regeneration and natural enemies of pests into food production processes. It minimises the use of non-renewable inputs (pesticides and fertilisers) that damage the environment or harm the health of farmers and consumers. And it makes better use of the knowledge and skills of farmers, so improving their self-reliance and capacities (Figure 3).

Sustainable agriculture is multi-functional within landscapes and economies – it produces food and other goods for farm families and markets, but it also contributes to a range of public goods, such as clean water, wildlife, carbon sequestration in soils, flood protection,

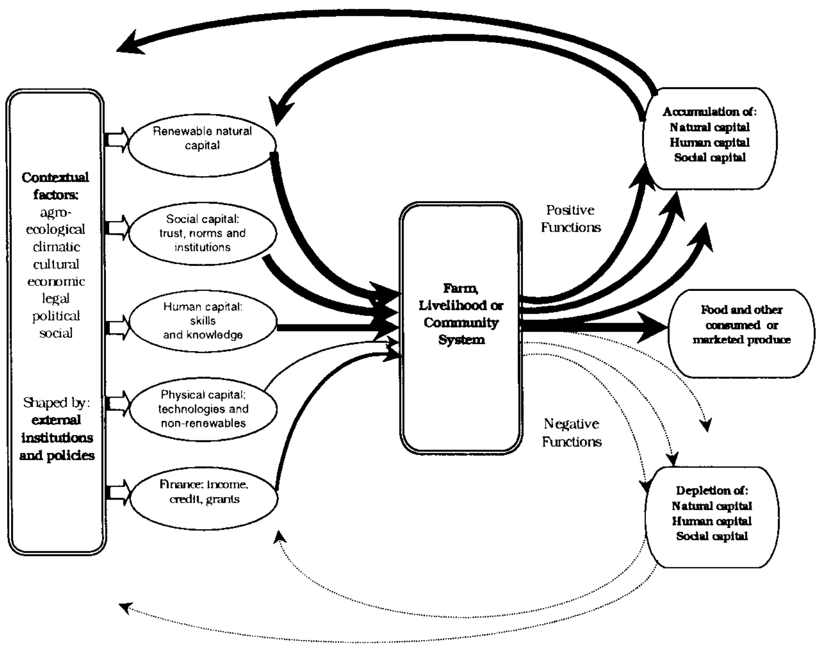

Figure 3. Assets-based model of agricultural systems – flows and outcomes in sustainable systems.

TABLE I. Typology of improvements for sustainable agriculture.

Improvement type	Description	Elements
Type 1	Finance	• Access to credit, grants, subsidies • Increased returns on sales of produce • Attract new sources of money for natural capital (e.g. eco-tourism, hunting of wildlife)
Type 2	Better use of non-renewable inputs and technologies	• Precision-farming, patch spraying, targeted inputs and slow-release for pesticides and fertilisers • Low dose (and non-toxic) sprays • Veterinary services • Pheromones, sterile males • Resistant crop varieties and livestock breeds • Machinery, handtools, ploughs • New cash crops, including energy crops
Type 3	Better use of available renewable resources (natural capital)	• Water harvesting • Soil and water conservation – e.g. contour cropping, terraces, minimum tillage, grass strips • Composting, livestock manures • Irrigation scheduling and management • Restoration of degraded or abandoned land • Rotational grazing • Habitat management for pest-predators • Drainage systems and sub-soiling • Raised beds or chinampas • Bio-pesticides and bio-fungicides
Type 4	Intensification of single sub-component of farm system	• Double-dug beds • Vegetables on rice bunds • Kitchen gardens • Fish ponds • Micro-environment improvements, e.g. gully cropping, silt traps
Type 5	Diversify by adding new productive natural capital and regenerative components	• Legumes in cropping systems (cover crops, green manures) and pastures • Integrated livestock (e.g. poultry, stall-fed ruminants etc.) • Fish in rice fields; Azolla in rice • Trees in cropping systems, including woodlots • Natural enemy releases for pest control • Habitat management, e.g. hedgerows, beetle banks, flowering strips
Type 6	Social and participatory processes that lead to organised group action for making better use of existing resources and development of new skills	• Farmers' research and experimentation groups • Resource management and users' groups (e.g. forest protection, fisheries, irrigation, watersheds) • Credit groups • Horizontal partnerships between external sectoral agencies (e.g. government and NGOs; private and public)
Type 7	Add value by processing to reduce losses and increase returns	• Post-harvest technologies • Processing primary produce before sale (e.g. dried fruit, chutney, oil press, sawmills) • Fuel-efficient stoves
Type 8	Add value by direct or organised marketing of produce to consumers	• Farmers' markets • Box schemes, farm shops and direct mailing • Community supported agriculture • Producer groups for collective marketing • Rural roads and infrastructure

landscape quality. It delivers many unique non-food functions that cannot be produced by other sectors (e.g. on-farm biodiversity, urban to rural migration, social cohesion).

A desirable end-point for both modern and pre-modern agricultural systems is clearly some design that enhances both the private benefits for farmers and the public benefits through other functions. Transitions in agriculture are often conceived of as requiring sudden shifts in both practices and values. But not all farmers are able or willing to take such a leap. However, everyone can take small steps, and small steps added together can bring about big change in the end (MacRae et al., 1993; Pretty, 1998).

But where do we start? Drawing on the assets-based model, a typology of eight improvements has been developed to illustrate where adjustments towards sustainability can be made (Table I).

Some projects/initiatives focus on one or two of these types of improvement; others on a larger number. Although evidence suggests that adopting one of these types of improvement can result in substantial benefits, this may not alone be enough to say that a system is now sustainable.

For example, water harvesting in dryland areas may produce in greater yields, but result in a net loss of nutrients. Precision-farming technologies can result in substantial reductions in pesticide and fertiliser use in modern systems, largely through reduced wastage, but may have little long-term effect if farmers assume this is all they have to do to become sustainable. Reducing waste is clearly a step towards sustainability, as negative impacts have been reduced, but this is not the same as making a positive impact on natural capital.

5. Sustainable agriculture in Africa: review of the evidence

Africa probably faces the greatest challenge of any continent with respect to food security, poverty and the environment. Agricultural production is low, economic stagnation widespread, political instability persistent, and environmental damage increasing. Large numbers of farmers still rely on ‘pre-modern’ systems of agriculture. There appear to be two options for Africa:

i. improve agriculture through modernisation, by emphasising pesticides, fertilisers, machinery and modern varieties and breeds;
ii. improve agriculture by emphasising the eight improvements listed in Table I.

Some have grave doubts that sustainable agriculture can deliver the necessary improvements in food production (Crosson and Anderson, 1999). Others have sought to redouble efforts to increase adoption of modern technology and inputs (cf Borlaug, 1992; 1994a,b; Sasakawa Global 2000, 1993–98). The argument is that farmers simply use too few fertilisers and pesticides, and the rhetoric is strong. Norman Borlaug, Nobel laureate, said in 1992 that agriculturalists ‘*must not be duped into believing that future food requirements can be met through continuing reliance on . . . the new complicated and sophisticated “low-input, low-output” technologies that are impractical for the farmers to adopt.*’

Clearly these ‘modern’ technologies can and do improve productivity. But the key questions are, given current levels of poverty, economic instability and lack of foreign exchange, are countries of Africa really likely to be able to take on this model? And if they do, what would be the external environmental and health costs? These pessimists would have us believe there are no alternatives – but evidence increasingly suggests otherwise.

This paper analyses 45 projects or initiatives from 17 countries in Africa drawn from the The University of Essex database on sustainable agriculture[1]. This represents a selection of known cases of improvement chosen for geographic spread and the trustworthiness of data on processes and outcomes. The list contains brief details of the types of improvements adopted in each project/initiative, and the key impacts on food production. It is important to note that such a ‘reductionist’ list does not do full justice to any of these cases, particularly where the outcomes have been positive on so many aspects of natural, social and human capital. Table II summarises the findings.

There follows a more detailed summary of eight of these cases:

Case 1. Mucuna (velvetbean) cover cropping in Benin
Case 2. Cheha Integrated Rural Development Project, Ethiopia
Case 3. Association for Better Land Husbandry, Kenya
Case 4. International Centre for Insect Physiology and Ecology, Kenya
Case 5. Ministry of Agriculture, Kenya
Case 6. Machobane Farming System, Lesotho
Case 7. Soil and Water Conservation in Niger
Case 8. Chivi Food Security Project, Zimbabwe

TABLE II. Summary of findings from 45 cases of sustainable agriculture in Africa.

45 projects drawn from 17 countries	Number of farm households and area under sustainable agriculture	Yield improvements of existing components	Additional production in system
Benin, Burkina Faso, Cameroon, Ethiopia, Ghana, Kenya, Lesotho, Madagascar, Malawi, Mali, Niger, Senegal, Sudan, Tanzania, Uganda, Zambia, Zimbabwe	• 730,000 farm households • 600–900,000 ha under sustainable agriculture	• Maize yields up 50–100% (i.e. up by a half to a doubling) • Sorghum/millet up 30–100% (depending on rainfall, and access to manures and fertilizers) • Rice yields – comparable for IPM; up 300% for SRI • Banana yields up 50–100% • Potato yields up 200% • Milk production up • Lowest yield increases 5–10%	• Vegetable production throughout the year (including dry season) • Fish production up • Land restored for cereal production (especially in drylands)

These have been selected, not because they are in any sense the ‘best’, but because they illustrate how key synergies have been released, how paradigms in thinking were broken down, (both among farmers and professionals), and how institutions have reformed to work differently.

CASE 1. MUCUNA (VELVETBEAN) COVER CROPPING IN BENIN (ORIGINAL SOURCE BOB CARSKY AND V MANYONG, IITA)

This is an example of the introduction of a simple regenerative component into farm systems combined with increasing farmers’ capacity for local-adaptation of the technology. The spread of mucuna (*Mucuna pruriens*) for suppression of the aggressive weed imperata (*Imperata cylindrica*) has occurred because of land scarcity, decline in soil fertility, lack of fertiliser, and weed encroachment. Soils on the plateaux of southern Benin and Togo are nearing exhaustion. Fertiliser use is low among the large class of smallholder farmers. But even if fertilisers were available, the benefit from their use is declining because of a degrading soil resource base. Another consequence of the reduced fallow periods is encroachment of imperata, an aggressive weed that is very difficult to eradicate by hand. Researchers with the Recherche Appliquee en Milieu Reel project introduced mucuna cover cropping to alleviate the constraint of low nutrient supply to maize, the staple crop.

The government extension services (Centre d’Action Regional pour le Developpement Rural – CARDER) became interested in this success and started testing the system. In 1990, the CARDER for Mono Province tested the system in 12 villages with 180 farmers. They expanded to other southern provinces in 1991 and the number of farmers testing mucuna grew to approximately 500. Large NGOs became involved and the estimated number of farmers testing mucuna grew to nearly 100,000 in 1996 throughout Benin.

Farmers who adopted mucuna cover cropping benefited from higher yields of maize with less labour input for weeding: maize following mucuna yields 3–4 t ha^{-1} without application of nitrogen fertiliser (similar to yields normally obtained with recommended levels of fertilisation at 130 kg N ha^{-1}); whilst yields on plots previously planted with maize and cowpea was 1.3 t ha^{-1}. Mucuna as an intercrop or as a sole crop provides more than 100 kg N ha^{-1} to the following maize.

The benefit : cost analysis over a period of 8 years indicated a ratio of 1.24 when mucuna was included in the system, and 0.62 for the system without mucuna. The ratio was as high as 3.56 if mucuna seeds were sold. However, yearly analysis of the benefit : cost ratio indicated a declining trend over time for all systems suggesting that addition of external inputs (probably P and K fertiliser) are required in order to achieve full sustainability. Adoption of mucuna throughout the Mono Province would result in savings of about 6.5 million kg of nitrogen or about USD 1.85 million per year.

CASE 2. CHEHA INTEGRATED RURAL DEVELOPMENT PROJECT, ETHIOPIA (ORIGINAL SOURCE: FOOD FOR THE HUNGRY INTERNATIONAL)

This is an example of an integrated and relatively small-scale project making a substantial impact on regional food security. It has been working in south-west Ethiopia since the drought of 1984, and has introduced new varieties of crops (vegetables) and trees (fruit and forest), promoted organic manures for soil fertility and botanicals for pest control, and introduced veterinary services. Some 12,500 farm households have adopted sustainable agriculture on about 5000 ha, resulting in a 70% improvement of overall nutrition levels within the project area, along with a 60% increase in crop yields. Some farmers have begun to produce excess crops which they sell in local markets, earning much needed income for their families. Thus an area once reliant entirely on emergency food aid has now become able to feed itself and have enough left over to contribute to surplus. The real promise of the programme, however, lies in the fact that farmers are replicating activities on their own initiative (including those outside the project area), where once they had to be encouraged to participate through food for work payments.

CASE 3. ASSOCIATION FOR BETTER LAND HUSBANDRY, KENYA (ORIGINAL SOURCE: PERS. OBSERVATION, 1997, 1999, 2000; JIM CHEATLE PERS. COMM.; PRETTY, 1997)

The ABLH is supported by the UK Department for International Development and promotes low cost methods of conservation-based farming that reduce poverty, improve rural people's livelihoods and boost rural economies. It works on the premise that systems of sustainable and productive land use can be developed largely with the existing skills, knowledge and social organisation of rural people. It facilitates the formation of self-help groups of farmers, promotes sustainable agriculture technologies to these groups, helps them to market the outputs, and helping them to find ways to process and pack produce so as to retain greater added-value. It is engaged in business development, supporting community factories, and developing certification schemes and farmers' own brands to give produce better returns in local and national markets.

The approach to sustainable agriculture is called 'near nil investment'. The basic principle is that poor rural families do not have the financial resources to invest in farm improvements. What they need are ways to boost productivity and income by making the best use of available human and natural resources. The technologies proven to work are concerned with the regeneration and recycling or organic matter for soil management, and the use of natural pesticides such as neem. The aim is to find ways to maximise returns from these technologies, and then 'top-up' with externally-sourced fertilisers and pesticides where necessary and safe. Other low-investment resource-conserving technologies and practices are also made available to farmers, including beekeeping and agro-forestry. Most activities are currently focused on homegardens, though progress is also being made with field crops such as soya and sunflower.

Double dug beds combined with composting, green and animal manures improve the soil. A considerable investment in labour is required, but the better water holding capacity and higher organic matter means that these beds are more productive, more diverse and are able to sustain vegetable growth long into the dry season. Once this investment is made, little more has to be done for the next 4 to 6 seasons (2–3 years). Many vegetable and fruit crops are cultivated, including sukumawiki and other kales, onions, tomatoes, cabbage, passion fruit, pigeon peas, spinach, peppers, green beans and soya.

Self-help groups have found that their family food security has improved substantially since adopting conservation farming. Before, they had to use cash when they were short of food in the dry season to pay for maize and vegetables. They had to sell their labour, rely on remittances from family members working elsewhere in the country, or sell cash crops. They would have to do this at a time when food prices were high and labour and cash crop prices low. Many also relied on collecting wild foods from forests. But now, families have found that by working more on their own farms rather than selling labour to others, they are getting greater returns. They have found that investment on their own farms in natural capital pays better returns in food production. Casual hiring out of labour has virtually disappeared among SHG members. Children have been major beneficiaries, as their health has improved through increased vegetable consumption and longer periods of available food.

CASE 4. INTERNATIONAL CENTRE FOR INSECT PHYSIOLOGY AND ECOLOGY, KENYA (ORIGINAL SOURCE: HANS HERREN, PERS. COMM., ICIPE ANNUAL REPORTS AT WWW.ICIPE.ORG)

The work of ICIPE is explicitly focused on designing low-cost integrated pest management technology. It works closely with farmers to test and adapt technologies. It is also producing unexpected synergistic effects through manipulation of agricultural systems and the paradigms that define them. ICIPE approaches sustainable plant pest management on four major fronts:

- biological control, using one organism to control another;
- botanical agents, natural pest control compounds that are derived from plants;
- habitat management, manipulating the cultivated and natural environment to preserve the pest–natural enemy balance and richness of species;
- pest-tolerant varieties of major food crops that deter insect damage.

One activity is investigating novel habitat management approaches to suppress cereal stem borer and *Striga* populations in maize and sorghum. This project is developing novel ‘push–pull’ strategies to repel stem borers from the cereal crop and attract them to intercrop or barrier forage grasses. It has found extra-ordinary multi-functionality in a range of fodder grasses and legumes in cereal systems.

The strategy involves trapping pests on highly susceptible trap plants (pull) and driving them away from the crop using a repellent intercrop (push):

1. The forage grasses, *Pennisetum purpureum* (Napier grass) and *Sorghum vulgare sudanense* (Sudan grass), attract greater oviposition by stem borers than cultivated maize.
2. Non-host forage plants, *Melinis minutiflora* (molasses grass) and *Desmodium uncinatum* (silver leaf) repel female stalk borers (*Chilo* spp.).
3. Intercropping with molasses grass (*Melinis minutiflora*) increases parasitism, particularly by the larval parasitoid, *Cotesia sesamiae*, and the pupal parasitoid *Dentichasmis busseolae. Melinis* contains several physiologically active compounds. Two of these inhibit oviposition (egg laying) in *Chilo*, even at low concentrations.
4. Molasses grass also emits a chemical, (*E*)-4,8-dimethyl-1,3,7-nonatriene, which summons the borers’ natural enemies.

5. Napier grass also has its own defence mechanism against crop borers: when the larvae enter the stem, the plant produces a gum-like substance kills the pest.
6. Sudan grass also increases the efficiency of the natural enemies (the parasitism rate on larvae of the spotted stemborer, *Chilo partellus* more than tripled, from 4.8% to 18.9% when the grass was planted around maize in a field and from 0.5% to 6.2% on *Busseola fusca*, another important pest).
7. ICIPE has found that intercropping maize with the fodder legumes *Desmodium uncinatum* (silver leaf) and *D. intortum* (green leaf) reduced infestation of parasitic weed, *Striga hermonthica* by a factor of 40 compared to maize monocrop. Reduction in S*triga* infestation by intercropping maize with the two species of *Desmodium* was significantly more than intercropping maize with soybean, sun hemp and cowpea.

Such 'push–pull', using the attractive plants as trap crops and repellent plants as intercrops, reduces stem borer attack and increases levels of parasitism of borers on protected maize, resulting in a significant increase in yield. Farmer participatory trials in 1997 and 1998 have shown significant yield increases in maize. The aim is now to develop a maize-based cropping system that will reduce yield losses due to both stem borer and *Striga* and at the same time improve soil fertility due to nitrogen-fixing action of *Desmodium*. Such a redesigned and diverse system has many of the characteristics of 'traditional' shambas (farms) in Kenya.

Further ICIPE research is showing the effectiveness of neem to control weevils in bananas, diamondback moth in brassicas, and fruitborers in tomatoes; is developing resistant cultivars based on traditional germplasm; is showing the value of sterile male release for fruit fly control; and is demonstrating control of the stemborer, *Chilo partellus*, through identification of a natural enemy from Pakistan, the parasitic wasp *Cotesia flavipes* (Chilo was accidentally introduced from Asia in the 1930s, and has no co-evolved local natural enemies), which has now been released in Kenya, Mozambique, Uganda, Zambia and Somalia.

CASE 5. MINISTRY OF AGRICULTURE, KENYA (ORIGINAL SOURCES: PERS. OBSERVATION; MOA/MOALDM ANNUAL REPORTS 1989–1999; PRETTY ET AL., 1995)

Kenya has a long history of state intervention in both soil and water conservation and land management. Early approaches focused on providing cash payments to encourage farmers to construct the labour-intensive measures such as cut-off drains and artificial waterways. But by the end of the 1980s, it had become clear that the conventional approach to soil and water conservation was unable to meet the prevailing environmental challenge.

The Government of Kenya recognised that the only way to achieve widespread conservation coverage was to mobilise people to embrace soil and water conserving practices on their own terms. All financial subsidies were stopped, and resources allocated instead to participatory processes, extension, training, tools and farmer trips. It adopted in 1989 the Catchment (or Area of Concentration) Approach. This is seen as a way of concentrating resources and efforts within a specified catchment (typically 200–500 ha) for a limited period of time (generally one year), during which all farms are laid out and conserved with full community participation. Small adjustments and maintenance would then be carried out by the community members themselves with the support of local extension agents.

Participatory methods imply shifts of initiative, responsibility and action to rural people themselves. Interdisciplinary teams drawn from various government departments work for about a week in the catchment. These teams often include officers from MALDM, as well as those from other departments and ministries, including Education, Environment, Fisheries, Forestry, Public Works, Water Development, and Health. They sometimes include staff of local and international NGOs who are actively working in the catchment. Following the Rapid Catchment Analysis phase, a Catchment Conservation Committee of farmers is elected as the institution responsible for co-ordinating local activities. A Catchment Report is prepared, which serves as a baseline document for planning, implementation, monitoring and evaluation, and for co-ordinated action by extension professionals based at Divisional and District level.

The Catchment Approach brings significant benefits over the individual farmer approach. The number of farms fully conserved each year in Kenya with various SWC measures has risen with the Catchment Approach from 59,450 (with doubts about sustainability) in 1988 to some 100,000 in the mid-1990s.

The process of implementation of the Catchment Approach itself has varied according to the human resources available and differing interpretations of the degree of participation necessary to mobilise the catchment community (Pretty et al., 1995). The impacts vary according to the quality of the interaction between extension staff and local people. When participation in planning and implementation is interactive, the impacts are substantially greater than when participation is simply consultative.

In an interactively planned catchment, an interdepartmental participatory rural appraisal is conducted to launch the catchment, which includes a *baraza* for presenting back findings and developing joint plans. The catchment committee is freely elected, and includes both men and women. After the catchment has been completed, the committees tend to remain active and committed to maintenance and replication. In conventionally planned catchments, the *baraza* is held mainly for publicity purposes, the catchment committees are more frequently selected by local leaders, and women rarely participate. The committees tend to become inactive soon after intensive contact with extension staff ends.

CASE 6. MACHOBANE FARMING SYSTEM, LESOTHO (ORIGINAL SOURCE: ALBERTA MASCARETTI, FAO)

The Machobane Farming System is an example of a fundamentally redesigned system yielding multi-functional benefits. Lesotho is severely affected by erosion and land degradation. During the last 20 years, arable land fell 14 to 9% of the country's total area, and crop yields are now about half the 1970s level. Dr. J.J. Machobane, a Mosotho agronomist, first conceived his system over 40 years ago, experimenting on his own land for 13 years before attempting to launch it amongst fellow farmers. Unlike most extension methods, the Machobane approach starts with the basic behavioural requirements for adopting its technical message:

- self-reliance – farmers must be convinced that they can achieve food security without external assistance;
- appreciation of the resource base – farmers must be ready to work hard, and be convinced that they can improve crop production by fully exploiting their resource base;
- learning and teaching by doing – farmers must be trained on their own fields and farmer trainers must be ready to do work along with them;
- spontaneous technology spreading – farmers learn from other farmers, and Machobane farmers have the duty to help their neighbours.

In Lesotho mountain areas, most crops are grown on terraced land, but poor soil structure, inadequate soil fertility management and erratic rainfall, mean that land productivity is low and variable. According to Machobane, these constraints can be overcome by rational exploitation of the resource base and minimising the need for purchased inputs. The technical elements include intercropping, localised placement of ash (from household waste) and manure, weeding, introduction of potato as a cash crop, preservation of natural enemies, row-rotations, and legumes with cereals.

Farmers adopting the MFS indicate three advantages of the system: (i) higher land productivity (0.4 ha per family needed for food security compared with the more normal 1.2 ha); (ii) large cash income obtained by planting potato; and (iii) better resistance to drought: their fields are green compared to non-Machobane fields during drought. In addition, MFS will substantially reduce farm income fluctuations through the combination of lowering yield fluctuations of individual crops, spreading risk of fluctuations in yields and prices by planting a larger range of crops and decreased reliance on imported inputs (fertilizers and pesticides). Some 2000 farmers are now practising this system.

CASE 7. SOIL AND WATER CONSERVATION IN NIGER (ORIGINAL SOURCE: ALBERTA MASCARETTI, FAO; REIJ, 1996; HASSAN, 1996)

The IFAD-funded soil and water conservation in Illéla district is an example of a key sustainable agriculture technology having substantial multi-functional benefits whilst improving formerly degraded or abandoned lands. Some 5800 ha of abandoned and degraded lands on the farms of some 6000 households in 77 villages have been improved with the adoption of tassas (also known as zaï in Burkina Faso). Large-scale erosion control measures were not successful in the region.

Tassas are 20–30 cm holes dug in soils that have been sealed by a thin surface layer hardened by wind and water action. Since this crust prevents infiltration by water, these areas are usually abandoned, devoid of vegetation, scattered with outcroppings of iron crust, and are prime sites for surface erosion. The holes are filled with manure, since soils in this region are normally lacking in organic matter. This also helps to promote termite activity during the dry season, so further enhancing infiltration. When it rains, the holes fill with water and farmers then plant millet or sorghum. Tassas are normally used in conjunction with stone bunds, taking advantage of the stones that farmers remove from fields for planting. These methods of soil and water conservation were learned by farmers of Illéla on a visit to Yatenga in Burkina Faso where, on the central plateau alone, some 100,000 ha have been restored – each now producing some 700–1000 kg of cereal per year. According to Hassan (1996), yields of millet without tassas, demi-lunes and contour stone bunds are of the order of 150–300 kg ha^{-1}. They rise to 400 kg with manure in a poor rainfall year, and 700–1000 kg ha^{-1} in a good rain year. Addition of some fertiliser increases yields again – to 650 kg ha^{-1} in poor years and 1400–1500 kg ha^{-1} in good ones.

This soil-development activity has allowed the region to attain average millet yields of 480 kg ha^{-1}, reaching levels of up to 700 kg ha^{-1} if chemical fertiliser is added (an as-yet uncommon practice). Comparatively, fields of similar quality levels produced only 130 kg ha^{-1} According to IFAD, food availability in participating households rose between 20% and 40%, depending on local rainfall conditions. Reij (1996) indicates that the average family in Burkina Faso and Niger using these sustainable agriculture technologies have shifted from being in annual cereal deficit amounting to 644 kg (equivalent to 6.5 months of food shortage) to producing a surplus of 153 kg per year.

Tassas are best suited to landholdings where family labour is available, or where farm hands can be hired. The technique has spawned a network of young day labourers who have mastered this technique and, rather than migrating, they go from village to village to satisfy farmers' growing demands. There are cases of land being bought back by farmers who recognised early on the profit that can be earned from this land.

Three key factors have contributed to the development and dissemination of this technology in the farming community:

- An action-research approach that combines flexibility, openness to farmer initiatives, a forward-looking attitude and willingness to negotiate.
- A technology that combines the core benefits of innovation: immediate results, simplicity, ability to be integrated into existing cropping systems, and replicability.
- A technological package that can adjust to the changing local context.

CASE 8. CHIVI FOOD SECURITY PROJECT, ZIMBABWE (ORIGINAL SOURCE: INTERMEDIATE TECHNOLOGY DEVELOPMENT GROUP)

This ITDG project is located in southern Zimbabwe, which falls into Zimbabwe's lowest categories of agricultural potential, and where drought occurs in three out of every five years. An approach which combined low-cost regenerative technologies with building farmers' capacities to participate in research, extension and within group structures has meant that now farmers report that their yields have more than doubled (up 100%) since the project was initiated in 1991. The main technologies are water harvesting (tied ridges and infiltration pits) and the adoption of clay pipes and ferro-cement rings for subsurface irrigation of women's vegetable plots. Some 35 women's garden clubs for raising and selling vegetables are now effective and families have become food secure with the greater range of produce spread through the year. According to some community participants '*food security is no longer a problem*'.

The multi-functional benefits of the project include farmers have acquired new skills for food production; local institutions have been strengthened in tackling their own problems; transformative training has increased confidence among local people, particularly poorest groups; increased involvement of women in community decision-making; greater capacity amongst farmers to articulate their needs to service providers, and research and extension systems have become more responsive to farmers' needs.

6. Key lessons learned – accumulating assets does pay

What does the empirical evidence tell us about these eight types of improvement? It indicates that (i) productivity increases with increasing number of improvements, and (ii) productivity increases with time if as natural, social and human capital are accumulated.

Each type of improvement, by itself, can make a positive contribution to raising production. However, the real dividend comes with combinations. As Uphoff (1999) comments with respect to the system of rice intensification (SRI) in Madagascar: '*no practice by itself makes as big a contribution to higher output as when the practices are used together. Rather than being just additive, we find a multiplicative effect*'. Synergistic effects tend not to be captured or appreciated by reductionist methods of analysis that measure the effects of one variable at a time, whilst holding all the others unchanged (the *ceteris paribus* approach). But this misses synergism – where the whole is greater than the sum of the parts.

Thus soil and water conservation that emphasises terracing and other physical measures to prevent natural resource losses is much less effective than combinations with biological methods that seek to increase the productivity of the system (e.g. green manures, cover crops), and finance for credit groups that reduces indebtedness of households.

There is a danger, however, in that this begins to sound a little like 'integrated rural development' – a now discredited term owing to the great expenditure on IRDPs in the 1970–1980s (Carney, 1998). The key difference, though, relates to process and who does the designing. If 'integrated' systems are entirely designed (or even imposed) by external professionals with little regard to local people's needs, desires and constraints, then they are more likely to fail. But if 'redesign' emerges from a participatory process, then it is much more likely to be robust and sustainable.

The second issue is time. If agricultural systems are low in capital assets (either intrinsically low, or have become low because of degradation), then a sudden switch to 'more sustainable' practices that has to rely on these assets will not be immediately successful – or at least not as successful as it might be.

In Cuba, the productivity and efficiency of sustainable agriculture increased over a three-year period – yields increased (number of people fed by one ha up from 4 to 4.8), energy inputs declined, and human labour requirements declined (SANE, 1998, in Altieri, 1999).

This is also clear in industrialised systems when farmers make the switch to strictly organic farming. This almost always results in a large cut in productivity (typically 30–50% for cereals), and economic viability is only maintained through grants from governments and/or receipt of premium prices from consumers. But despite the limited number of longitudinal studies, yields do appear to increase over time as soil fertility improves, as predator numbers increase, and as elements of the system increasingly are able to provide valued services to farmers (Dabbert, 1990; Lampkin and Padel, 1994; see also Tilman, 1998; Drinkwater et al., 1998).

The same principle applies for accumulation of social capital. The past decade has seen the emergence of more than 300,000 local resource management groups worldwide – for irrigation and watershed management, forest protection, integrated pest management, and farmers' research (Pretty and Ward, 2000). What is particularly interesting is when comparisons have been made in the same context (with the same set of technologies in use), between farmers working in groups and those working individually, it is clear that social capital (in the appropriate form) pays – both for private returns to farmers and public benefits to natural resources.

Sustainable agriculture systems also become more productive when human capital increases, particularly in the form of farmers' capacity to innovate and manage actively their farm systems for sustainable outcomes. Sustainable agriculture is not a concretely defined set of technologies, nor is it a simple model or package to be widely applied or fixed with time. It is more a process for social learning. Lack of information and management skills is a major barrier to the adoption of sustainable agriculture. We know much less about these resource-conserving technologies than we do about the use of external inputs in modernised systems. In addition, much less research on resource-conserving technologies is conducted by research institutions.

It is clear that the process by which farmers learn about technology alternatives is crucial. If they are enforced or coerced, then they may only adopt for a limited period. But if the process is participatory and enhances farmers' capacity to learn about their farm and its resources, then it appears that the foundation for redesign and continuous innovation is laid. As Bunch and Lòpez (1996) have put it '*what needs to be made sustainable is the social process of innovation itself*'.

7. The next 10,000 years of African agriculture?

It is clear that sustainable agriculture in Africa, in its form envisaged here, can deliver substantial increases in food production at low cost. In the 45 cases, some 730,000 farm households have already substantially increased total farm productivity. Were these approaches to be widely adopted, they would make a significant impact on local and regional food security.

A 50–100% increase in basic grain yields is clearly possible with sustainable agriculture. With access to some fertilisers, this dividend would increase further. These increases are combined with additional increases in production arising from better utilisation of formerly unproductive or low-productive elements of farm or community systems. Note though that an increase in yields on existing farm components may not be necessary if additional productive components are added (such as fish ponds, vegetables in double-dug beds, cereals on restored land). The total production is the important measure, and sustainable agriculture systems are almost always more diverse and more multi-functional than both 'modern' and 'pre-modern' ones.

These increases in yields may only be the start of improvements, as synergistic and asset accumulation effects are expected to increase the dividend over time.

But there are clearly major constraints to overcome. Population growth will continue to present many challenges. There will also be losers along with winners, and these losers are powerful players. This model for Africa's second 10,000 years' of farming implies a limited role for agro-chemical and seed companies. They are unlikely to accept such a loss of market lightly. It also suggests greater decentralisation of power to local communities and groups, combined with more local decision-making. This means reduced opportunities for rent-seeking and other forms of corruption from officials in private and public organisations. Research and extension agencies will have to change too, adopting more participatory approaches to work closely with farmers, and so must adopt different measures for evaluating job success and the means to promotion.

But the most fundamental current constraints centre on national policies. The only country in the world with an explicit national policy supporting sustainable agriculture is Cuba. Most countries have elements of 'green' policy – but none seeks to make the most of the synergism on offer when policy is integrated in the same way as sustainable practices on the farm. Greening the edge of national agricultural policies will simply not deliver as much as greening the middle. This may come as no surprise, given the lack of empirical evidence to date – 'sustainable agriculture might sound good, but does it really work?'

But even if the intention is present for both policy reform and for putting it into effect, there are still many threats to overcome or avoid if sustainable agriculture is to succeed and spread. These include lack of land tenure or security, civil disorder and wars, institutional inertia, the backlash from potential losers (when 'the empire strikes back'), macro-economic decline of whole countries or even regions, and climatic change and disruption (e.g. from El Nino patterns).

Nonetheless, there are fewer excuses now. National agricultural policies that put sustainable agriculture policies firmly centre stage, with appropriate support, incentives, and institutional reform, would begin to see African countries and their people reap substantial dividends.

Notes

[1] University of Essex database is currently under development as part of the SAFE-World research project – The Potential for Sustainable Agriculture to Feed the World.

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