Beyond competition

Pathways for Africa's agricultural development

Prem Bindraban, Erwin Bulte, Ken Giller, Holger Meinke, Arthur Mol, Pepijn van Oort, Peter Oosterveer, Herman van Keulen & Meike Wollni

Report 242

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For quality of life

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Plant Research International B.V., Wageningen
April 2009 Report 242

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Acknowledgements

The study has been carried out at the request of and funded by the Dutch Ministry of Agriculture, Nature and Food Quality.

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Summary

The food situation

Food insecurity in sub-Saharan Africa (sSA) has been alarming for decades with one in three people undernourished. These 240 million people continue to suffer under business as usual. With almost 70% of the population living in rural areas and dependent on agriculture, this sector needs full support, to contribute to the Millennium Development Goals of halving poverty and hunger by 2015. The international community has development of Africa south of the Sahara high on the agenda with revived attention for the important role of agriculture in poverty reduction and hunger alleviation. The sub-continent has not experienced a green revolution.

Although food supply could be raised substantially on current agricultural lands by increasing production efficiencies of crops and animals, this is constrained by the enormous variability of production factors, risks in the food chain, lack of political stability, infrastructure support, capital investment and knowledge. These co-limitations are providing a tremendous challenge for targeted development investments. Further, expansion of agricultural lands will be needed to provide an adequate diet for the growing population. The need to use the current and future production potential of the continent more efficiently will further intensify because of the increasing claims on the continent's resources by developed and emerging economies to satisfy their increasing demand for agricultural commodities, including food, feed, fibre and fuel. While this might pose a threat, proactive adaptation measures might help rural Africa to capitalise on this increasing demand.

Sub-Sahara Africa will continue to face both internal and external challenges. African nations should devote attention to development of specific institutional and managerial skills, knowledge networks and technologies to effectively negotiate and manage these challenges. Africa should be given the opportunity to set its own priorities, rather than being driven by vested national or international interests, and leapfrog development to avoid increased competition for its scarce resources.

Agricultural development

All developed and developing nations have realised an agricultural revolution prior to the development of the industrial and service sector, which implies that agriculture serves as a stepping stone towards an overall improvement of living standards. So far, however, countries in sSA favoured strategies for the development of their industrial sectors, primarily mining activities. Revenues from exports of natural resources have not been re-invested in economic development and the agricultural sector was neglected. The continent is further beset with a range of biophysical problems (climate variability and change, low soil fertility, pest and diseases), unfavourable socio-economic conditions (including internal and external policies), and a lack of hard and soft infrastructure to support a vibrant agricultural sector. Disappointments with attempts up to the 1980s to enhance productivity may have caused the reduction in foreign aid for African agriculture over the past two decades, and the already inadequate amounts of national funding of research and development have even been declining. Structural Adjustment Plans that pinned faith on markets as the institutional framework to spearhead development were unsuccessful, with sometimes even devastating impacts, such as the collapse of the seed sector. There is, therefore, no one-size-fits-all solution, with available technologies alone being ineffective without appropriate institutional and market support.

The production base and diversity challenge

A sound analysis for estimating the production base must be founded on principles of production ecology. This will establish benchmarks to compare the current levels of productivity to those that would be achievable via changes in farming practices and institutional settings. Currently the productivity of arable land in sSA is so low that food production barely suffices to provide an adequate diet for the population. The agricultural sector in sSA has hardly intensified, and the increase in food volume was largely achieved by expansion of the cultivated area, in contrast to other continents where per area yield increases were the main driver for increased food production (Figure S1).

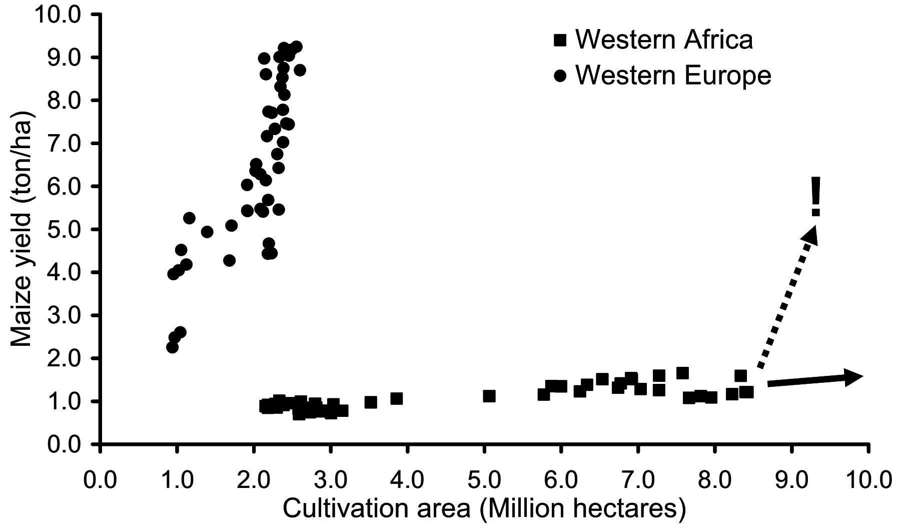


Figure S1. Illustration of the different routes through which the increase in food volumes have been realised. This holds for virtually all crops, even those native to sSa. Dotted arrow indicates desired yield increase strategies to minimize claims on additional land.
Source: FAO data.

These different pathways result from differences in the ease to increase yield, and the support from institutional economic conditions. The green revolutions in the OECD countries occurred in areas with favourable biophysical conditions. In these regions, rainfall is reliable or irrigation is feasible. Productivity on soils with favourable characteristics was further increased through the application of fertilisers. Pest, diseases and weeds were effectively controlled. Hence, production environments were adjusted to the needs of plants and animals, aided by favourable policies that stabilized prices and market conditions and created supportive institutions.

In contrast, yields in sSA remained low due to continuous production without inputs that led to depletion of soil fertility that is already low and differs within short distances, erratic rainfall patterns and high pest, disease and weed pressures. The combined impact of all these factors leads to a very high production risk, including frequent total crop failure and death of animals. This adverse situation is further exacerbated by unfavourable socio-economic and institutional conditions, and the absence of hard and soft infrastructure. These unfavourable conditions are not unique to sSA, but occur also in southern Asia for instance or in production systems with limited control of production factors, such as upland rice. Increasing yield is much more cumbersome as location-specific agronomic interventions are required, supported by more effective and diverse market and institutional conditions.

Through optimal agronomic management changes supported by sound policies, current production could be doubled or tripled if the variable rainwater resources were properly managed, soil nutrients adequately applied and crops protected from weeds, pest and diseases (Figure S2). This would suffice to provide the current population with an adequate diet. However, achieving this productivity increase, if realized, would take decades. The potential for expanding the irrigated area to increase production volumes is limited. Of the 183 million hectares of agricultural land in sSA, only about 9 million is under some form of water management and only an additional 3 million hectares could be profitably converted into irrigated production. Any expansion of agricultural land must be carefully planned to respect land rights, and prevent exploitation of fragile eco-systems (e.g. biodiversity), possibly resulting in irreversible environmental damages and carbon emissions.

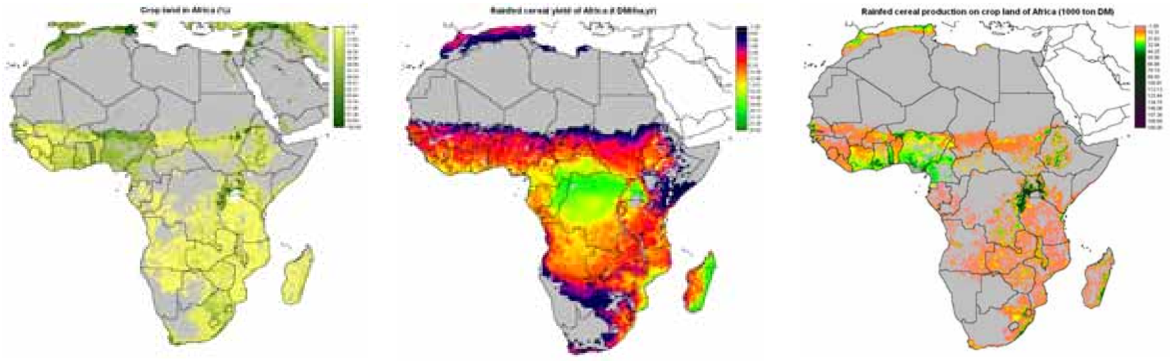


Figure S2. *Calculated ecological production potentials based on rainfed agriculture.*

A. Current distribution of agricultural land (From dark to light green - decreasing fraction of grid is agricultural land).

B. Maximum attainable biomass production under rainfed conditions on the entire continent.

C. Production volumes on current agricultural lands.

Source: Conijn et al., 2009.

The interaction of the high biophysical variability (spatial and temporal) and diverse economic and poor institutional conditions have resulted in a myriad of production systems that are essential to cope with the low and highly variable productivity base. Soil fertility is, for instance, extremely low and differs within short distances, rainfall patterns are highly erratic, and pest and disease pressures are high, resulting in high production risks, including frequent total crop failure and death of animals. The resulting production systems are complex with often ten to fifteen crops grown simultaneously within the same farming system, often in combination with animal husbandry. These complex systems provide a multitude of risk management strategies designed to cope with the existing variability. Many of these production systems entail a high degree of risk aversion, representing a basic, yet effective safety first' survival strategy (Figure S3). While this strategy might ensure bare survival under adverse conditions, it also impedes development. Under favourable conditions, it often results in sub-optimal production levels, as farmers cannot afford to risk valuable inputs such as seed or fertilisers. This severely limits production in favourable seasons, creating a gap between attainable and attained production outcomes. Changing socio-economic conditions (population pressure, increasing competition for scarce resources, particularly water) often aggravate the situation, making agriculture in many places barely viable, in spite of its crucial role for food security and societal development.

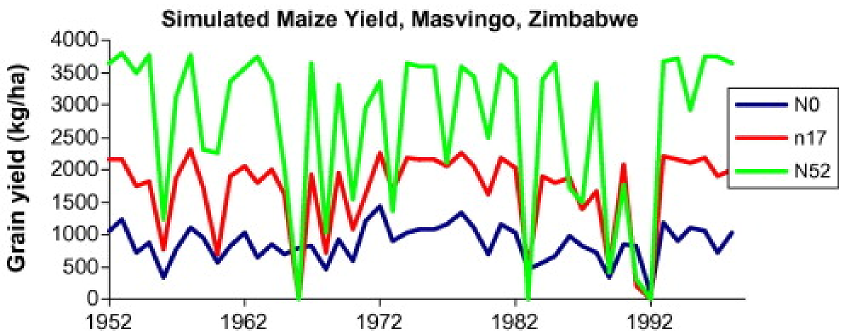


Figure S3. *Average yield increases with increasing fertilizer application (kg N/ha), but so does yield risk. Effective management of the variable rainwater is essential to reduce yield risk.*

Source: Twomlow et al., 2008.

Shaping conducive conditions

While high diversity might impede rapid development of the agricultural sector, we must acknowledge its importance in a region characterised by high spatial and temporal variability. Even under such circumstances, the basic concept underlying the success of the green revolution still holds: enabling technologies that are designed to suit local biophysical and social conditions are needed to lift productivity (Figure S4). The challenge in the case of sSA is that this will require a much wider range of these enabling technologies, than, for instance, in the rice and wheat based cropping systems of Asia. Biophysical production factors, economic and institutional conditions should be shaped in such a way to create a low risk investment climate for agriculture. This will require a combination of measures to control larger, systemic risks (e.g. agricultural insurance schemes) while taking advantage of the high diversity of production systems. First and foremost, however, is that civil wars and conflicts need to be prevented, to avoid further human suffering and to ensure stability and create the pre-conditions needed for investment in sustainable agricultural development.

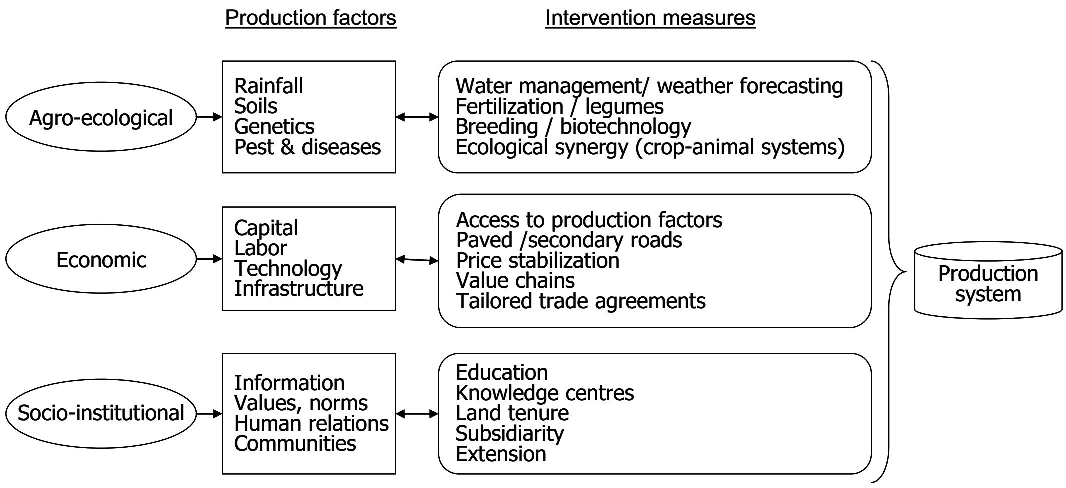


Figure S4. Production systems are a consequence of complex interaction of agro-ecological and economic conditions within a socio-institutional environment.

Agro-ecology

Agronomic practices need to be flexible and account for site-specific conditions. For instance, to improve soil fertility farmers need to purchase fertilizer. Given their lack of cash to purchase such production inputs, fertilizers could be made available in small quantities and with varied compositions to raise the production potential of the most promising fields. In combination with the application of manure, this can be a very effective strategy to increase production. Legumes play a catalyzing role in enhancing the overall low fertility of African soils through stronger integration in production systems. Phosphorus and micronutrients should be specifically considered to prevent imbalances in fertilization and nutritive value of agricultural produce. The development of integrated water management practices that optimize rainwater use in combination with small and medium scale water storage should reduce production risks. This is critically important because the irrigation potential in sSA is limited.

Climate Risk Management

Seasonal climate forecasting can provide a step towards better water management. A high quality forecast can provide farmers with alternative management approaches that do not change their intrinsic risk profiles while capturing so far unrealised benefits during the better seasons. This is feasible, because sSA's highly variable climate is at least partially predictable. sSA is dominated by the African monsoon, a subset of the global monsoon system. Much is known about these systems and their predictability, including some local peculiarities that need to be considered in order to predict regionally specific monsoonal features such as onset, duration and spell characteristics. Such knowledge forms the basis for the existing predictability of climate variability and change across sSA, a potential that remains largely untapped.

Advanced breeding technologies are needed to deal with the wide variety of crops and production constraints. The diversity of cropping systems creates opportunities for better integrated pest, disease and weed management, but will require better education and information. Intensification of animal production should be balanced with crop production, because of the low productivity of grasslands. Hence, all agro-technical means available to improve crop and animal performance and that of the farming system, should be embraced, including the use of agro-chemicals and advanced technologies including biotechnology and information technology, as well as integrated approaches.

Economic conditions

Technological innovations will only be adopted if simultaneously measures are taken to improve access to a range of production resources, including labour, capital, inputs, land, etc. Understanding the constraints faced by farmers is important to develop policy measures that facilitate such access. This might include the provision of credit, the development of input markets and the provision of technical assistance among others. In this context, technologies as well as institutions need to be designed to meet the specific conditions in sSA and to prevent large imbalances in development that might result from some farmers not adopting these new technologies. Design of microfinance institutions and repayment schemes might offer the right incentives for repayment, provided they are tailored for sSA's socio-economic conditions.

In traditional commodity markets price volatility is often high. Small-scale farmers that are unable to bear this risk only devote a small part of their land to commercial agriculture or opt out of the market altogether. To supply the growing urban population, however, a dynamic development in domestic food chains is lead by supermarkets. Recent experience shows that the engagement of farmers in high-value markets is difficult due to the high quality requirements and compliance with strict criteria. Steady demand from supermarkets stimulate vertical integration and is biased towards large scale production to secure quality and quantity, but might still offer an opportunity for small scale farmers provided they realise lower per-unit costs and secure adequate volume and quality. Much of the risks faced by farmers are the result of farmers relying on a single buyer. Small-scale farmers require technical assistance and information to adapt their production to the demands of specialized markets. A promising approach for providing this support is through producer organizations.

Another promising approach for fostering market opportunities is the expansion of regional trade. Currently, only 9% of the agricultural imports come from farmers located within the region. Regional production of food that replaces imported food in distributed aid could generate a secure market outlet with fair prices to local producers. However, for regional trade to expand, major infrastructural constraints need to be overcome. For farmers to be able to respond to markets, basic conditions should be put in place through government intervention, including infrastructure, education, market information, etc. Targeted policies can help kick start markets for instance by stabilising prices through buffer stocks. Cost and price stabilizing measures should be country and crop-specific, in order not to jeopardize the profitability of domestic agricultural production. As such, 'infant crop' arguments with temporary trade restrictions can lead to long term overall economic benefits over short term gains. For least developed countries in sSA to engage in international markets and to provide access to their markets a country-specific pace of liberalisation should be pursued. In WTO rounds, African countries should be strongly represented in order to shape their own policy and development path, which might constitute a departure from 'Washington consensus' style recommendations based on liberalization and deregulation.

Institutional arrangements

Properly functioning institutions should secure access to means of production (capital, labour, land, and knowledge/technology) and to markets (infrastructure, communication and information on price and quality, etc.). Social capital, trust and institutions vary widely across sSA. They have been shaped by historic and current political governance, peace/conflict, culture, economic situation and the like. These societal characteristics heavily affect the functioning of institutions that can support or hinder advances in poverty reduction. Collective actions, such as cooperatives to enhance the integration of farmers to markets, are based on trust and commitment, but have performed weakly in the past. Problems with conventional research and extension lies in the process of generating and transferring technologies, as they need complementary organizational, political and other changes to be effective. It is suggested that a pluralism of extension models are endorsed to fit the different contexts. Innovative extension approaches, such as farmer field schools that directly involve farmers in field testing and technology adoption, and close linkages between policies, farmer organisations and research institutions. Rural associations could act as intermediaries between policy makers thereby identifying key requirements for pro-poor growth through agriculture. A stronger voice for small farmers is essential to increase their bargaining power and to generate improvements in the food distribution systems between farmers, traders, supermarkets and governments.

Coordinated decision-making at micro, meso and macro levels is essential to improve conditions across all scales. To embrace diversity, delegation of responsibilities is important and central authorise should engage only in those tasks that cannot be performed effectively at intermediate or local levels. The optimal level of decentralisation is critical to balance interests of various groups. This will vary from country to country and should be tailor-made. This will require governance processes that ensure transparency and equity. Negative externalities may arise, for instance, when villages are allowed to exploit forest resources without safeguarding future production and common interests. Decision makers should be supported to develop the necessary competencies and skills to solve complex problems. In line with these considerations, coordination of the many international policy, aid programmes and organisations working in African agriculture is needed to better fit these conditions.

Increasing population and increased commercialization of land-based activities have raised pressure on land and its monetary value that undermines the social, cultural and spiritual significance of land. Land reforms and legal arrangements of land tenure are important to prevent some from being marginalized while others gain excessive privileges. Formalization of tenure is a governance as well as technical issue.

Formalizing land tenure

Formal land tenure registration systems, particularly titling, which has been promoted for many years, tend to be expensive, badly tailored to local contexts and inaccessible for poor groups. Yet, recent land tenure reforms in Ethiopia, Mozambique, Uganda and Niger show how enabling pro-poor frameworks can be developed. Flexible land tenure systems were installed, which build on positive aspects of socially embedded rules and on group organization. In all these countries, verbal as well as written evidence is accepted for registering land rights. In both Mozambique and Niger, collective rights may be registered and build on the principle of collective management of common property resources. Collective management options appear to be promising in reaching some of the poorest and most disadvantaged groups, such as pastoral groups in the Niger case (IIED, 2006).

Institutional failures may arise by design and by ineffective implementation, calling for new innovative institutional arrangements to better match the diversity of sSA. Institutional changes will require concerted and long term engagements of local, national and international stakeholders. Key for development are systems of good governance that are transparent, participatory and accountable, all governance principles that are often lacking in African countries.

Beyond competition

Current technologies, institutional arrangements and the ways markets function have recently led to a collapse of various global systems, including the financial, industrial and mortgage systems, with implications for energy and food systems. Less immediate, but progressively pressing are the apparent reduction in oil reserves, increasingly scarce water resources, increased variability and production risk due to climate change, deteriorating land quality, air and water pollution, and loss of biodiversity. This deterioration of the production base may imply that continuation of 'business as usual' might evolve in an ever fiercer competition for resources.

Resolving these issues calls for fundamentally new approaches, requiring a break with current institutional arrangements, stakeholder interests, market functioning and technological means. Production of biofuels does, for instance, not fundamentally address emerging petrol-related problems, because of the continued use of outdated combustion technologies and because vested interest continue to be served. Similarly, increasing resource use efficiency in rice may require a shift from traditional flooded rice systems to rice grown as any other cereal crop. Such fundamental changes are complex and their implementation requires reconciliation of different and possibly conflicting objectives. In light of the diverse production environment, these new approaches should be flexible, geared towards creating enabling conditions allowing bottom-up responses, and be designed so as to maximise learning along the way.

This approach of transformational change creates new opportunities. Africa should benefit from this environment and embrace advanced techniques and technologies to leapfrog development. This is vital for its development, as are high organisational skills and diversified market conditions. Mobile phones and cheap, wireless computers eliminate the need for costly grid-wiring. Information, such as seasonal forecasts, early warnings of extreme events or commodity prices, can be communicated cheaply and on time. Decentralised energy systems such as solar panels and small, community-based bioreactors can provide energy in remote areas, freeing up labour currently required for collection of scarce firewood, improving cooking and reducing the need for fossil fuel. In agriculture, integrated production systems might be preferred over mono-cropping from an ecological and social perspective of sustainability. In these systems, ecological synergies may arise and be benefitted from, such as the creation of refuges in non-productive areas for natural enemies of pests on crops in adjacent production fields. Such synergies may yield valuable insights for enhancing the productivity of complex production systems, inherent to most of sSA. The use of advanced bio- and nanotechnology should be evaluated without ideological prejudice to raise use efficiencies of resources, including land, labour, water, capital and nutrients.

The African pathway

Embracing the enormous diversity of the production systems implies that thousands of location-specific successes will have to be achieved. To be successful this approach incurs high costs, will be knowledge intensive and requires enduring efforts. Ultimately, however, this will raise the overall level of standard of living for the majority of the population.

Priority should be given to enhance the productivity of crops specific to the African dish, like bananas, root crops and small grains, properly placed within the local production system. Increasing the productivity of rainfed agriculture is to be given highest priority, as it will continue to make the largest contribution to Africa's own food production. The resilience of the production systems should be enhanced through ecological synergies. Legumes, for instance, form a large proportion of the current diets and are important crops to maintain or even steadily increase the productivity of agricultural systems. Their productivity and ability to fix nitrogen as well as their performance under erratic environmental conditions could be further enhanced through environment-specific breeding. Integration in complex production systems could facilitate balancing soil nutrients. Specific emphasis will be needed for the requirement and management of phosphorus, as an emerging nutrient that might be in limited supply in the future.

Cowpea-based production systems

Cowpea (or niebé in French) is a most important food legume in sSA that thrives in dry environments. Its ability to fix nitrogen from the air makes it a source of nutrients for the subsequent cereal crop. It is a major source of protein, minerals and vitamins in daily human diets and it is equally important as nutritious fodder for livestock. It is referred to as 'hungry-season crop' because is it harvested before the cereal crop and is of vital importance to the livelihood of millions of people. Yet crops often fail due to frequent drought. Early maturing varieties were developed to escape terminal drought, though their sensitivity to intermittent moisture stress during the vegetative growth stage depresses performance. Changing climatic conditions and highly variable rainfall during the growing season call for drought tolerance during different growth stages to reduce production risks. In addition, resistance to leaf eating insects and pests during growth and post-harvest should be improved.

The integration of crop and livestock systems constitutes a great potential to enhance overall productivity. However, the nomadic and sedentary systems in sSA face major constrains. The encroachment of sedentary arable farming systems on 'traditional' dry-season pastures in the savanna regions prevents the optimal use of high-quality wet season pastures in the northern Sahel. By integrating animal husbandry with arable farming, the traditional semi-nomadic systems could serve as 'delivery room', providing young animals that could be fattened in the savanna (Figure S5). The feedlots would then be located closer to urban centres where demand for animal products is highest. This requires intensification (including the use of external inputs, such as chemical fertilizers) to improve the quality of crop residues and pastures (also through the use of leguminous forage crops).

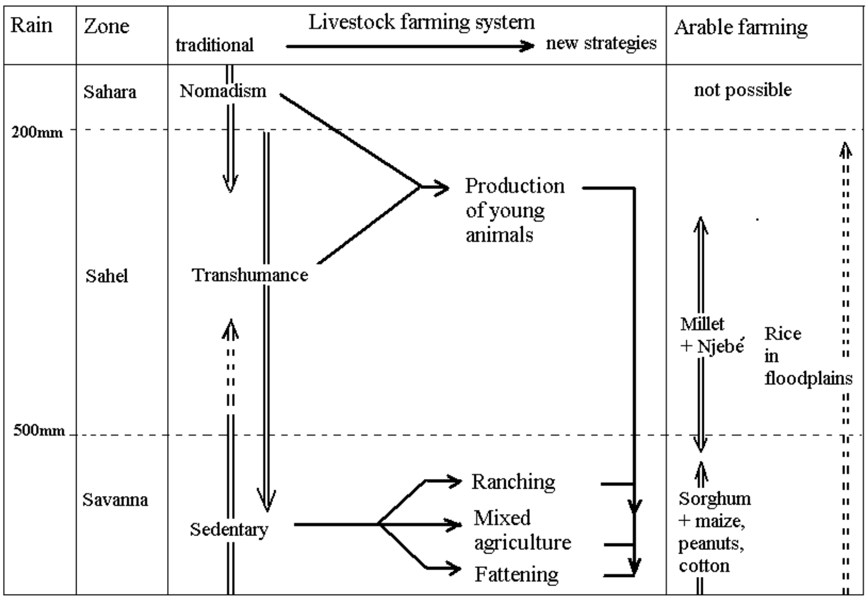


Figure S5. Integration of nomadic, semi-nomadic (transhumance) and sedentary systems in sSA to enhance productivity.
Source: Van Keulen and Schiere, 2004.

Energy supply is essential to increase labour productivity in agriculture. While analysing the role and introduction of solar panels is beyond the scope of this analysis, its use could help to leapfrog development as it could free up labour currently required for the collection of scarce firewood. Biofuels might be introduced through small-scale undertakings and integrated in complex production systems, for instance as hedgerows, to diversify rural income and catalyse rural development. The fuels could be used to trigger technological innovations, such as to run irrigation pumps or light vehicles for transport.

This 'African pathway' is important for a sustained overall development of sSA to reach the majority of the population and to make balanced use of available resources. The use of advanced techniques and technologies, and production ecological insights are vital, as are high organisational skills and diversified market conditions.

The global pathway

With the rapid development of populous countries, such as China and India, and natural resource-rich countries like Brazil and Russia, the demand for virtually all commodities has dramatically increased and will continue to do so. This leads to a growing interest in Africa's production base by these foreign nations to secure their own growing needs for food, feed, fibre and fuel. These claims pose an additional threat to Africa's food security. Proactive and timely adaptation measures, both technically and institutionally, might help rural Africa to capitalise on this increased demand instead.

Increasing awareness about the need to replace meat consumption by plant proteins, such as in the EU, could stimulate the emergence of a large legume market. The energy crisis has triggered policy measures for obligatory blending of transport fuels with biofuels in many large economies. Due to the economic or ecological limitations in these countries to supply their own needs, import of biomass or biofuels is foreseen for the near future. These developments may create opportunities for sSA to supply foreign economies with some promising agricultural commodities. Even if production efficiencies can be increased substantially, it will be inevitable for sSA to further expand its agricultural area to engage in these options, because its current agricultural area is insufficient to provide its population with a healthy diet. Any expansion, whether to satisfy their internal food demand or external claims, should be carefully considered and planned.

Engagement in the international biofuels market by sSA should be pursued with great care, as it is experiencing great uncertainties and biofuels exports are controversial. It might trigger investments in infrastructure and create overall economic growth. However, mitigating impact on GHG emissions is grossly overstated and could even be negative. Also, large-scale production of biofuels can impact negatively on the resource base (e.g., land, finances, labour), which may lead to displacement of people and further threaten the continent's already fragile food security.

A GM-fee soybean provider

Current debates about the desire for GM-free food in Europe may create a potentially large market for GM-free soybeans. The acreage of GM-based soybean production in the current exporting countries is rapidly increasing and approaching 100%. This legume crop can be grown in various regions in sSA and could supply GM-free soy to niche markets such as Europe (including feed, but also for food in the current transition towards more plant protein diets). Soybean also fits the current production systems in sSA and can be stored easily. This facilitates collection from many small farmers. Successful introductions in Nigeria and Zimbabwe demonstrate this potential at small scales. Any claim on Africa's resource base for export should be carefully considered in relation to requirements for its own food security.

The cultivation of soybeans for food and feed, but also the rapidly increasing market for edible oils, and other legumes to supply the increasing protein demand, could be an interesting options that fit development strategies of Africa. Options for both small and large scale production should be considered within the context of Africa's development. Systems developed elsewhere could be adapted to local conditions, such as the cultivation of rice under aerobic rather than under inundated conditions. Even the limited potential for expanding irrigated agriculture should be exploited as effectively as possible to secure food supply and facilitate development throughout sSA.

The 'global pathway' should allow quick results with large volumes of food to respond to the growing demand of the increasing population in sSA and to benefit from global opportunities.

1. Introduction to the current food situation

Sub-Saharan Africa is not likely to meet the internationally agreed Millennium Development Goal on halving hunger. Currently, the calorific value of per capita food consumption in Sub-Saharan Africa is still below the level of an average vegetarian diet, while in most regions the nutritional balance is inadequate. The African continent has not been able to profit from agricultural production growth as other continents have (Figure 1.1).

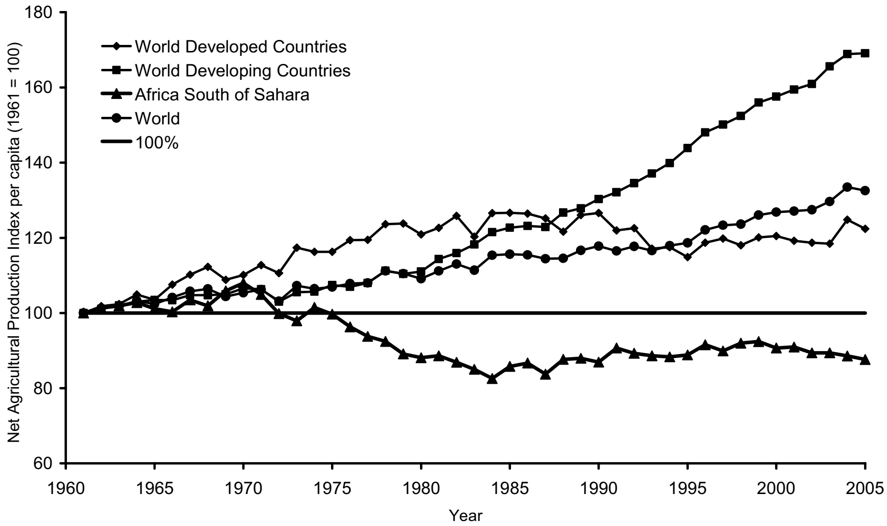


Figure 1.1. Value Index of Per Capita Agricultural Production from 1961-2005 (FAO-data).

Despite the importance of the agricultural sector in the economies of Sub-Saharan Africa, its performance over the last 40 years has been disappointing: agricultural and food production per capita have stagnated in the last 20 years and cereal yields are less than half those of other developing regions.

As a result, average food consumption in Sub-Saharan Africa is only two-thirds to less than half of the diets in Europe. National food intake in various countries is far below daily requirements such as for protein intake in countries like Eritrea and Burundi (lowest in protein intake in Figure 1.2). The situation is even worse for the rural poor people within these countries due to income disparity within countries (Figure 1.3). In general two thirds of the poor live in rural areas (e.g. Renard *et al.*, 2004). The figure also shows the large difference between (groups of) countries.

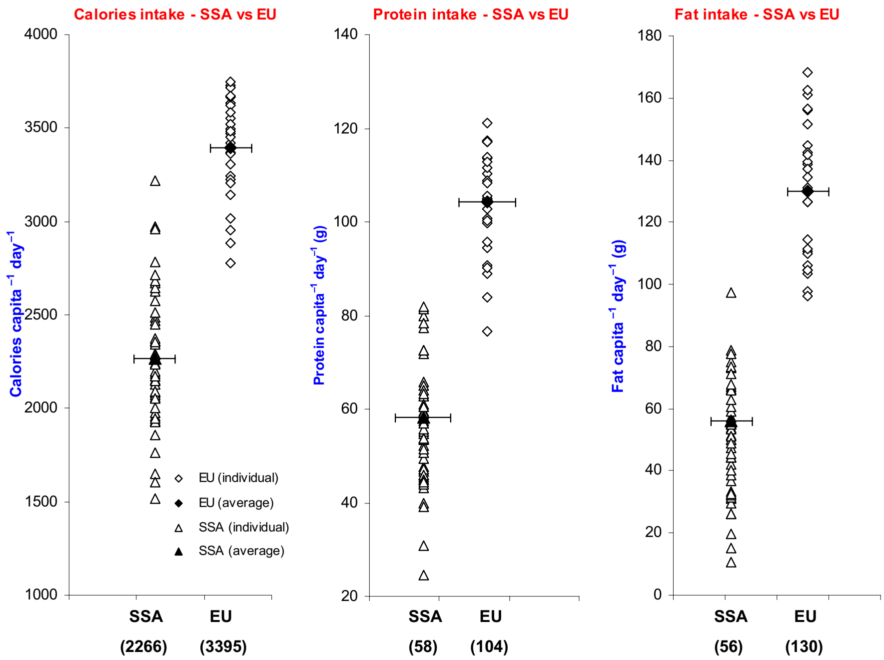


Figure 1.2. Country average intake of calories, protein and fat based on the consumption pattern (consumption data from FAO).

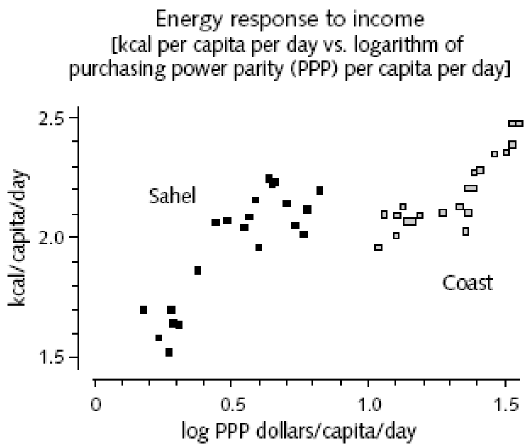


Figure 1.3a. Energy response to income.

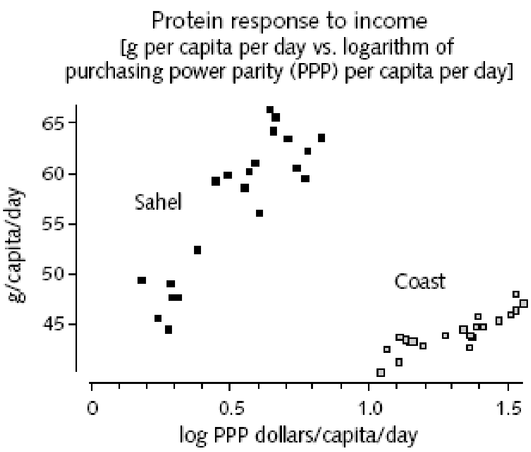


Figure 1.3b. Protein response to income.

Many attempts have been made to address this weak agricultural performance, but so far with very limited success. Why is this the case, when comparable efforts in other continents have resulted in considerably better results? During the 1960s and 1970s, the focus of international aid was on bringing the Green Revolution also to Africa, copying the success of Asia: promoting a technological package to increase productivity via higher use of (improved) external inputs. National governments were actively involved in supporting extension services, subsidizing input provision such as fertilizers, and in creating marketing boards and buffer-stocks to secure prices and reduce their fluctuation. This episode was followed by the structural adjustment era of the 1980s and 1990s, which focused strongly on the dominance of market institutions, and the reduced role of interventionist states and international organizations to accelerate African agricultural development. Both strategies fell short on a number of points in stimulating African agriculture. Key in any analysis of these shortcomings, and of any alternative proposal to promote more effective changes, is understanding the importance of diversity. Due to the wide variety of local contexts in the African continent, a pluriform approach that specifically addresses the diversity is likely to work more effectively in increasing agricultural performance.

Much of the success in Asia was based on improved varieties of lowland rice and irrigated wheat and therefore strongly contingent on the availability of (a) irrigation water and (b) large areas where this irrigation water could be applied. The African situation, where 93% of all agricultural land is under rain-fed agriculture, is very different.

Until the mid 1980s, most interventions aimed at improving agricultural performance in sSA followed the Green Revolution approach mentioned above which basically consisted of a one-size-fits-all technology package for agriculture involving the use of external inputs, massive investments in agricultural infrastructure and modern seeds (Dano, 2007). However, these attempts had little success. African farmers do not apply as much improved seeds, chemical pesticides and inorganic fertilizers as their counterparts in South and Southeast Asia - the economies of scale work against them. While the average fertilizer application rate in South Asia almost tripled from 37 kg per hectare in 1980/81 to 109 kg per hectare in 2000/01 and more than doubled in East and Southeast Asia over the same period, the rate in Sub-Saharan Africa remained almost stagnant, increasing only slightly from 8 kg per hectare to 9 kg per hectare in these two decades (FAOSTAT). The transnational corporations involved in selling hybrid seeds, chemical pesticides and inorganic fertilizers obviously did not make much profit in Africa, mainly because African farmers were poorer, the basic infrastructure was mostly absent, and Africa's farming systems and conditions were highly diverse. Moreover, the purchasing power of the African consumers was much smaller, because of low population densities and low income levels (Van Keulen and Breman, 1990; De Ridder *et al.*, 2004). Africa's agricultural system is a mosaic of diverse arable farming, forestry and livestock ecosystems where any one-size-fits-all formula appears doomed to failure. For instance, less than 5 per cent of Africa's cultivated land is irrigated, compared to over 40 per cent in south Asia. Although most African farms consist of small-holder family enterprises, they do not constitute a homogeneous category. They include various types of farming systems with highly variable levels of performance and viability, depending on their degree of security of tenure, the size and quality of land holdings, the size and structure of the workforce and access to finance and markets. Within any one country there can be many ecological zones crisscrossed by communities with different social and market characteristics and, especially in the smaller countries, it is difficult to find sufficient human, physical and financial resources to cater for each of those circumstances (FARA, 2008). Too little as well as much diversity is costly and inhibits sustainable development. Proactive, stakeholder-supported design of agricultural systems and their management can help in finding the right balance.

In the 1960s and 1970s, FAO provided support for fertilizer research in many countries in sub-Saharan Africa as part of the Freedom from Hunger Campaign. The results obtained in the various environments even for the same crop pointed to the complexity of farming environments in Africa (Rötter and Van Keulen, 1997; Rötter *et al.*, 1997). The establishment of IITA in 1967 was an effort to better understand the complex farming systems of the humid tropics of Africa. A major step forward in understanding this complexity was the development, in the 1970s, of 'farming systems' research, which increased scientists' understanding of the systems that were intended to benefit from scientific outputs. However, the farming systems approach failed to realize its early promise and the search for new ways of doing business has since continued (De Laiglesia, 2006; Collinson, 2004). Disappointment with the results achieved is probably best illustrated by the substantial reduction in foreign aid for African agriculture (See Figure 1.4).

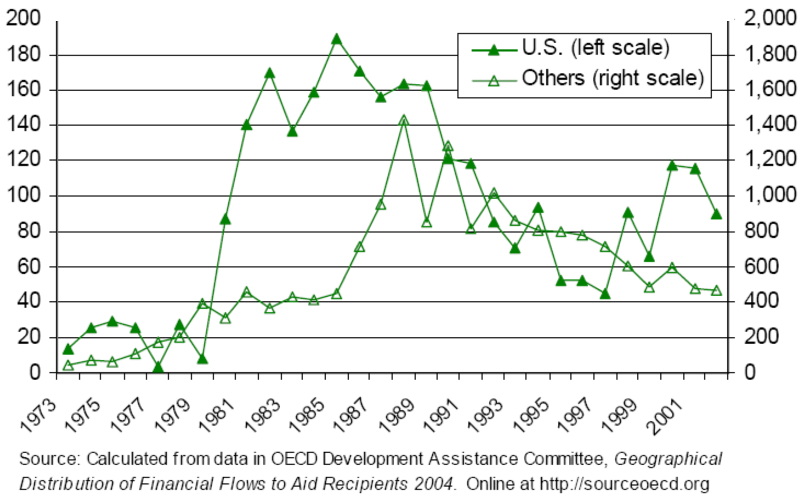


Figure 1.4. *Foreign aid for agricultural production in Sub-Saharan Africa, 1972-2002 (US$ m).*

Over time, it has become clear that the linear research-extension-farmer linkage and the technology transfer approach championed by the public extension service in the 1960s and 1970s can not play an effective role in agricultural service delivery. Very few of the innovations promoted by extension services have been taken up by farmers, because they did not fit the particular farming practices, because they did not involve women, or because they required institutional arrangements that were not in place. Africa's diversity calls for innovations that are adapted to specific contexts. As Howden *et al.* (2007) point out: multidisciplinary problems require multidisciplinary solutions that are well integrated and account for co-limitation.

Through the diagnosis of the development constraints facing developing countries published in the famous 1981 Berg Report, the World Bank prescribed Structural Adjustment Programs (SAP) as an effective panacea to resuscitate economic growth and development in these countries. SAPs recommended a substantial rolling back of state involvement in development processes, against a backdrop of the inflexible advocacy of market reforms. The SAPs aimed at establishing and supporting formal institutions and included producer price reform, removal of subsidies, liberalization of internal and external trade, new foreign exchange regimes premised on severe devaluations, cost-sharing for state-supplied services, privatization and contraction and restructuring of government institutions. This SAPs uniform strategy for all indebted countries in Africa was accompanied by 'conditionality', i.e. concessional finance to compliant adjusting countries. A survey covering 1985-87 showed that 'strong adjusters' received an annual increase in concessional finance of 19 per cent, while 'weak adjusters', suffered a decrease of 4 per cent per annum over the same period (UNDP/World Bank, 1989). The faith pinned on the market as an alternative institutional framework for spearheading development soon degenerated into disappointment, however. Ultimately, SAPs greatly weakened the capacity of the state in the socio-economic development process that is necessary for rapid and sustainable economic recovery (Chinsinga, 2007). SAPs have had a devastating fiscal impact on public sector institutions such as research, extension, education, credit and fertilizer systems that served small-scale farmers. In Niger, for example, the ONPV[1], which had played a vital role in regulating cereal markets and distributing food aid during crisis periods, has witnessed a reduction in its staff numbers from 600 in the 1980s to around thirty in 2005, which has seriously reduced its ability to intervene.

Conscious of the limited effectiveness of these policies, Poverty Reduction Strategy Papers (PRSP) were introduced to promote better adapted and more specific policy interventions, while increasing local ownership. However, the promotion of PRSPs has only had limited effects on agricultural policies in Africa. The process of formulating the policy paper is mostly restricted to a small number of strategically placed officials, while fundamental political interactions and change processes have not been much affected (Booth, 2005). The re-emergence of a develop-

[1] *ONPV = Organisation Nationale de Protection des Végétaux.*

ment service within the technical ministries remains an unfulfilled prerequisite for the restoration of state public services in the fight against poverty. The structure of inequality underlying poverty has not been addressed either by the PRSPs. These inequalities relate for instance to the issue of tenure reform, the position of small-scale family farms, gender inequality, market access, etc. (See also Booth, 2005). Issues specifically related to food security were also hardly dealt with (Bindraban *et al.*, 2003). Despite the explicit intention of PRSPs of being more locally specific, this seems to remain largely a promise, as donor interests seem more influential than those of the local population (Oxfam, 2004).

International competition

Globalization is increasingly shaping the African opportunity set. There is increasing pressure on African resources to satisfy international demand for minerals, food, and energy. Large-scale plantations of energy crops, managed by multinational corporations, are one example of this trend. Another one is the recent interest in African mineral resources spurred by rapid economic growth in Asia, and in particular China. There is no consensus on how such 'competing claims on African resources' affect African development prospects. While some perceive them as a threat to African sovereignty, others believe they represent a great opportunity for trade and profits. When turning to economic theory, we learn that there is evidence to support both views, and that the pre-conditions in terms of institutional quality and governance determine whether competing claims translate into collective gains or overall deterioration of welfare. For example, Brander and Taylor (1997) analyze how enhanced international demand for a renewable resource can spell doom for an exporting country if property rights to that resource are not well defined or enforced. In the context of market (or policy) imperfections, enhanced trade can impoverish the exporting country in the long run by encouraging over-exploitation of a fragile resource base. Similar insights apply to the case of land resources that may be converted into energy or food plantations - the net welfare effects depend on the institutional context. Prominently: this context determines how net benefits are shared between the multinational firm and the host country (negotiation), how the land resources are managed (monitoring and regulation), and how extra income for the host country is re-invested in the economy (corruption, priority setting, project implementation). To attenuate concerns that globalization threatens the development prospects of African countries, therefore, extra attention could be devoted to developing specific skills in the institutional domain of host countries that are conducive to effective negotiation and management, as well as raise accountability of incumbent decision-makers.

There is no silver bullet for reaching a more profitable agriculture because of the complexity and diversity of the issues involved. Interventions are needed in different domains and at different spatial, time and governance scales. These interventions need to be coherent and concerted and tuned to the specific needs of the various contexts. If not so, then options may result that may not fit the local conditions (e.g. IAASTD, 2008). For instance, while organic agronomic approaches could fill a (market) niche during a period of low input availability, the ultimate aim has to be sustainable development based on an integrated approach, whereby all agro-technical means are evaluated on merits in terms of their economic and environmental performance, rather than on the basis of ideology. This also requires the creation of institutional and economic conditions that suit local circumstances.

To create appropriate economies of scale that allows the efficient application of proven technologies or management practices, we need to re-visit the possibilities of larger scale interventions to boost agricultural productivity for some specific commodities. While such an approach might not have been effective in the past, changes in the global system may have created different conditions and opportunities. The global volume of international trade has increased substantially over the past few decades, a range of different agricultural production systems has emerged, and recently the demand for food and feed, and lately (bio-)fuel has dramatically increased.

This report aims to describe the complexity and diversity of farming systems across sSA. It makes a plea for recognizing and embracing them to arrive at effective recommendations for enhancing agricultural development and improving food security in sub-Saharan Africa. Options and opportunities from large scale production systems are considered to be part of this diversity as it may fit the rapidly changed global situation on food, feed and fuel.

2. Plea for recognizing diversity

2.1. Generic concepts

Agricultural productivity has been increased successfully in several global regions. Europe and other OECD countries heavily supported agricultural development after the Second World War to guarantee food supply (e.g. Common Agricultural Policy of the EU). New agricultural industry was stimulated e.g. for the production of mechanical equipment and agro-chemicals, while stable market conditions were created through subsidies, price policies and purchasing mechanisms, and research and extension were supported (Van Keulen, 2007). Similarly, Asian countries have effectively stimulated their agricultural development from the 1960s onwards, leading to the Green Revolution. Advanced technologies, principally High Yielding Varieties, large-scale irrigation development and agronomic inputs, including fertilizers, biocides and other agro-chemicals, partly as spill-over of knowledge about grain production from developed countries, were embraced and research institutions and extension services were heavily supported to secure continuous progress. Stimulating market conditions, including government interventions to control price fluctuations and to create buffer food stocks, reduced risks for farmers and secured affordable food for consumers. Also, protective border measures were taken to limit the impact of international price fluctuations on internal prices and distortion of local production. Indonesia and Vietnam for instance, implemented special rice programs (e.g. Wardana *et al.*, in prep). Not only has the productivity increased per unit land area (Figure 2.1), but also the productivity per labour hour. It increased more than 6-fold in the EU15 and only 21% in Sub-Saharan Africa (Bindraban *et al.*, 2008). Hence, one farmer in the EU15 could feed 6 times more people in 2000 compared to 1961, while still four farmers are needed today compared to five in 1961 in sSA to feed the same number of people.

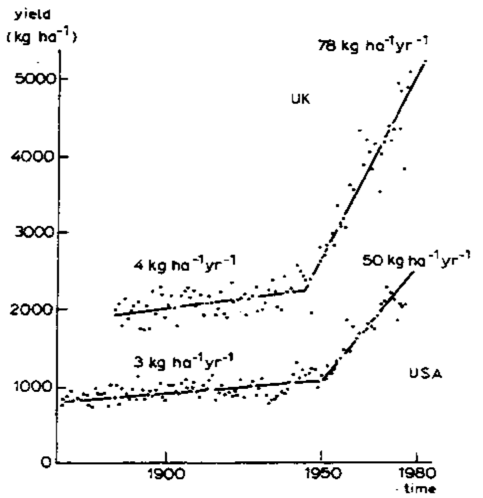


Figure 2.1a. Transition in productivity due to simultaneous implementation of technological measures and institutional arrangements in developing nations after WOII (wheat yield over time).

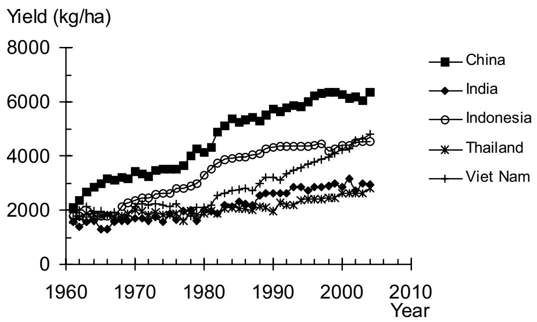


Figure 2.1b. Rapid developments in agricultural productivity in some Asian countries following a similar comprehensive approach as developed nations (rice yields). Source: FAO data.

The agricultural sector in sSA has hardly intensified, and the increase in food volume was largely achieved by expansion of the cultivated area, in contrast to other continents where per area yield increases were the main driver for increased food production (Figure 2.2).

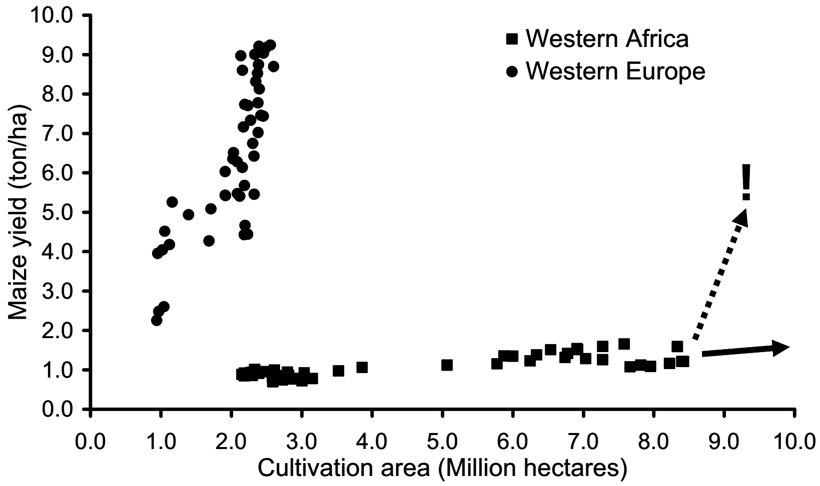


Figure 2.2. Illustration of the different routes through which the increase in food volumes have been realised. This holds for virtually all crops, even those native to sSa. Dotted arrow indicates desired yield increase strategies to minimize claims on additional land.
Source: FAO data.

These different pathways result from differences in the ease to increase yield, and the support from institutional economic conditions. The green revolutions in the OECD countries occurred in areas with favourable biophysical conditions. In these regions, rainfall is reliable or irrigation is feasible. Productivity on soils with favourable characteristics was further increased through the application of fertilisers. Pest, diseases and weeds were effectively controlled. Hence, production environments were adjusted to the needs of plants and animals, aided by favourable policies that stabilized prices and market conditions and created supportive institutions.

In contrast, yields in sSA remained low due to continuous production without inputs that led to depletion of soil fertility that is already low and differs within short distances, erratic rainfall patterns and high pest, disease and weed pressures. The combined impact of all these factors leads to a very high production risk, including frequent total crop failure and death of animals. This adverse situation is further exacerbated by unfavourable socio-economic conditions, and the absence of hard and soft infrastructure to support a vibrant agricultural sector. These unfavourable conditions are not unique to sSA, but occur also in southern Asia for instance or in production systems with limited control of production factors, such as upland rice. Increasing yield is much more cumbersome as location-specific agronomic interventions are required, supported by more effective and diverse market and institutional conditions.

The conditions at the onset of the Green Revolution in OECD countries and Asia were much different from those in Sub-Saharan Africa, which may have constrained progress in Africa. Many Asian countries had a well-developed internal market due to the high population to land ratio that in turn facilitated intensification. Low-cost fertilizers were made available and farmers were already attaining high yields from their local varieties and embraced high yielding alternatives. Also, major investments in infrastructural and institutional arrangements were made. Figure 2.3 shows similar type of responses to be likely in Africa under similar conditions. Under increasing population density agricultural land use expands, which eventually leads to intensification, i.e. increased use of external inputs, such as fertilizer, triggered by increasing purchasing power.

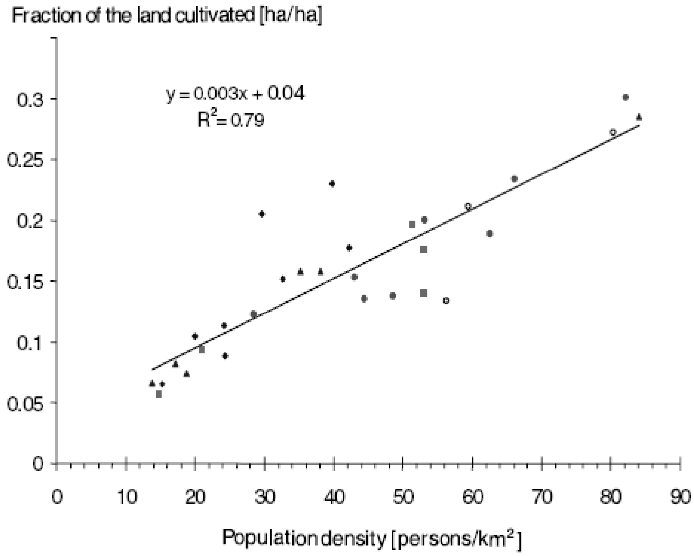


Figure 2.3. Relation between cultivated area as a fraction of total land and density of people active in agriculture in Burkina Faso. Each point represents a province. classified, on the basis of differences in rainfall, population density, livestock density, fraction of the land cultivated, fertiliser use and cereal production into the western (diamonds), south-eastern (squares), north-eastern (triangles), northern-central (closed circles) and three central provinces around the capital (open circles). The regression fomula and trend line are based on all data points.
Source: De Ridder et al., 2004.

The necessity for taking a comprehensive set of measures to boost productivity is well established, though views on the extent to which and by whom the required measures should be governed has been subject to debate. Agro-production systems result from complex interactions of a range of production and environmental factors that can be controlled to a certain degree (Figure 2.4). The more these production factors are controlled, the better production risks can be managed. Supplemental or full irrigation for instance reduces risks due to erratic rainfall.
A similar reasoning may apply to economic factors such as pricing, where farmers tend to push production under guaranteed prices. While the overall risks can be reduced for some single factors, packages of measures are generally required, as production and income risks might even increase under incremental adjustments as illustrated in the next section. It is this complexity of factors that under less well controlled conditions lead to development of a wide range of production systems as farmers tend to cope maximally with risks. The need for targeting of specific technologies to particular farming systems, to types of farmers, and to locations within their farms is captured as the need to identify the socio-ecological niche for technologies (e.g. Ojiem *et al.*, 2006), and calls for recognizing the need for design of appropriate technologies that are well embedded in the local social, economic and agro-ecological reality of local farmers' situations.

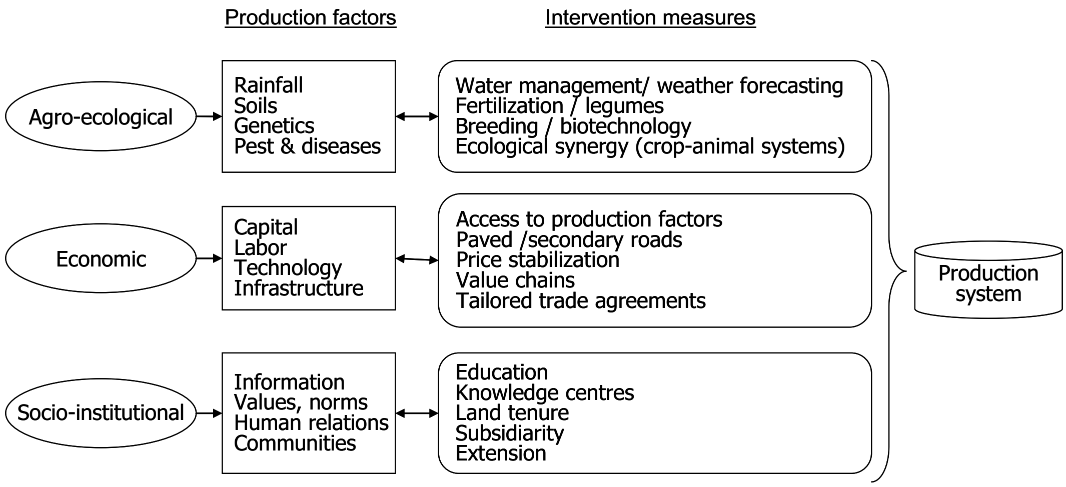


Figure 2.4. Production systems result from the complex interaction of agro-ecological, socio-cultural and economic conditions within a political/institutional environment (based on Ojiem et al., 2006).

It is this comprehensive approach that is required to increase agricultural productivity. The approach consists of promoting a mix of technical solutions (e.g. fertilization, farm-scale water harvesting, manure and crop residue recycling), knowledge-based solutions (e.g. farm management training, risk analyses) and economic and institutional improvements (e.g. access to irrigation, markets and micro credits). Only if we get this mix right will we be able to create what is also known as 'social capital', an essential ingredient for successful agricultural production in sSA. Social capital refers to features of social organisation, such as trust, norms and networks, that can facilitate coordinated collective actions (Field, 2003); for sSA, education at all levels plays a particularly crucial role.

2.2 Overall ecological production potential

Enhancing agricultural production implies the search for an integral improvement of the use efficiency of various production factors simultaneously, i.e. land, water, nutrients, labour, capital, and so forth in order to increase the yield of crops and animals. When assuming these conditions to be in place, what then is the production potential of the African continent. Or put the other way around, is the production potential large enough to make a large effort to invest in agricultural development as a means to increase food security and overall economic development.

Plant growth is complex due to many interactions, synergies, compensations, suppressions, facilitations and competitions that occur in plant growth processes and due to interaction of plants with the biotic and abiotic environment. Any sensible analysis of productivity increase ought, therefore, to take basic principles of production ecology into consideration. Bindraban and colleagues (2000) applied this approach for developing an integral measure for land quality and identified the yield levels of crops that could be attained when the ecological production factors would be utilized most optimally. More recently Conijn and colleagues (2009) estimated production potentials to identify the trade off between land for food and fuel. The analysis was carried out for rainfed conditions, implying that no irrigation is applied, while fertilizers are assumed to have been supplied to secure that nutrient availability meets crop requirement (Figure 2.5). Here, average rainfall over a period of 30 years is taken and therefore not reflecting variability.

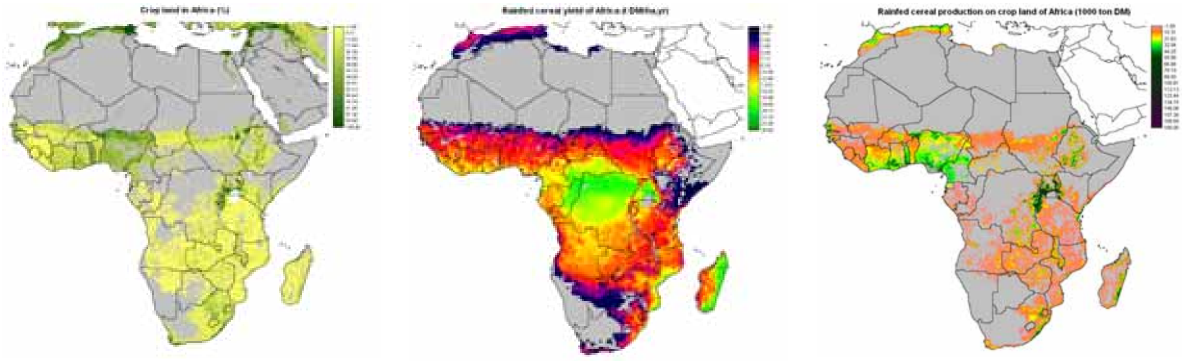


Figure 2.5. *Calculated ecological production potentials based on rainfed agriculture.*
A. Current distribution of agricultural land (From dark to light green - decreasing fraction of grid is agricultural land).
B. Maximum attainable biomass production under rainfed conditions on the entire continent.
C. Production volumes on current agricultural lands.
Source: Conijn et al., 2009.

The results show that a huge amount of food could be produced on the African continent, though at the expense of natural ecosystems (Figure 2.6a). When constraining production to current agricultural land, thus restricting expansion into natural lands, the agricultural productivity in sub-Saharan Africa would have to increase by a factor 2-3 on the current agricultural land in order to meet the dietary needs of the 900 million African people, which is close to the production potential under rainfed conditions (Figure 2.6b). As this increase in productivity will take at least 2-3 decades, being extremely optimistic, and the number of people will have increased to some 1.5 billion by then, the required 4-5 times higher production would exceed the production potential of the current land, implying the necessity of expansion of agricultural land to meet food demand. Production volumes could be increased also by substantially expanding the irrigated area, but the availability of water is severely limiting (outside the rainforest areas). Production potentials can be realized only under optimized growth conditions, i.e. sufficient nutrient application to meet crop demands, protection against pests, diseases and weeds, and the optimal use of the water from rainfall.

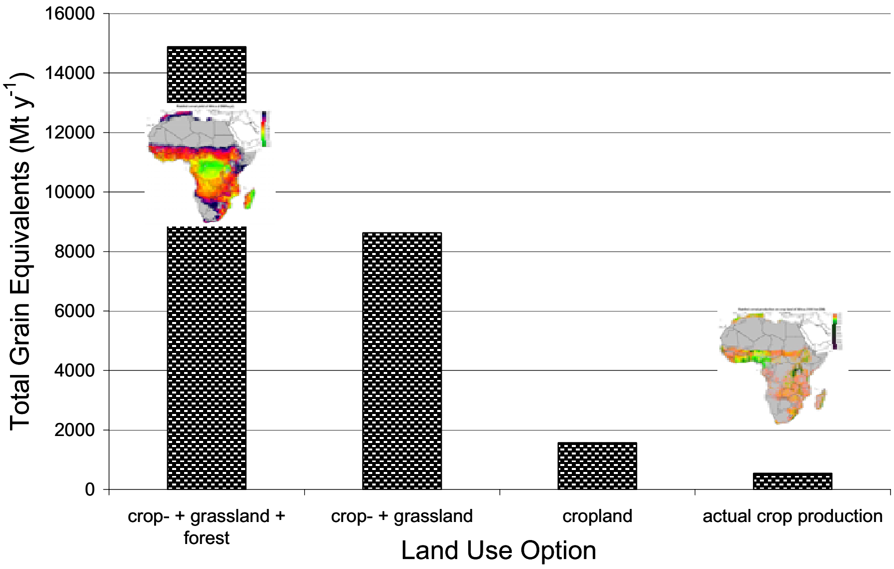


Figure 2.6a. *Total production expressed in grain equivalantes under cultivation of different land use systems. The actual crop production reflects the current production obtained on the current cropland.*
Source: Conijn et al., 2009.

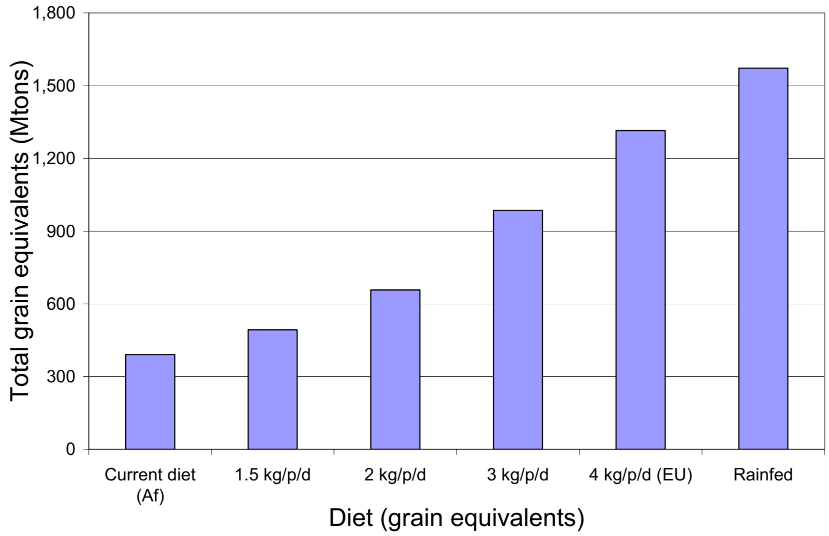


Figure 2.6b. Comparison of current food consumption per person in Africa of approximately 1.2 kg grain equivalents per day as compared to a European diet of 4 kg. The maximally attainable production on the current crop land (right bar) exceeds this demand slightly.
Source: Conijn et al., 2009.

The above observation that more, rather than less land will be needed for the production of food, implies that the production of any hectare of biofuels will require net clearing of natural lands, either indirectly through displacement of food-agriculture when produced on current agricultural land or directly on new lands. With that, biofuels will not mitigate but rather exacerbate climate change (Conijn *et al.*, 2009).

2.3 Agro-technical diversity

The potential as presented in the previous section should be interpreted with great care. Agricultural production in Sub-Saharan Africa appears to be low and erratic. Crop production is constrained by a range of co-limiting and strongly interacting factors.

The soils of Sub-Saharan Africa are formed from old, weathered rocks that are low in plant-available nitrogen and phosphorus, the two most important nutrients needed for healthy plant growth. The characteristics of the dominant clay minerals are such that the nutrient storage capacity of the soils is limited. Not only are the soils poor, but the climate is also extreme, rainfall being either low, irregular and erratic, or too high and intense. The annual water balance, measured as precipitation minus evaporation, is so low that perennial plants do not contribute as much organic matter to the soil as in other parts of the world. Low organic matter content contributes to the lack of nutrient storage capacity and to a low water retention capacity that makes the soil prone to erosion. The poor quality of African soils is an important limiting factor for African agriculture, even in regions like the drought-prone Sahel, the semi-arid transition zone from the Sahara Desert to the West and Central African savannah.

Co-limitation implies that multiple factors are limiting production at the same time. Consequently, alleviating a single production-limiting factor such as soil fertility might have little effect, or even be contra-productive. Also, a new bottleneck may emerge as soon as one bottleneck is removed. This may mean that solving soil fertility problems alone, for instance, is unlikely to result in the desired production increases, e.g. simply adding more fertilizer is only part of the solution.

2.3.1 Plant material

At the end of the previous century, the proportions of farmers' fields in Africa planted with improved varieties were 40, 17, 26 and 18% for rice, maize, sorghum and cassava, respectively, much less than in other continents (Evenson and Gollin, 2001). Till recently, emphasis has been placed on the major cereal only, similar to Asia, while a much broader range of crops make up the dishes in Africa. Quality sowing seed is virtually absent in most countries of sSA. With the economic restructuring, public research institutes were abolished as private sector would assume activities in seed supply. This strategy failed and expertise for breeding locally adapted varieties and the facilities to produce quality basic material for seed production were lost (Van der Burg, 2000). Rather than increasing crop yield potential for favourable biophysical production conditions, there is a need for varieties that are tolerant or resistant to the poor and variable biotic and abiotic conditions. These characteristics are likely to contribute to a more resilient production system.

2.3.2 Soil fertility

Adding a small amount of fertilizer to a potentially high value crop can be extremely effective as long as access to other production factors such as water and labour is ensured and biotic stresses such as pests, weeds and diseases can be controlled. Numerous studies have shown that if several factors are tackled at the same time significant increase in production can be achieved whereas tackling individual factors has little effect (de Ridder and van Keulen, 1990; Ahmed and Sanders, 1998; Ahmed, Sanders *et al.*, 2000; Breman, Groot *et al.*, 2001; de Ridder, Breman *et al.*, 2004; Rowe, van Wijk *et al.*, 2006; Rufino, Tittonell *et al.*, 2007). An illustration for the field scale is provided in Figure 2.7, where the synergistic effect of the combined use of organic and inorganic fertilization only was able to increase yield over time in the Sahelian region, whereas recycling of organic matter alone could not sustain soil quality over time.

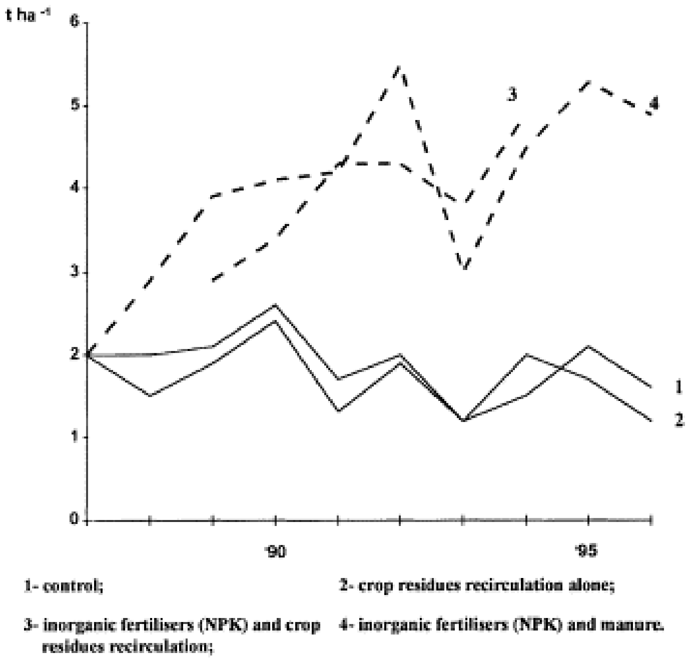


Figure 2.7. Progress in production increase at the field scale under different management practices. Crop residues recirculation alone is hardly able to sustain land productivity. Combined with the input of nutrients from external sources through fertilizers (inorganic and manure) a strong positive effect on land productivity is observed (Details: Maize yield in the coastal Savanna of Togo).
Source: Breman, Groot et al., 2001.

Substantial emphasis has been placed on understanding the local heterogeneity in farming systems and land productivity across regions (Windmeijer and Andriesse, 1993), landscapes, within farming systems and within and between farms (Giller *et al.*, 2006; Vanlauwe *et al.*, 2006). Within any given country or region there are localised agroecological gradients and within every village a wide diversity of farming livelihoods can be found, differing in production objectives and in wealth and resource endowments (Tittonell *et al.*, 2005a; Zingore *et al.*, 2007a). As a result of strong effects of past management by farmers, strong soil fertility gradients can be found across distances of only 50-100 m, due to the repeated preferential allocation of organic residues and fertilizers to favoured fields, commonly those closest to the homesteads (Tittonell *et al.*, 2005b; Zingore *et al.*, 2007a). More wealthy farmers who have substantial numbers of cattle and manure, and adequate labour, tend not to have strong gradients of soil fertility across their farms. The poorest farmers also tend to have fairly uniform poor fertility across their fields, as they have little access to animal manure or other organic residues and often little labour available for investment on their farms. The intermediate groups of farmers, who are generally by far the greatest proportion of farmers in any given area, tend to have strong gradients across their fields, due to the preferential allocation of limited organic manures to the fields closest to their homesteads. The most alarming finding is that more than 60% of arable land falls into the most degraded, unresponsive category in the villages.

The existence of these local soil fertility gradients explains most of the variability in performance of introduced technologies to improve production. The legume-based technologies for soil fertility enhancement perform poorly in degraded outfields. The soil condition strongly influences the efficiency with which mineral fertilizers are used by crops: on sandy granitic soils, N use efficiency by maize varied from >50 kg grain kg^{-1} N applied in fertilizer on the infields (i.e. those closest to the homestead), to less than 5 kg grain kg^{-1} N on the outfields (i.e. those far away from the homestead) (Figure 2.8). Similar strategies in soil management practices have been found through sSA (See Vanlauwe *et al.*, 2006; Zingore, 2006 for East and southern Africa and Wopereis *et al.*, 2006 for West Africa).

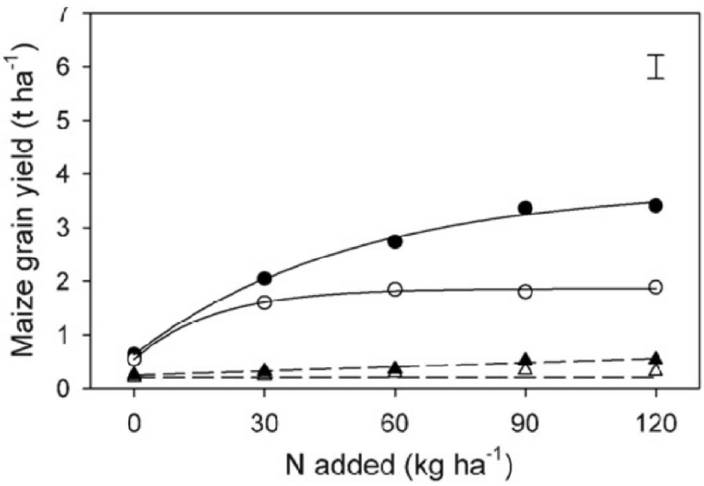


Figure 2.8. Maize response to different rates of N with (solid symbols) and without P (open symbols) on a smallholder homefield (circles) and outfield (triangles) on a sandy granitic soil (Zingore et al., 2007b). The lack of crop response to N and P fertilizer on the outfields was subsequently shown to be due to critical shortage of other nutrients (calcium and zinc) that could be supplied in small amounts of cattle manure (Zingore et al., 2008).

These findings of synergies between production factors suggest the need for careful analysis of current production systems to arrive at appropriate agro-technical suggestions for enhancing productivity, that should be well embedded in the wider socio-economic context. This production-ecological principle of increasing efficiency when addressing several factors at the same time has been elaborated upon by De Wit (1992) and can be observed at various spatial scales (e.g. Bindraban *et al.*, 2008).

2.3.3 Rainfall and irrigation

Over 95% percent of agriculture in Africa is rainfed, implying a large dependence on rainfall amounts and patterns. Annual rainfall patterns throughout sSA vary considerably from year to year and from place to place, which further complicates one-size-fits-all measures.

Figure 2.9 shows how yields vary with annual rainfall patterns at a site in Zimbabwe - while fertilizer has in most years a positive effect on production, it has zero or even a negative effect in the dry years. As result, many African farmers apply risk-adverse strategies that secure a minimum production in any year but which fail to capitalise on good seasonal conditions.

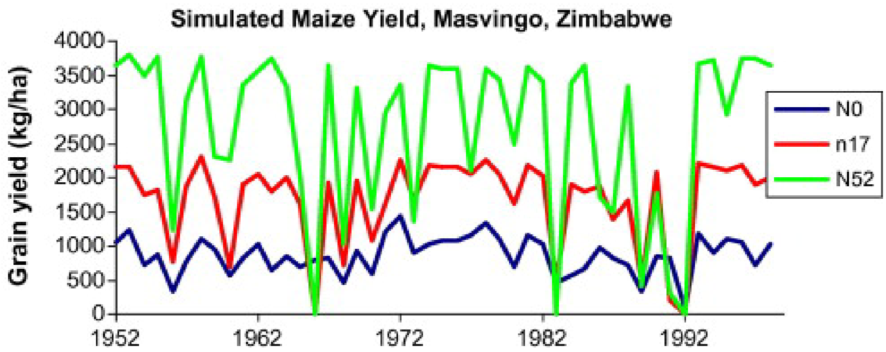


Figure 2.9. Yield response of maize varying with annual rainfall patterns at 3 levels of fertilizer application (0, 17 and 52 kg N/ha).
Source: Twomlow, Mugabe et al., 2008.

Of the 183 million hectares of agricultural land in sSA, only about 9 million is under some form of water management (Peacock *et al.*, 2007). While investment in expanding irrigation seems a promising way to improve agricultural production, estimates place the area of additional irrigation that would lead to profitable investments as part of dam-based schemes at only 3 million hectares (IFPRI, forthcoming). Hence, for economic reasons, small-scale water management and storage approaches are likely to be a key component in efforts to increase agricultural production (Brown and Hansen 2008). Small-scale irrigation schemes have, however, a patchy history due to the lack of attention to institutional aspects. Still little emphasis has been placed on diverse strategies for effective water management viewed from the highly diverse production conditions of sSA.

2.3.4 Weeds, pests and diseases

Farm surveys consistently point to weeds, pest, diseases and soil fertility as the key determinants of low productivity. Climate variability and change will further exacerbate these problems, requiring strategic vision and planning to better deal with these issues within the context of sSA. These yield reducing factors are known to have dramatic impacts on yield loss, sometimes even causing complete crop failure.

The importance of weeds is often underestimated. The success of the green revolution in Asia is partly related to weed control: flooding rice fields is the single most effective weed control measure. However, using water as a herbicide was never an option for sSA, where weeds are generally controlled by manual labour (possibly including mechanized control with animal traction) or, in some cases, with herbicides. However, herbicides are often not available, too expensive or require a level of mechanization and management skills that is incompatible with existing management systems. Safety and environmental concerns are also increasingly raised within this context.

Labour availability often limits effective weed control in sSa because a) herbicides are rarely available or too expensive, while their use can be controversial; b) labour is becoming short due to urbanization & HIV; disinvestment in the agricultural sector resulted in an image problem, providing young people with few incentives to engage in agricultural; and c) weed control measures must be gender sensitive given that mechanical weed control is mostly regarded as a woman's task.

Weed control and soil fertility are co-limiting production in many systems and environments. The competitive advantage of weeds over crops increases disproportionally as water and nutrients become more limiting. Hence, avoiding water and nutrient limitations can be a very effective weed management strategy. However, interactions should be carefully analyses for every specific case, either location or practice. While zero tillage is, for instance, an ideal management practice to reduce soil erosion, to reduce evaporative losses and to improve soil water storage, it requires increased effort to control weeds during the cropping cycle, but also at times of fallow.

Pest and disease control is also strongly linked with weed control measures, as insufficient weed control can provide 'green bridges' for pest and diseases that will carry them through seasons and rotations. Climate change poses additional challenges as it may reduce the frequency of conditions suitable for spraying insecticides, herbicides and fungicides, requiring alterations in spray technologies and practices (Howden *et al.*, 2007) whilst elevated CO_2 may reduce the efficacy of products such as glyphosate for weed control (Ziska *et al.*, 1999).

The occurrence and severity of impact of pests and diseases is strongly governed by local environmental conditions and crop management systems. They range from Heliothis moths in cotton, the Cassava Mosaic Disease to beetles and viral infections of yams. A complete review is beyond the scope of this document. Many of the pests respond strongly to climate signals and their impacts are very dependent on climatic variability. Adaptation measures are only likely to happen via increased understanding of impacts and potential responses of recent climate variability manifestations (last 20 years) and may best be delivered via the two key emerging strategies, i.e. integrated pest management and area-wide management referring to coordinated responses of farmers and policy makers across an entire region.

These tools rely on good knowledge and education, a supportive policy framework and intensive monitoring including the use of computer simulations of pest numbers to flag high-risk periods for each species of pest. The latter technologies are poorly - if at all - developed for sSA compared with the well-developed agricultural sectors in Europe, USA and Australia.

In the absence of these support mechanisms, farmers either apply excessive amount of chemical as 'insurance treatments' (if they can afford it), or, more likely, simply suffer the consequences. Investment in the teaching of farm management practices, the development of policy frameworks that support area-wide management and the intensification of production need to go hand-in-hand to improve the situation.

2.3.5 Animal production

The share of the livestock in the agriculture sector in African countries can exceed 80% (Botswana, Mauritania, and Namibia) and is estimated to make up more than half of the cash income of farmers in mixed crop-livestock systems. In some semi-arid regions ruminants are practically the only means of food production. In the land-locked Sahel countries, the contribution of the livestock sector to GDP ranges from 10 to 15%, and 8 to 9% in countries with seaboards, like Senegal, Ghana and Togo. The contribution of animal production to the agricultural GDP averages nearly 40%, ranging from 5% in Côte d'Ivoire to 44% in Mali (MRA/Niger, 2001; MRA/Burkina Faso, 2005; MEP/Mali, 2004). Overall, eleven percent of the African population totally depends on animal production (Kruska *et al.*, 2003; Heap, 1994). Livestock is an important source of income and insurance during food shortages, with short-cycle livestock like poultry providing an income especially to women. Milk and meat production, processing and trade generate high levels of employment in the livestock sector. Current total meat self-sufficiency is inadequate to meet dietary needs. Africa also has a great trade deficit in livestock and livestock products (Abassa, 1995).

Livestock provide a number of functions:

- food as milk and meat;
- animal traction for ploughing - the area cultivated often depends on the availability of oxen. In some systems cows are used for ploughing due to the lack of oxen. There are often reciprocal agreements between households without livestock to borrow animals for ploughing;
- manure for management of soil fertility - in some farming systems manure is traded as a resource;
- cattle often play a financial role - as an investment in cattle, shoats can be sold in times of need, or to pay the 'lobola' or dowry (bride price).

Despite the multiple functions, the production of livestock, as well as the number livestock units, show a highly irregular pattern, with periods of increase and decrease, related to weather variability. Production rates of veal per inhabitant are low at 2 kg to 10 kg in African countries. There has been an overall shortfall during the past 20 years for the three main products - meat, milk and eggs - in the Sahel countries, for instance, except for products of small ruminants. Historically, the regional supply of dairy products has never covered regional demand, with a deficit of about 1.3 million t between 1980 and 1990, and a forecasted deficit of 2.5 million t by 2015. The growth in demand is partially a result of very rapid population growth and a high rate of urbanisation. Another imbalance is the low level of trade among the various zones of the region, leaving complementarities based on geographical position or agroecological potential untapped (Sahel and West Africa Club/OECD, 2005). A third imbalance concerns disparities between rural and urban areas, due to differences in income and the diversification in the diets of urban consumers (Delgado *et al.*, 1999; Huang and Bouis, 1996). The proportion of food expenditure allocated to animal products may reach 30.8% in urban areas (Thillier-Cedan and Bricas, 1997).

2.3.6 Production systems

Diversity is the norm in African farming systems. Dixon *et al.* (2001) provide a comprehensive description of farming systems globally and identify and broadly delimit farming systems based on: (i) natural resource base; (ii) dominant livelihoods (main staple and cash income source a balance between crops, livestock, fishing, forestry and off-farm activities); (iii) the degree of crop-livestock integration; (iv) the scale of operation. The main characteristics of degree of crop-livestock integration; (iv) the scale of operation. The main characteristics of the major farming systems in Africa are shown in Table 1.1, and the geographical distribution in Figure 2.10.

Table 1.1. Farming systems of Sub-Saharan Africa, North Africa and the Middle East.

Farming system	Land area (% of region)	Agric. pop (% of region)	Principal livelihoods
Region: Sub Sahara Africa			
Maize mixed	10	15	Maize, tobacco, cotton, cattle, goats, poultry, off-farm work
Cereal-root crop mixed	13	15	Maize, sorghum, millet, cassava, yams, legumes, cattle
Root crop	11	11	Yams, cassava, legumes, off-farm income
Agro-pastoral millet/sorghum	8	9	Sorghum, pearl millet, pulses. sesame, cattle, sheep, goats, poultry, off-farm work
Highland perennial	1	8	Banana, plantain, enset, coffee, cassava, sweet potato, beans, cereals, livestock, poultry, off-farm work
Forest-based	11	7	Cassava, maize. beans, cocoyams
Highland temperate mixed	2	7	Wheat barley, teff, peas, lentils, broadbeans, rape, potatoes, sheep, goats, cattle, poultry, off-farm work
Pastoral	14	7	Cattle, camels, sheep, goats, remittances

Farming system	Land area (% of region)	Agric. pop (% of region)	Principal livelihoods
Tree crop	3	6	Cocoa, coffee, oil palm, rubber, yams, maize, off-farm work
Commercial large- and smallholder	5	4	Maize, pulses, sunflower, cattle, sheep, goats, remittances
Coastal artisanal fishing	2	3	Marine fish, coconuts, cashew, banana, yams, fruit, goats, poultry, off-farm work
Irrigated	1	2	Rice, cotton, vegetables, rainfed crops, cattle, poultry
Rice-tree crop	1	2	Rice, banana, coffee, maize, cassava, legumes, livestock, off-farm work
Sparse agriculture (arid)	18	1	Irrigated maize, vegetables, date palms, cattle, off-farm work
Urban-based	Little	3	Fruit, vegetables, dairy, cattle, goats, poultry, off-farm work

Source: Dixon et al., 2001.

Farming systems in sSA comprise many root crops, especially cassava. Cereals are less important: the main crops are coarse grains like millet and sorghum, followed by maize, though their importance is increasing, especially of rice. The farming systems described provide a snapshot of dynamic systems that are constantly evolving.

The farming systems are however not static and should be seen as 'moving targets'. Farmers will increasingly face the challenge to live up against the impact of climate change that may reduce rainfall amounts and make rainfall even less predictable. Rapid urbanization coupled with rapid rates of population growth makes that urban centres grow at some 5-6% annually and growth rates generally remain just above 3% in rural areas, even when the effects of HIV/AIDS are taken into account. Thus, rural areas of Africa are highly dynamic: in many areas sedentary agriculture has only been practised for the past 50 years and has changed dramatically over this period. All these pressures render communities highly vulnerable in future.

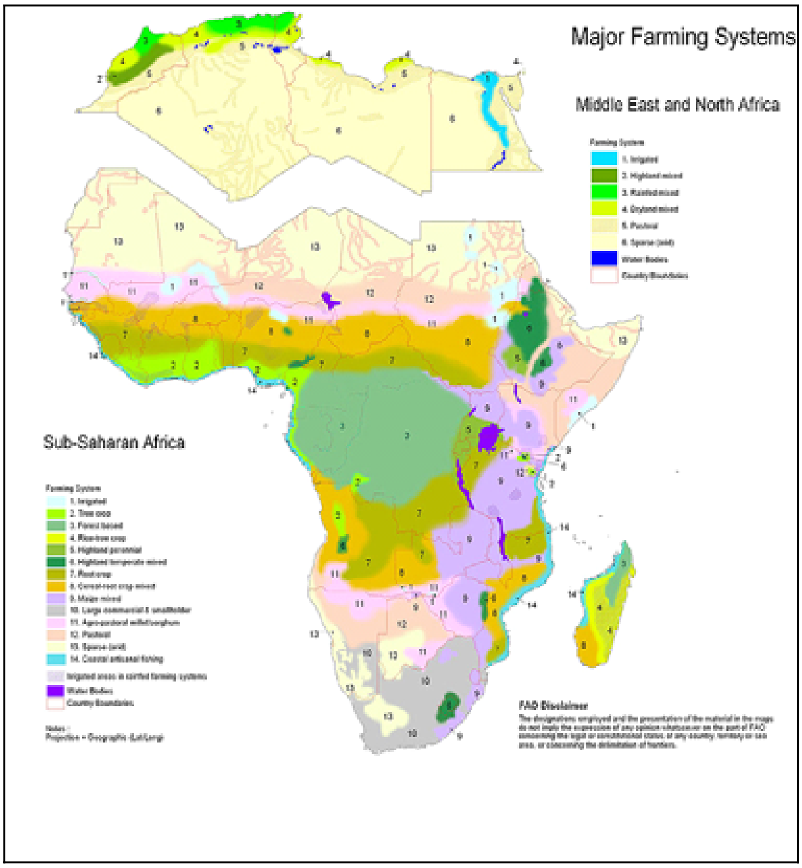


Figure 2.10. Farming systems according to Dixon et al. (2001). Although this classification recognizes the broad differences in agroecology across Africa, each large farming system masks a huge diversity within countries and at local scales.

Animal production in pastoral systems depends essentially on the use of grassland and shrubland - grazed by livestock on uncultivated land mainly in the arid and semi-arid zones. Pastoral systems account for a third of the cattle and half the small ruminants in sub-Saharan Africa, providing 60% of the beef and veal, 40% of the small ruminant meat and 70% of the milk in these countries as a whole (Seré, 1994). The main constraints are concerned with land tenure, ownership rights and the scarcity of fodder resources (Touré, 1996).

Off-land animal production systems are totally independent of any agricultural use of the land, as they use only animal feed: cultivated fodder and agro-industrial by-products, whether concentrated or unrefined - cereals, oil seed cakes, bran, hay and straw. These systems are found in or on the outskirts of towns, and have blossomed in the past 25 years in the wake of growing urbanisation. Their focus is mainly on poultry farming (for eggs and meat), pig farming, but also on fattening thin sheep and cattle coming from the pastoral systems, and they are generally carried on in close association with western companies, that supply feed formulas and ready-mixed feed, chicks or breeding sows and chickens, advice and testing, and exotic breeds. Milk is most frequently produced in family or collective milk-production units and fattening enterprises. In-depth socio-economic surveys have however shown a very low profitability of these milk-production systems (Hamadou and Tiendrebeogo, 2004; Hamadou *et al.*, 2002; 2003), as they survive at the virtue of African consumers' preference for fresh milk and the lack of longer marketing channels to supply towns from small-scale dairy farmers whose production costs are lower. The fragility of these urban systems is illustrated by the intensive cattle fattening in permanent stalls with the use of purchased concentrated feed and fodder that was fairly widespread in Africa in the 1970s, but has been practically abandoned since then.

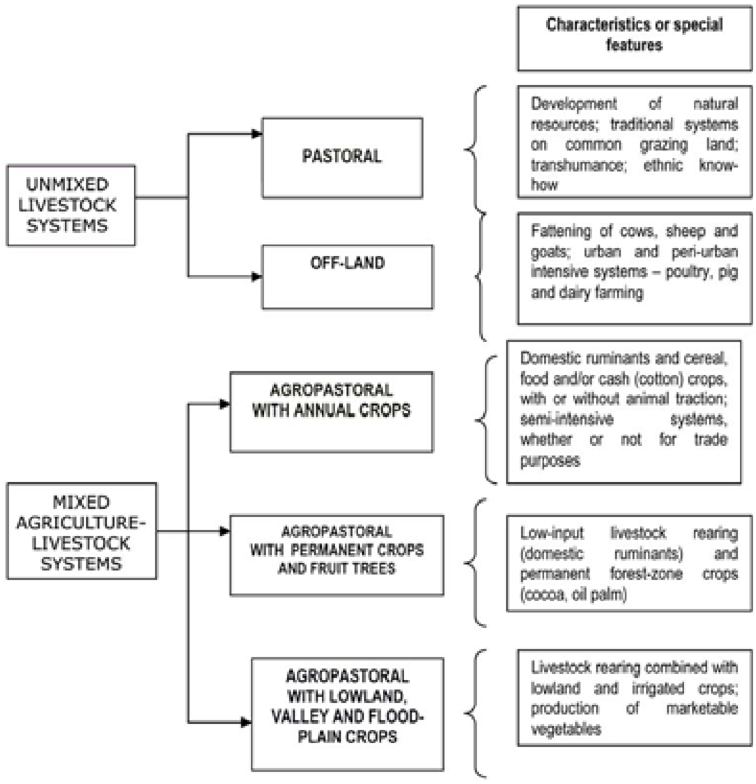


Figure 2.11. Evolution in regional supply and demand for animal products.

Agropastoral or mixed farming systems are the most widespread and use a combination of grazing on uncultivated land, fodder crops, agricultural and agro-industrial by-products and purchased feed, in a mixed multi-crop and livestock farming system (Figure 2.11). Livestock rearing provides manure and traction, as well as a reserve of capital, and is intended mainly for household consumption. For lack of a regular outlet, dairy production is in general only a secondary product. The combination of agriculture and livestock has become the driving force of agricultural development in the savannah zones of the region (Kamuanga, 2002). The sustainability of mixed agriculture-livestock systems requires, however, the introduction of fodder crops, thereby reducing dependence on the cattle feed market. Fodder plants have been popularised over the past 25 years in different forms including rangeland improvement, fodder banks, erosion control measures, permanent pastures, but with uneven development and limited success (Bosma *et al.*, 1996). The main problem is still that of the effective adoption of fodder crops as an integral component of cropping systems. Also, synergy may be exploited in some systems like with cotton that provided cake for protein supply.

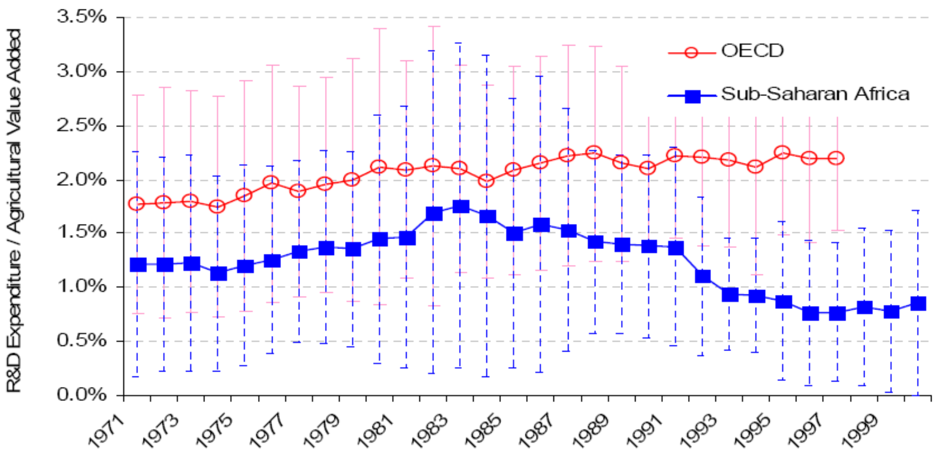
Notwithstanding the diversity of the farming and cropping systems, the use of technologies in general is a pre-requisite to enhance agricultural productivity. The large diversity on the African continent and the increasing vulnerability call for tailored measures for improvement.

2.4 Recognizing institutional diversity

Increasing agricultural production requires next to adequate technological innovations also an appropriate institutional environment for farming. This institutional context is in Africa as divers as farming systems. Changing institutions via a blueprint approach will therefore not suffice because of the variety and the complex linkages between different institutions. Compared to other continents Africa has a larger number of small states (in terms of population), a high cultural diversity, a less stable political environment, and a complex recent history branded by colonialism. The complexity involved in changing institutions should however not withhold interventions but they should have a context-specific focus built on understanding the issues involved and acknowledging the need for prioritization. Instead of a uniform approach, different policies and institutional arrangements should be promoted at different moments at particular locations.

Of particular importance for increasing agricultural productivity in Sub-Saharan Africa are the access to the necessary means of production as well as to adequate and improved knowledge and information. In most African countries, knowledge infrastructures including research, education and extension services have remained underinvested and sometimes dysfunctional for many years (cf. Figure 2.12). Even the contribution of foreign donors to R&D in agriculture and to agriculture related ODA[2] has decreased over the last years (Masters, 2005; World Bank, 2007). In the past, the CGIAR institutions have been essential to support agricultural development in Asia and Latin America, and this might still be a major channel through which international R&D for African agriculture can be enhanced. But CGIAR funding has also stagnated lately, although the research agenda has switched to crops that are more relevant for Africa.

Securing an adequate basic knowledge infrastructure for agriculture is essential (NEPAD, 2002), but the selected approach should be much more focused to the specific demands of particular (groups of) farmers. Addressing the locally specific agricultural problems through research and development effectively requires bringing in the end user perspective and recognizing the multidimensional character of agricultural productivity change. Much of the problem with conventional agricultural research and extension lies with the processes of generating and transferring technologies, as they need complementary organizational, policy and other changes to enable them to be put into productive use. Improving farming practices requires research but should be complemented with organizational, policy and other changes to enable farmers to put technologies into productive use (Hårsmar, 2007).



Note: Error bars show standard deviation across sampled countries.
Sample size varies from n=13 to 21 for SSA, and n=8 to 15 for OECD.
Source: Agricultural R&D is from IFPRI (2003), available online at www.asti.cgiar.org;
agricultural value added is from World Bank (2004), online at www.worldbank.org/data/wdi.

Figure 2.12. Public expenditure on agricultural R&D in Africa and the OECD, 1971-2000.

Securing access to the means of production, such as land, water, forests, fishing grounds, capital and labour, is essential for African farmers, both in terms of short-term food production and food security, as well as in terms of long-term investments in maintaining their productive capacity. Land rights in particular are politically sensitive as changing existing institutions will always result in winners and losers. Standard responses, such as individual land titling, may be insufficient to protect poor people's and ethnic minority rights, or even harmful (for example, to women, if land is assigned only to men). It is essential to acknowledge the existence of multiple and hybrid forms of land rights and to promote reforms of the institutional context that allow mixtures of various kinds of land entitlements.

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[2] *ODA = Overseas Development Assistance.*

Agricultural exports are widely considered an important motor of development. But the institutional framework and rules for international trade needs considerable attention to enable African countries to further enhance their agricultural exports. The participation of African stakeholders in trade negotiations, such as those in the WTO, but also on a more bilateral scale, is usually falling short on several accounts. On all major agricultural negotiation rounds, African countries and stakeholders are strongly under-represented, lack up-to-date knowledge and expertise, lack information on the technicalities of negotiations such as procedures, lack networks and confidence in negotiations, lack budgets for travelling, and can easily be pressed by donors. This also counts for assisting Africans in bringing trade cases before dispute panels. This all reflects the unequal power balances in world trade. Supportive programs to assists African countries in agricultural trade negotiations are doing a little here, but more needs to be done.

In relation to this, adapting the trade rules towards special and differentiated treatment for African countries and African smallholders in international trade is increasingly called for, for instance with respect to the European Economic Partnership Agreements but also within the WTO. Of particular and growing importance in international food trade are the SPS[3] (and other technical) requirements, as these are increasingly perceived by African countries as being barriers to trade and exports (e.g. Otsuki *et al.*, 2001). While the necessity of these standards are hardly debated due to the increasing globalization of food scares, many sub-Saharan African countries fear that the increasing stringency of food safety and quality standards will be discriminatory and protectionist, as they exclude especially African smallholders from entering global markets. Lack of in-country technical and administrative capacities, and costs of compliance are the main reasons. It requires public and private efforts in policy, research, infrastructure and oversight. But it might also mean adapting SPS standards, for instance by basing them more on a geographical than on a commodity base, as Scoones *et al.* (2005) suggest. There should be an African focus on the WTO's 'special and differential treatment' arrangements, so that inappropriate rules can be vetoed or avoided.

High value agricultural markets are important for African agriculture and in stimulating sustainable niche markets (public and private) labels can play a vital role, by setting and implementing specific conditionalities. Fair trade labels and eco-labels form an attractive international institution which can combine agricultural niche market development with sustainable development. Moreover such labelling institutions increase transparency into African agricultural development, which is often lacking. The recently established Round Tables on sustainable international value chains (on Sustainable Soy, Palm Oil, Biofuels) are interesting mechanisms to further develop particular high value niche markets that are sustainable, but they seem to be focused towards and involving primarily the larger stakeholders. How can smallholders become part of these and other new institutional arrangements to stimulate sustainable agricultural production and niche markets?

Urbanization in Africa signifies that a rapid growing part of the population will live in, sometimes very large, cities. Next to growth in urban agriculture, this also means an increasing market for food offering farmers a new outlet for their produce. The most dynamic section in the domestic food market is formed by the supermarkets. In South Africa, supermarkets are responsible for roughly 55% of overall food retail (Reardon *et al.*, 2003), but even in Kenya supermarkets comprise 37% of food retail in 2003 (Humphrey, 2007). Supermarkets have recognized the need for diversity in formats to reach not only the richer consumers but address the demands of larger groups of (potential) clients. Supplying supermarkets generally means an increase in vertical coordination in the chains to secure quality and reduce costs. Although vertical coordination often means a bias towards large farmers, small farmers may still profit if there is no alternative, if their unit cost of production is lower, and if they can secure volume and quality (Boselie *et al.*, 2003). Nevertheless, as prices in supermarkets are generally higher than in other local food outlets, this means that supermarket shoppers are mostly confined to the richer middle class and therefore only cater for a limited market share for the foreseeable future (Minten, 2007).

3 SPS = Sanitary and Phyto-Sanitary requirements.

Extension for agriculture

Agricultural extension has been faced with reduced political interest and funding over the last decades. Where in the 1960s and 1970s much was spent on building and improving extension services, often in combination with the provision of seeds, fertilizers and other chemical inputs to farmers, this activity has seriously diminished in recent years. Disappointment about the high costs involved and the limited impact on the ground, in combination with the general goal of reducing state involvement in economic activities as part of the Structural Adjustment Programmes, are the main causes for this retreat.

In response, scientists, farmers' organizations and politicians insisted on renewed support to agricultural research and dissemination, as this remains an indispensable building block for agricultural development. At the same time competing views on the optimal model for agricultural extension emerged. Eicher (2007) distinguishes six basic extension models:

1. national public extension: the historically dominant model
2. commodity extension and research model: self-financed commodity-based system
3. training and visit (T&V): launched in the early 1970s
4. NGO extension model: since the 1990s, complementing weak or inexistent public extension services
5. private extension: user-paid extension services
6. farmer field school (FFS): since the 1980s and very popular in recent years applied to spread new technologies, such as Integrated Pest Management

These different models are debated and compared to identify the most effective and efficient one without a clear winner. There is however, a view shared by many that the linear knowledge model, where knowledge flows from research via extension and education to end-users, is outdated and more participatory models are necessary (OECD, 2006). Research, education, extension and farming practices should be closely connected through user-based networks to create plural extension systems that fit the heterogeneous needs of poor producers, with particular attention to women and small farmers. In addition, it has become acknowledged that diffusion of technologies alone is often not sufficient because they need complementary organizational, policy and other changes to enable them to be put into productive use (Scoones, 2005). Therefore, innovative extension strategies should be based on the 'transition-perspective', combining technological, social and institutional change in different constellations at different levels (Geels & Schot, 2007)

Farm and rural non-farm activities are synergistic in Africa and therefore the broad development of institutions, infrastructure and facilities must be seen in the light of how they affect agricultural production and competitiveness. Thoughtful, innovative ways of tapping into, and intelligently using, local information and experience about local soil conditions, drought cycles, pests and diseases should be sought when formulating region-specific agricultural innovations and support services.

The need for a 'livelihood' focus

The role of agriculture in food security and income generation must be considered within the extended livelihoods of rural people. The alternatives for income generation, both locally and further afield (often in urban centres) determine farmers' interest and ability to invest in agriculture. Many smallholder farming families receive remittances from family members working in towns and cities (Andersson, 2001). The strong connections and interdependence between rural and urban family members often determine the ability to invest in new agricultural technologies. Dorward *et al.* (2003, 2004) recognize different livelihood strategies among rural communities: those who are 'stepping up', investing in agriculture to improve their livelihoods; those who are 'stepping out', investing in education and opportunities for off-farm employment as an alternative to an agricultural-based livelihood; and those who are 'hanging in', often the poorest households for whom agriculture provides food security at best, and who are often working for other farmers to earn cash and food. The investment in, and appropriateness of agricultural technologies and entry points for improving agricultural productivity differ for each of these groups.

2.5 Economic perspectives for emphasizing diversity

2.5.1 Household ability to adopt technologies

Farmers adoption of productivity-enhancing technologies and their responses to economic policies depend to a large extent on their access to input and output markets. In the absence of functioning markets farmers' production and consumption decisions are interdependent and influenced by household characteristics and endowments (Sadoulet and de Janvry, 1995). Markets can be missing completely for a whole village due to its remoteness and high transportation costs. But market failure can also be idiosyncratic affecting single households within a community. This is for example the case for poor households that lack collateral and therefore do not have access to financial markets. In addition, the small amounts of credit that these households demand are usually not profitable for formal banks to provide. In many rural areas, microfinance institutions have been implemented to narrow the gap between credit demand and supply to the poor. These institutions rely on group lending schemes and peer pressure to replace formal collateral. However, as opposed to Latin America and Asia, the success of these microfinance institutions has often been limited in Africa due to lower repayment rates (Lapenu and Zeller, 2001). This has sometimes been attributed to government involvement in the past, where loan recovery was not followed strictly and farmers got used to perceiving loans as gifts (Buckley, 1997). A key challenge for the promotion of financial services for the poor is designing adequate financial institutions that provide the right incentives to borrowers to repay their loans, which must rely on local organizations and norms to be successful. Microfinance institutions in Ghana for example have successfully built on the experiences and institutional structures of the traditional *susu* system of savings to expand their loan services (Basu *et al.*, 2004) (see box in section 3.3).

In order to understand low adoption rates of promising, high-yielding agricultural technologies by African farmers, it is essential to understand the constraints faced by rural households. The lack of access to financial services and credit as mentioned above can be one important reason for low adoption rates, especially in the case of more capital-intensive technologies that require the purchase of high-yielding seeds and large amounts of chemical fertilizers. But low adoption rates are also observed for low external input technologies, such as SRI (System of Rice Intensification) (Uphoff, 2003). In Madagascar, Moser and Barrett (2003) found that non-adoption of SRI was due to the lack of labour during the growing season in addition to liquidity constraints. In SRI, yield increases are very sensitive to the timing of the transplanting of rice seedlings. However, poor farm households in Madagascar need to complement their incomes with off-farm activities during the growing season in order to obtain cash income to fulfil their basic needs. Therefore, those households that lacked sufficient family labour and liquidity were not able to reallocate their labour, even if that led to higher yields and overall incomes at the time of harvest. It is therefore critical to take into account the different constraints faced by households when introducing technological innovations. While some farmers will be able to take advantage of the technologies others might be excluded unless the technological innovations go hand in hand with measures to improve access to productive resources (labour, capital, intermediate inputs, land, etc.).

Labour productivity

A pitfall in stimulating agricultural productivity has appeared to be the overemphasis on land productivity, thereby neglecting enhancement of labour productivity. While rice yields could be increased by 150% following adoption of an Asian-like system in Western Africa, returns on labour increased by less than 70% (Spencer and Byerlee, 1976). Land management systems such as alley cropping, which reduce soil erosion and increase yield, are only profitable under high population density and low labour costs for instance (Ehui, 1990; Sanchez, 2002).

2.5.2 Market access and price policies

While integration into functioning markets is the basis for farmers' ability to respond to economic incentives and consequently adopt technologies and increase agricultural production, the question is how to achieve this integration. International commodity markets have often been characterized by volatile prices and declining terms of trade. Price volatility and uncertainty impose risks on farmers that poor rural households are often unable to bear in the absence of suitable insurance schemes. As a result, smallholders have often opted out of markets relying on subsistence agriculture. Policies are needed that enable farmers to access markets, cope with price risk and adequately respond to economic incentives.

In the past, price policies targeted at stabilizing food prices have often jeopardized the profitability of domestic agricultural production. Here again it is essential to take into account the different livelihood strategies pursued by rural households. While net buyers of staple foods (those household that buy more food than they produce) benefit from low staple food prices, net sellers loose (Deaton, 1997). Minten and Barrett (2008) add to this the cross-cutting category of households that mainly depend on unskilled wage labour to make a living[4]. While they are net buyers of food and therefore benefit from low prices, they also experience a negative effect through the induced decrease in production and consequently demand for wage labour (Minten and Barrett, 2008). Without taking demand and domestic production numbers into account, blue-print economic policies will fail to achieve the desired effects on poverty alleviation. Instead, a country and crop-specific assessment of the costs and benefits of price stabilization measures needs to be performed to adapt policy measures to the specific context.

With highly volatile prices in traditional export commodities, much emphasis has recently been given to the integration of farmers in developing countries into high-value product markets. These market segments provide the opportunity for farmers to obtain a higher price for their products and to engage in a more stable long-term trade relationship. Because of the higher degree of specificity involved in the production and marketing of high-value food products, transactions in these segments are often characterized by contractual agreements. However, the effect of high-value supply chains on developing countries, and especially on the rural population, is not conclusive to date. Maertens and Swinnen (2009) find in their study of the horticultural export sector in Senegal that agribusiness firms initially contracted with farmers but moved to vertical integration due to high standards and difficulties with contract enforcement. Nonetheless, the overall welfare effect on the rural population was positive, because smallholders and landless people were employed on the company-owned estates. It is important to note, however, that in the case of the Senegal study land access was not a constraint and farmers were able to continue farming their own land. Eventually, the impact of vertical coordination and integration depends on the institutions in place, including the land tenure system and contract enforcement rules, as well as on the jobs and incomes created in rural areas.

Another option for creating markets is the expansion of regional trade. Regional markets in Africa are not well developed: only 9% of African agricultural imports come from farmers located within the region. There seem to be un-tapped opportunities for economic growth; however, the lack of infrastructure that connects rural areas to urban centres often prevents effective competition of domestically produced goods with imports. One attempt to spur agricultural production in Africa is the 'purchase for progress' initiative of the World Food Program (WFP) launched in 2008. The program is partly a response to criticism of food aid being procured from developed countries' surplus production and serving their interests (Barrett and Maxwell 2005). The objective of the program is to provide farmers in Africa with a secure market outlet and fair prices for their produce, thus creating economic incentives for farmers to increase their production, while at the same time providing the people in need with food aid.

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[4] Minten and Barrett (2008) find that in Madagascar based on the 2001 National Household Survey 71% of the households are net buyers of rice, 7% are autarkic (i.e. producing exactly the amount of rice they consume), and 22% of the households are net sellers. Looking exclusively at the rural population, they find that although 70% of them grow rice, 66% of the rural households are still net buyers of rice.

2.5.3 Macroeconomic and policy environment

African farmers will only be able to benefit from market developments, if institutional and macroeconomic conditions are favourable. Collier (2007) in his book describes different conditions that can lead to poverty traps preventing economic development. Among the most important factors that influence economic performance are civil war and conflict. While conflict negatively affects economic growth, poor countries are also more prone to conflict. This leads to a perpetuation of the situation with violent conflict hindering economic development and low incomes providing favourable conditions for the rise of violent conflict. Conflict thus has a sustained effect on the economic basis of a country. Collier (2007) refers to the example of the Democratic Republic of the Congo that will need about 50 years at its present rate of economic growth to achieve its income levels from 1960. Furthermore, conflict raises transaction costs, uncertainty and distrust. In an uncertain environment, farmers are reluctant to invest in their land and raise productivity, because they cannot be sure that they will be able to capture the returns on their investment. As a consequence of high costs of market transactions, farmers may also focus on subsistence rather than cash crops (Deininger, 2003), with negative implications for existing trade and market relationships that need to be rebuilt (from scratch) after the conflict is over.

Furthermore, Collier (2007) points out the importance of governance for economic development. He observes that in low-income countries the discovery of natural resources has often led to the empowerment of rent-seeking governments failing to invest returns from the export of natural resources into economic growth (referred to as the *natural resource curse*) and neglecting the agricultural sector. 'Bad governance' and corruption have negative impacts on government investments in infrastructure and the provision of services especially in rural areas. In many African countries policies have been geared towards serving the urban population, thus marginalizing the rural sector examples.

Finally, Collier (2007) stresses the importance of geographical factors, such as access to coast lines. Obviously, a landlocked country has fewer opportunities with regard to global trade than a country with access to ports. Additionally, the set of opportunities of a country depends on its neighbours. If the neighbours experience economic growth, the landlocked country can potentially benefit from spill-over effects, especially if it uses these countries as markets for its products[5]. However, this is obviously not an option for a country like Uganda, surrounded by countries with low infrastructural development, civil unrest and stagnant development. High transportation costs and risks in the neighbouring countries effectively prevent the supply of their markets or the use of their ports. Accordingly, the scope for being integrated into international value chains is limited. It is estimated that transportation costs in landlocked countries are 50% higher than for a typical coastal country (The World Bank 2008). For landlocked countries in Africa freight costs average one-third of export values (twice as much as for sSA in general). One way to overcome these disadvantages is engaging in the production of high-value commodities that have an added value high enough to be exported profitably by air. Uganda for example engages in the production of flowers (mainly roses) for European export markets, which are exported by air. As noted by Dijkstra (2001) Uganda's competitive position in flower exports is largely determined by its ability to obtain competitive air freight prices. Unfortunately, being a landlocked country, fuel transport to Entebbe airport is expensive compared to countries such as Kenya. However, the report concludes that Uganda has a competitive position in flower exports if it is able to improve the handling procedures at the airport (that determine flower quality) (Dijkstra, 2001).

Social capital, trust and institutions vary widely across Africa. They are formed historically and are influenced by past and current political governance, peace/conflict, culture and economic development. At the same time, they have a significant effect on the effectiveness of development policies end economic growth. Institutions are necessary to foster economic development, but institutions can also prevent advances in poverty alleviation if they fail to adapt to new circumstances. Recently there has been a renewed emphasis on cooperatives and farmers' groups as a tool for integrating farmers into markets (The World Bank, 2008). While collective action can be a promising and empowering strategy it also hinges on factors such as trust and commitment. In many African countries cooperatives have had a history of bad performance because of government interference, corruption and

[5] This has been the case for landlocked countries in Europe, such as Switzerland.

compulsory membership. In those cases, it is especially important to rebuild the trust in farmer-based organizations and in the opportunities offered by collective action.

2.6 From silver bullets and best-bets to 'best-fits'

Realisation of the production potential and therefore increasing agricultural productivity in Africa calls for a comprehensive approach of simultaneous measures to be taken. The agronomic production potentials have to be benefitted from, favourable economic conditions should be available or created, while the level of organisation or institutions should support the productive sector to emerge. The need for these simultaneous measures as outlined in Figure 2.4 has been presented in Figure 2.13.

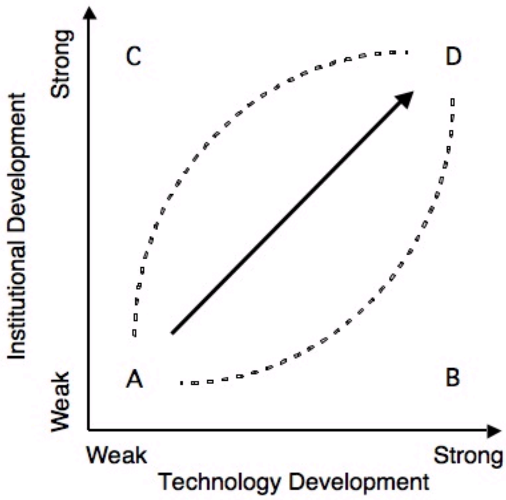

Figure 2.13. The linkage between development of technologies and institutional development. If technology development outpaces the institutional development required for a technology to be successfully implemented and adopted by farmers it will be doomed to failure (Point B). Conversely, if a strong market demand for a crop exists, but well-adapted varieties and appropriate technologies for production of the crop are not available, the intervention will also fail (Point C). Only when all components are in place to ensure good productivity and strong market development will technology uptake be achieved on a large scale (Point D).
Source: Giller (2001, p.306), (based on Dorward et al., 1998).

During the 1990s much emphasis was placed on the identification of 'best-bet' technologies for different regions and target groups, recognising that technologies had too often been presented as widely applicable 'silver bullet' solutions (Waddington *et al.*, 1998). These technologies could then comprise 'baskets of options' that could be recommended for testing and implementation by development workers (extension and NGOs) and farmers. Agroecological regions were considered as fairly homogenous units that could be useful as recommendation domains. When these 'best bet' technologies for improving soil fertility were subjected to widespread testing, they frequently failed. Among the reasons for the disappointing results was the farmers' choice of fields for technology testing: often farmers allocated their most degraded or weed-infested soils for the trials. Essentially, the soil fertility was too poor for the soil improving technology to give immediate benefits, or in some cases to work at all. Severe soil degradation led to such strong soil fertility constraints that there was virtually no crop response to fertilizer, or the soil-improving legumes produced only minimal biomass. Moreover, risk management in agricultural production systems is a basic precondition for productivity to increase. This implies to all aspects as laid out in Figure 2.2, including the harsh and highly variable biophysical conditions, stable market conditions and supportive institutional arrangements.

While agricultural research has raised our understanding of African smallholder farming system, the number of 'success stories' remains limited. There is general consensus that agriculture must be considered within the frame of the 'extended livelihoods' of the populations within rural areas (Andriesse *et al.*, 2008). A key challenge when implementing 'revolution style' policies in Africa is to address the diversity at all scale levels. At the macro level, African countries differ widely in terms of biophysical conditions, access to markets (e.g., presence of navigable rivers and port, or not), political regimes, social norms and traditions, presence of valuable natural resources (e.g., oil), and so on (see also Collier 2007). Policy reform or interventions that are successful in one country may be ineffective, or worse, in other countries. Diversity is similarly important at the meso level (local governance, institutions, infrastructure), and the farm or plot level where divergent initial soil features may have been accentuated by decades of management and use. Hence, a development agenda should focus on institutional frameworks capable of embracing diversity by utilizing local information to a large extent.

3. Embracing diversity

Chapter two provided an overview of the diversity encountered at different levels (micro, meso, macro) in Africa. Africa is a continent with great cultural and socio-economic diversity, as well as a wide variety of agro-ecological and climatic conditions and should therefore not be treated as one single issue. Blueprint measures generally fail to recognize the diverse local conditions and will not lead to the desired outcomes. Top-down approaches that impose 'best practice' measures without taking the local conditions into account have been proven ineffective in the past. Instead it is critical to identify solutions specifically tailored to the circumstances faced by a country or region and adapted to local needs. For this purpose, local knowledge is essential in order to derive 'best fit' solutions that fit the specific context.

The increasingly dominant paradigm of thinking towards enhancing agricultural productivity is one of 'market-led diversification and intensification'. Whilst linkage to markets (particularly for cash crops such as cotton, tobacco, etc.) can provide the opportunities for purchasing fertilizers to drive up productivity, not all market-led intensification leads to sustainable production systems. A good example is the influence of urbanization on developing the market for cooking bananas (Matoke) in Uganda. Rapid economic growth, with a concomitant increase in the population of Kampala has led to rapid expansion of the market for Matoke in the city. This leads to a one-way nutrient transport in the cooking bananas to the urban centre, as the bananas are produced in traditional systems with virtually no addition of fertilizers. Thus decline in banana production is likely (and already appears to be happening) unless alternative methods of soil fertility management can be sought.

Thus new approaches for enhancing productivity in Africa must take account of, and harness, the dynamic nature of farming systems and the heterogeneity between regions, farmers and their fields. Both mineral fertilizers and organic matter are scarce nutrient resources, necessitating steps to increase availability of these resources and to manage them efficiently. A key issue is tailoring soil fertility management to new opportunities for market development, some of which bring new opportunities and some new threats for sustainable soil management. The proposed approach represents a substantial shift in concepts from traditional 'blanket recommendations' to focus on the targeting of best-fit technologies to different farmers and crops within production systems using simple 'rules-of-thumb' derived from scientific principles and local farmers' knowledge.

3.1 Agro-technological options

The production potential of sSA will have to be fully used for the provision of food. Even then, additional land will be required, putting a claim on natural areas and grasslands. Integrated approaches will be needed to cope with the high biophysical risks faced by the farming community.

3.1.1 Plant genetics

The wide diversity of food items consumed in sSA calls for crop improvement of a larger number of crops, than the major cereals only. Moreover, the diversity of the production environments and farming systems, and the general lack of farmers to irrigate their crops or to apply chemical inputs, implies that crop-improvement research needs to emphasize resistance and tolerance of crops to adverse environmental conditions, rather than to attain high potential yield levels under well controlled biophysical conditions. Crop improvement and breeding approaches should be attuned to the development of new varieties to fit into local niches and to involve extensive farmer participation (De Vries and Toenniessen, 2001; Bindraban *et al.*, 2006).

Because blueprint approaches, including government or private sector as seed producer, have proven unsuccessful, new approach has to be pursued. To revive the seed sector, the formal sector (CGIAR-institutes, NARs, internationally operating companies) and the informal sector (farmers, local entrepreneurs, NGOs) should cooperate. The role of each and every stakeholder should be acknowledged in this process to release new varieties that are resistant and tolerant to the harsh and variable biotic and abiotic conditions of sSA (Smolders, 2006; Louwaars, 2007).

Many of the current initiatives in biotechnological improvement in Africa result from spill-over effects of activities developed outside the continent, rather than being initiated from desires and needs coming from within. An overview of developments on resistance for abiotic stresses reveals, for instance, that most attention has been paid to tobacco, with some also on rice and potatoes (Thomson, 2003). An example of where a targeted single trait improvement could have a large effect on African agriculture is described by Toenniessen and colleagues (2003). This concerns the Cassava Mosaic Disease (CMD), the most prevalent cassava disease in Africa, causing reductions in yield of 20 - 90%. Host plant resistance appears to be the most effective means of control, as farmers cannot afford insecticides to control the white fly vector. Some resistance has been detected in an interspecific backcross progeny of a cross between cultivated cassava and the wild relative. Recently, a novel dominant gene that confers resistance to CMD was detected in a Nigerian variety which was shown to be qualitative in nature and stable across environments. In order to develop resistant varieties for Africa, through either conventional breeding or biotechnology, it is important that particular attention be given to issues relevant and specific to the continent itself. Deteriorated seed systems

Breeding for climate adaptation

Cowpea [Vigna unguiculata (L.) Walp.] is one of the most important food legumes in the tropic and sub-tropic regions. A remarkable feature of cowpea is that it thrives in dry environments and this makes it the crop of choice in the semi-arid/arid zones of West and Central Africa. Additionally, cowpea used to be the first crop harvested before the cereal crops are ready and therefore it is referred to as 'hungry-season crop'. It is the most economically important indigenous African legume crop (Langyntuo *et al.*, 2003) and is of vital importance to the livelihood of several millions of people in West and Central Africa. With more than 25% protein in seeds as well as in young leaves (dry weight basis), cowpea is a major source of protein, minerals and vitamins in daily human diets and is equally important as nutritious fodder for livestock (Singh *et al.*, 2003b). Cowpea is a most versatile African crop; it feeds people, their livestock and because of its ability in nitrogen-fixation, it improves soil fertility, and consequently helps to increase the yields of cereal crops when grown in rotation and contributes to the sustainability of cropping systems. Although cowpea belongs to the inherently more drought tolerant ones among the popular crops grown in Central and West Africa (Singh *et al.*, 1997; Ehlers and Hall, 1997; Kuykendall *et al.*, 2000; Martins *et al.*, 2003) it still suffers considerable damage due to frequent drought in the Savanna and Sahel sub-region. Early maturing varieties escape terminal drought (Singh, 1987), but if exposed to intermittent moisture stress during the vegetative growth stage, they perform very poorly (Mai-Kodomi *et al.*, 1999a). The early maturing cowpea cultivars tend to be very sensitive to drought that occurs during the early stages of the reproductive phase (Thiaw *et al.*, 1993). Unstable rainfall in the early cropping season seems to be the pattern in the sub-region, and the duration of the rainy season appears to be reduced. Where until recently early maturing cowpea varieties could escape most of the detrimental effects of drought, the changing conditions require varieties that not only finish their lifecycle early, but can also tolerate drought spells in the reproductive stage. Therefore breeding efforts now concentrate on incorporating tolerance to terminal drought.

3.1.2 Climate

Extreme climatic events such as years of extreme drought, excessive rainfall leading to flooding or days with extreme temperature can have dramatic effects on production (Wheeler, Craufurd *et al.*, 2000; Porter and Semenov, 2005), and there is emerging consensus that the Sahel region will experience an high degree of climate variability in the future (Held, Delworth *et al.,* 2005; Kamga, Jenkins *et al.,* 2005). Forecasts of extreme events can support policy makers and farmers in anticipating on forecasted extreme events.

Because large agricultural investments require 15-30 years to pay of (Reilly and Schimmelpfennig, 1999), long term impacts of climate change should be taken into consideration. (Liu 2008) has shown for 6 major crops that the climate change scenarios yield more or less the same results: a sharp decline in wheat yields, a sharp increase in millet yields, slight increases in rice and millet and almost unchanged production levels for sorghum and cassava. The study does not take into account, however, the intrinsic, self-adaptive capacity of the rural sector. New crop distributions could be pursued, such as the replacement of sorghum by maize and vice versa, or new crop varieties could be used which are more adapted to harsher climate conditions. Without adaptation, most studies (e.g. Parry, Rosenzweig *et al.*, 2004; Liu, 2008) produce alarming results, with production per capita not keeping pace with population growth.

Climate science has reached a level where some of the forecast products can now be used operationally at farm level, providing the products are tailored to stakeholder needs, such as in Australia (Meinke, Nelson *et al.,* 2006; Howden, Soussana *et al.,* 2007; Lo and Wheeler 2007). This approach that accounts for spatial and temporal variability is knowledge intensive but also sufficiently meaningful for farmers, as it resembles a scientific equivalent of farmers intuitive approach to agricultural risk management. As (Twomlow, Mugabe *et al.*, 2008) note farmers, for instance, simply ignore fertilizer recommendations if these are not tuned to their local conditions and strategies for coping with risks.

Howden et. Al (2007) argue that though incremental adaptation will have substantial benefits under moderate climate change, more systematic changes will be required for more severe changes. Therefore, a proactive approach is needed to risk management across sSA that combines recognised, existing vulnerabilities (e.g. Liu *et al.*, 2008), with our scientific understanding of future climates, sound on-farm risk management strategies (training) with institutional support for infrastructure improvements.

3.1.3 Soil management

New approaches to the problem of building soil fertility use the principles of 'Integrated Soil Fertility Management' (ISFM), and 'Balanced Nutrient Management' recognising that: 1) neither practices based solely on mineral fertilizers or solely on organic matter management are sufficient for sustainable management of agricultural production; 2) well-adapted, disease- and pest-resistant germplasm is necessary to make efficient use of available nutrients (Vanlauwe *et al.*, 2002); and 3) good agronomic practices in terms of planting dates, planting densities and weeding are essential to ensure efficient use of scarce nutrient resources (Tittonell *et al.*, 2006). In addition to these principles we recognize: 4) the need to target nutrient resources within crop rotation cycles, going beyond recommendations for single crops (Giller, 2002); and 5) the importance of integration of livestock within the farming systems (Rufino *et al.*, 2006). Participatory plant breeding approaches have made major advances in the speed of development of new varieties of a range of staple cereal and legume crops. Improved understanding of seed systems indicates that while the private sector is important for cereals, many self-pollinating crops require local initiatives to enhance availability and uptake of new varieties.

The resources available to different groups of farmers, in terms of land, labour and cash, coupled with their production goals, determine their capacity to invest in ISFM. Labour constraints often restrict the efficiency with which the scarce resources are used. An overriding conclusion from reviewing the scientific literature on ISFM is that research has been insufficiently embedded in the constraints of farmers. This means that many technologies remain 'on the shelf' without widespread uptake by farmers.

Integrated Soil Fertility Management (ISFM)

Both sites and production systems and partners should be selected that can concur on the feasibility of ISFM to trigger agricultural intensification based on more viable and remunerative production systems. Experience has shown that intensification generally takes place when a number of basic conditions are met, as has been spelled out in Figure 2.2. The ISFM project focuses on production systems that are intensive and market-oriented. That does not mean favouring only sites that have the best economic potential or targeting the richest farmers. The purpose is to find situations where inputs can be made available and accessible to more crops, more farmers, and more fragile soils.

Table 3.1. ISFM improvement of crop yields and fertilizer profitability in West Africa (IFDC, 2008).

	Farmer's practice			After 4 years of ISFM		
	kg/ha	PFP [1]	VCR [2]	kg/ha	PFP [1]	VCR [2]
	Maize: a) bush fields Sudanian savannah [3]					
Yield	750		-	2750		4
N	0	-		100	28	
	Maize: b) compound fields Sudanian savannah [3]					
Yield	3000		-	4600		12
N	0	-		100	46	
	Maize: c) degraded soils Coastal savannah [4]					
Yield	750-1500		-	4600		12
N	0	-		50	92	
	Sorghum: South Sahel & North Sudanian savannah [5]					
Yield	1000		-	1800		8
N	0			50	36	
	Cotton: South Sudanian savannah [6]					
Yield	1150		5	2000		8
N	60	19		60	33	
	Irrigated rice: Coastal savannah [3]					
Yield	3000		8	5500		12
N	70	43		100	55	

1) *Partial factor productivity = kg of crop per kg of fertilizer N.*
2) *Value-cost ratio = value of crop divided by the cost of NPK fertilizer.*
3) *Improved crop residue recycling.*
4) *See 3) + mucuna cover crop.*
5) *See 3) + 'zai'.*
6) *See 3) + improved rotation.*

Investment in soil conservation bears fruit in Burkina Faso

The central plateau of Burkina Faso is characterized by poor soils and a high population density (up to 100 people per km2) with annual rainfall of 500 to 700 mm. By 1980, vegetation was disappearing rapidly, cereal yields averaged 400 to 500 kg ha^{-1}, the level of the water table was rapidly falling, while between 1975 and 1985 up to 25% of families left the villages. Soil and water conservation (SWC) methods over the last 15-20 years have contributed to remedy some of these problems with substantial improvements. Previously attempts by the extension services and NGOs to introduce SWC techniques such as bunds, appeared fraught with technical and financial problems for the farmers and were not adopted. However, there was a traditional use of planting pits applied on a small scale for rehabilitating rock-hard barren land that rain water could not penetrate. Farmers improved this technique by widening the pits and applying manure with concentrated water and nutrients at the same spots. This attracted termites that digested the organic matter, making the nutrients more readily available to plants. The termites also dug tunnels that improved the soil structure. This pitting technique is less constrained by labour shortages because the land is prepared in the dry season where there are fewer farm operations. The prior preparation of the pits also enables farmers to plant immediately on the onset of the rains. All this enable better responses to fertilizer in crop yields and biomass production, leading to:

- Yields of sorghum and millet have greatly increased and the food security of households has improved.
- The process of deterioration of vegetation has been halted on farmed plots of land on which the soil and water conservation techniques have been adopted (more than 100,000 ha restored).
- Increased investment in livestock by men and women is observed, as well as more intensive livestock production, producing more manure to improve soil fertility.
- More fodder is available for livestock, as a result of the regeneration of vegetation.
- A large number of villages have noted a rise in water levels (+ 5 m or more), as a result of the increased infiltration of rainfall and runoff.
- Rural-rural and rural-urban migration has decreased since the SWC programs started.
- The organizational ability of villagers has improved.
- The local population considers there to have been a substantial reduction in rural poverty (up to 50%) between 1980 and 2002.
- The cumulative impact of SWC is also observed in agricultural statistics at provincial level.

This low-cost SWC practice triggered agricultural intensification and improvement of the environment, by reducing risks and boosting productivity. Other factors are also involved. The devaluation of the West African currency (the CFA franc) in early 1994, for example, stimulated investments in livestock, while improvement of the major roads linking Ouagadougou and the two regional capitals reduced travel costs and allowed traders in Côte-d'Ivoire, Ghana and even Nigeria to send their trucks to the province of Yatenga to buy seeds, dolichos and vegetables.

Sources: Reij and Waters-Bayer, 2001; Kaboré and Reij, 2003; Jones, 2006.

Need for balanced crop fertilization

Continuous cultivation without inputs typically leads to depletion of soil nutrient stocks, with deficiencies of nitrogen and phosphorus being most widespread. An important source of N for productive agriculture is biological nitrogen fixation, through which grain legumes contribute the majority of protein consumed by the poor form (Giller, 2001). Nitrogen is stored in soils in the soil organic matter that declines rapidly under continuous cultivation without inputs. Organic manures - such as animal manure or biomass from legumes - can maintain the supply of N, but rarely in the amounts required for large yields of cereals. The dynamic cycling of N requires that soil productivity is maintained by frequent additions of N as fertilizer or organic manure (Giller *et al.,* 1997). Phosphorus is the next most important nutrient that is often available in short supply - either due to the inherent small stocks of P in light-textured (sandy) soils found across drier regions, or due to the fixation of P into unavailable forms which is a major problem in heavy-textured (clay) soils which are predominant in the humid tropics. Animal manures can supply P, but only if applied in large quantities, and plant residues contain too little P to be of use. There are many deposits of rock phosphorus

(RP) in sSA, but few are sufficiently soluble to be applied directly to crops without pre-treatment (Buresh *et al.*, 1997). Although there was considerable attention to 'soil fertility recapitalization' in the 1990s, recommending one-off large applications of RP, it is clear that frequent small additions more soluble forms of P give a much more efficient and affordable use of scarce nutrient resources (Buresh *et al.*, 1997). Whilst all crops need an adequate supply of P, legumes are particularly responsive and large inputs from nitrogen fixation are only possible when P deficiencies are corrected (Giller and Cadisch, 1995).

Fertilizer is a scarce commodity in Africa. Forms commonly imported and available in Africa are diammonium phosphate (DAP), urea, triple superphosphate (TSP), potassium chloride (KCl), and complex NPK fertilizers (IFDC, 1995). When fertilizers are available and used, this leads to enhanced productivity and greater demand for, and extraction of other nutrients that in turn may become limiting for crop growth. After N and P, the nutrient that is needed in large quantities and most often in short supply is K. Few of the fertilizers available in sSA contain the other macronutrients, such as S, Ca and Mg that are required by crops in large amounts, and micronutrients such as Zn, and B that are essential but required in much smaller amounts. Deficiencies of Zn are widespread on sandy soils and can constrain crop growth such that use of NPK fertilizer is very inefficient (Zingore *et al.*, 2007). Integrated soil fertility management, where fertilizers supply the NPK and animal manures other essential nutrients such as Zn and Ca is an approach to rehabilitate such soils and sustain production (Grant, 1981; Zingore *et al.*, 2008). Van Asten and colleagues (2004) found synergistic effects of joint application of Zn and P on nutrient uptake that led to increases in crop yield. Application of either phosphorus or zinc alone gave little yield improvement, the addition of Zn led to more efficient use of P, presumably due to enhanced uptake by the root system.

Some recent initiatives on fertilizer manufacture and blending in sSA have recognized the importance of the secondary macro- and micronutrients. In Kenya, the Athi River Mining Company now produces and markets two blends of fertilizer under the name Mavuno. These blends for basal dressing or top dressing combine imported N and P with local minerals (gypsum and dolomitic limestone), muriate of potash, and micronutrients (B, Zn, Mn, Mo and Cu). The use of local minerals makes Mavuno 15% cheaper than the fertilizer types (DAP and urea) on which they are based (Poulton *et al.*, 2006).

It is important to avoid fertilization strategies that lead to strong dilution of the micronutrients in crops, as this can reduce the nutritional quality of food. Some of these phenomena have, for instance, been observed in various instances in Asia (Ladha *et al.*, 2003; Nambiar and Abrol, 1989). From a perspective of diet diversity and nutritive value, research on fertilisation strategies for mixed cropping systems is required. Much research on soil fertility has focused on the major cereals and cash crops, with relatively little research until recently on the important starch and root crops such as cassava (e.g. Adjei-Nsiah *et al.*, 2007; Fermont *et al.*, 2009).

3.1.4 Water

Effective management of water is key to the success of African agriculture. Much emphasis has been placed so far on (donor driven) large scale irrigation. As the availability of water is low on the continent, any large scale initiative should critically look into the use efficiency of water. The water productivity of irrigated rice cultivation is for instance still extremely low, at 4000 to over 10.000 liters of water needed for the production of one kilogram of rice. While minimal values of only 1500 to 2000 liters are reported in Asian countries under optimum management conditions, the choice of irrigated rice cultivation itself could be critically reviewed. When soil and weather conditions and markets would allow it, other high-value crops, in particular vegetables, might be more profitable and make more efficient use of water. In Ethiopia on the other hand, poor agronomic management of vegetable cultivation has been associated with the depletion of freshwater resources used for irrigation (Jansen *et al.,* 2007). Also, dry cultivation of rice could be considered as in Brazil. Enhancing the use options through expansion of the cropping system, such as in the Office du Niger, also offers opportunities to improve agricultural productivity.

Office du Niger, Mali

The Office du Niger, set up in 1932, is one of the largest irrigation schemes in sSA (Gabre-Madhin *et al.*, 2002). In the early 1980s about 50,000 ha was irrigated at rice yields of only 1.5 tons ha^{-1}. This was mainly due to government control of production, milling and marketing in combination with tenure insecurity, poor maintenance of irrigation infrastructure, and inefficient water management. Under donor pressure, the government agreed in 1988 to comprehensive reforms with two major components: more decentralized management of the irrigation areas, and liberalization of rice milling and marketing. Now, farmers are involved in water fee determination, management of maintenance and, through their participation in management committees, in oversight of performance contracts. The reforms triggered the following impacts:

- Paddy yields increased from 1.5 to 5.5 tons ha^{-1} and production more than tripled to about 300,000 tons.
- Diversification of income occurred through the introduction of dry season crops, notably onions which reached 70,000 tons in 1999;
- Water fee collection increased from 60% to 97%.
- Thirty-thousand hectares have been rehabilitated and the irrigated area is being expanded by another 30,000 ha.

The economic rate of return at completion of the Office du Niger project was 30%. Net rice revenue increased from \$450 ha^{-1} in non-rehabilitated areas to \$1000 ha^{-1} in rehabilitated areas. This project has clearly succeeded in overcoming the institutional problems that are commonly identified as key constraints to improvement of irrigation performance in many countries. The project benefited from inspired in-country leadership, as well as a common approach among the many donors. Apart from its supply side achievements, the project also benefited from the 1994 devaluation and price liberalization on the demand side.

Much emphasis has also been placed on in-situ water conservation in farmers fields. Raising bunds and other measures needed appear to be highly labour intensive and not necessarily lead to increase labour productivity, even though crop yields might increase. Less or not practiced on the African continents are medium scale irrigation facilities, such as 'tank systems' in Southern India. These community driven systems collect water through curved dikes along a sloping landscape to supply several hundred hectares of up to a hundred farmers.

Because little irrigation water is available for large scale irrigation, most emphasis should be placed on increasing the water of rainfed agriculture. The options to realize improvements in water use efficiency that can be obtained in rainfed production are insufficiently addressed in the international water debates. Worldwide, these systems occupy 83% of world's agricultural land and produce 60% of world's food. Moreover, the need to improve agricultural productivity in these regions is high because they inhabit most of world's poorest people as is the case in Africa (e.g. Renkow, 2000). These regions are also poorly endowed in socio-economic and institutional development lacking physical and knowledge infrastructure, with poorly developed markets and inadequately functioning social structures (UNEP, 1992).

The potential to improve water use is however large as yields could be 3 to 4 times higher than current yield levels in sSA. Various agronomic measures can be taken to improve soil water storage for crops to withstand longer periods of drought, such as mulching, water harvesting and conservation, crop selection, timing of planting, etc. (Singh, 1998; Li *et al.*, 2001). Supplemental irrigation, in particular during crop sensitive phases, by using underground water, even if of poor quality, or rainwater harvested in tanks, can make all the difference between a total crop failure and good yield and is the best potential use of limited water supplies (Joshi *et al.*, 1998; Singh, 1998; Savenije, 1998).

Crop breeding can target site-specific conditions, such as drought and salinity, to further reduce production risk. Targeting crops to specific ecological conditions requires incorporation of wider and location specific genetic material. This becomes feasible with more efficient and rapid ways of breeding, including genetic modification, and statistical, modelling and numerical methods to support breeding efficiency (Bindraban, 1997; Podlich & Cooper, 1998; Yin *et al.*, 1999a,b; Mackill *et al.*, 1999; Cooper *et al.*, 1999; Price & Courtois, 1999; Yin *et al.*, 2000).

In setting out water management strategy, single or combinations of these and other practices at various scales could be integrated in order to either aim at full irrigation of a limited area in Africa, and more importantly at reducing production risks due to periods of drought.

3.1.5 Weeds, pests and diseases

If the overall productivity of cropping systems in sSA is to be lifted, weeds, pests and diseases should be effectively controlled. Increased control might provide additional employment opportunities for the rural poor, providing the productivity is such that appropriate wages can be paid.

Weed control is a sub-national issue that requires:

- good management skills and knowledge at the field and farm level;
- good regional policies that regulate herbicide availability, cost, distribution and safety at farm to regional levels;
- research for development that explicitly addresses weed control issues via a range of technological and managerial innovation technologies - from intercropping and species selection based on their weed-suppressive characteristics to breeding programs that develop cultivars that are less susceptible to competition by weeds in terms of their physiological (e.g. early vigour) and morphological (e.g. leaf angles and size) characteristics.

Striga

The parasitic weed Striga severely limits sorghum production (a stable food) in the dry-zones of sSA. While sorghum productivity is initially constraint by a lack of water and poor soil fertility, these factors weaken the sorghum plants, making them more susceptible to Striga infestations (van Ast, 2006). This often turns a low yield potential into a total crop failure.
A successful intensification strategy would require lifting all production constraints simultaneously. To achieve this, local farmers knowledge must be combined with scientific understanding of Striga - soil fertility management strategies. Such strategies form important prerequisites for achieving food security and improving the livelihoods of the rural population.

There is a wide range of potential management practices available to control pest and disease impacts. At present, few of them might be immediately applicable for sSA, which indicates that we need to create the pre-conditions as already outlined above. Potential management practices include:

- Breeding of crop plants to create insect or disease resistant and herbicide tolerant varieties, either through conventional plant breeding or genetic modification
- Importation of exotic natural enemies of pests that were previously introduced without them. Also repeated, mass (inundative) releases of parasitic wasps to control insect pests.
- Isolation and propagation of local natural enemies/diseases (e.g. Metarhizium on locusts, termites)
- Cultural practices such as crop rotations, mixed crops, use of physical barriers to reduce disease transmission
- Chemical pesticides and increasing bio-pesticides (e.g. Bt) and bio-fumigation of soils using Brassica species as alternate crops
- Monitoring and use of predictive models to improve timing of interventions to coincide with high risk periods.
- Landscape scale-management involving groups of farmer cooperating to reduce communal threats. e.g. when growing melons in rotation with soya beans or sugar, or chickpeas mixed with cotton.

These measures generally will need to be fine-tuned so as to cope with new challenges arising from climate change. One example is for better indicators of successful crossing over from one season to the other of a wide range of insect pests and plant diseases. This information could then be used in phenological models and GIS producing geographical scale outputs in real-time. Associated with this will be a need for enhanced communication to make farmers aware of the nature of any imminent pest and disease risks and effective options for their control.

Most of these measures will require the establishment and maintenance of effective governance processes such as, for instance, the creation of Agricultural Protection Boards.

3.1.6 Production systems

The production systems in sub-Sahara Africa have an additional feature that further complicates on-size-fit-all solutions. They are dominated by a complex (inter)cropping of numerous crops, often in combination with animals, as compared to specialized mono-cropping systems globally. This suggest that the available technologies that are tuned to specialized cultivation, as developed during the green revolution, may not be appropriate to African agriculture. Specialized mono cropping systems account for 10% of African production and can secure some of the bulk food production, but will not ensure a widespread agricultural and rural development. It is not likely that the production systems can be changed within one generation, implying that technologies and other measures should be geared to mixed systems.

Pigeonpea-maize intercropping

Intercropping of long-duration varieties of pigeonpea (*Cajanus cajan*) with maize in East and southern Africa. Both crops are planted at the same time, but early development of pigeonpea is slow, so that maize is harvested before the pigeonpea begins to form substantial biomass. After the maize is harvested, pigeonpea can grown on for several months to produce a complete canopy cover and yield of up to 1.5 t ha^{-1} of grain. Maize is planted at the same spacing as in the sole crops, and yields of maize in the intercrop are maintained close to those in the sole crop. Inputs of N through fallen leaves from the pigeonpea can be up to 75-90 kg N ha^{-1} (Sakala *et al.*, 2000), which gives substantial benefits of N for production of the subsequent maize - doubling maize yields in many cases! Pigeonpea-maize intercropping is a common farmers' practice in southern Malawi, and parts of Mozambique and Tanzania, but is possible only where some rains fall during the long-dry (7-8 month) dry season.

A consortium led ICRISAT scientists together with partners from national research organisations and the NGO Technoserve surveyed potential local and international markets for pigeonpea and identified a series of opportunities for accessing better market prices (Jones *et al.*, 2002). These included export opportunities to Europe and to India, the world's largest consumer of pigeonpea. By linking to milling companies and guaranteeing good grain quality through introduction of ICRISAT pigeonpea varieties, the export market grew rapidly - by 2002 some 40,000 t ha^{-1} of pigeonpea were exported from Babati, central Tanzania and sold into markets in Europe and India and this trade has continued to grow.

The key components of success in this case were the relatively deep soils without strong deficiencies of phosphorus and other nutrients in the extensive areas where pigeonpea is grown, the identification and sourcing of suitable varieties of pigeonpea, effective linking to the market through traders, and secure and stable markets for the increasing quantities of grain produced and sold by smallholders. Thus technical problems at the local level were overcome at the same time as the institutional problems of linking to international markets were addressed.

The role of livestock in reducing poverty should be strengthened in the sSA region as a whole. Livestock rearing in rural areas prevent poor men and women from falling into food insecurity and might bring them even out of the vicious cycle of poverty. It often constitute a reserve of wealth, steadily built up and used to counter food and income risks. This savings and insurance function will remain important so long as the commercial financial system (banks and insurance companies) remains inaccessible to the majority of people. Livestock represent more than half the capital held by rural inhabitants.

Livestock offer an important entry point for sustainable intensification of agricultural production, linked to introduction of fodders/forage production. Care has to be taken however to balance the various components in the production system. Intensification of animal production should be well designed to revolve the low productivity of grasslands. Supply of fodder is of large importance to enhance and sustain animal production.

Livestock rearing has a determining role to play in increasing the yields of cereals and certain cash crops in sSA. A farmer who works his land by hand can complete a year's full technical schedule on only 0.4 ha with hand implements only, whereas with the help of two oxen the area can be expanded to 5 ha (CIRAD, 1996). Cattle also provide excellent fertilizer: on 1 ha of land, their manure can increase cereal yields by 25% (Harrisson, 1991), and the animal excreta help regenerate very fragile soils (Baumer, 1985). In the west of Burkina Faso (the cotton basin), the Action Plan and Investment Programme for the Livestock Farming Sector (PAPISE, 2005) reports that ownership of cattle allows the production of 1 to 2 t of manure per year per animal, equivalent of a 50-kg bags of complete fertilizer, or enough to fertilize half ha of cotton or maize.

Box 2. Role of livestock rearing according to a rural producer

This is basically what one interviewee said: 'You know, our farming with hoes is a way of hiding shame. It's so you don't just sit at home every morning and become the laughing stock of the village. In fact, it's thanks to poultry, sheep and goats that I manage to feed my family and pay for school fees and even medical care. For example, when a member of my family is ill, I sell a sheep or a goat so that I can pay for fuel for the ambulance to take the person to a medical centre. When the children ask for school supplies, the solution's simple: I sell chickens or guinea-fowl.' (Sanon, 2003).

The genetic diversity and the potential for increasing the meat and/or milk yields of small ruminants are high, but untapped, as it is for poultry and pigs (Gbangboche *et al.*, 2005). Dairy production is low also (Gonçalves, 1995) at 0.5 litre a day, which could be raised to more than 2 litres with management and feed improvements (Agyemang *et al.*, 1997). Still much is to be achieved with breeding, as the large differences in productivity can also be attributed to genetic factors. The desire for a multi-purpose nature of tropical domestic species, and to survive the severe disease pressures (parasites, major infectious diseases, dietary deficiencies), has governed the choice of breeding stock, suppressing production potentials.

A major success of research on agroforestry has been the widespread dissemination of *Calliandra calothyrsus* to provide high-quality fodder for livestock. The ability to provide abundant forage from trees growing in hedgerows that take up a minimal amount of land has led to extensive use for milk production and for fattening goats. Other tree legumes such as *Leucaena collinsii, L. diversifolia* and *L. trichandra* are used in the same way by farmers in Central Kenya, as well as forage legumes such as *Desmodium intortum*.

Balancing systems components

Smallholder dairy production has been developed in central and western Kenya through heifer schemes and linked to forage improvement research by KARI, KEFRI, ILRI/ICRAF. All animals are kept in zero-grazing units. Napier grass and legumes (creeping legume forages e.g. Desmodium and multipurpose trees e.g. Calliandra) have been introduced and widely adopted by farmers (at least 300,000 farmers documented using Calliandra). Problems created when the parastatal marketing board, which marketed the milk over long distances to Nairobi, was dissolved, but local marketing and marketing to closer urban centres has developed. Over the last 10 years forages have become so important in urban, peri-urban and rural areas that Napier grass is grown all along available roadsides and even in the central reservation of the main feeder roads in Nairobi. Napier has also become a traded resource - many farmers who do not have dairy cattle grow Napier and sell to those with cattle. This provides a useful regular income but means that forage producers are mining their farms and production declines unless they fertilize the Napier grass. Most of the manure produced by the cattle owners is used for vegetable production for the market. Farmers who become involved in smallholder dairy tend to be wealthier - can invest in necessary housing, improved cross-breed cattle, and expand into goat production, etc. (Tittonell *et al.*, 2009).

A main comparative advantage of the arid, semi-arid and sub-humid regions concerns animal production intended for the regional market and mainly involving cattle and small ruminants. Natural limits have not yet been reached to benefit from the intensification of these extensive systems based on a strengthened integration with agriculture, though that needs to be supported through agro-technical inputs. Economic analysis indicates the cost-effectiveness of fattening programmes, using by-products, fodder cereals or other fodder crops. Development under such condition should be seen as a 'stepping up' - not linear development but step-wise. A farmer with local breed cattle, for instance, starts to use better quality feeds and the increased revenues allow buying better animals, being a step up to next system state, etc.

The integration of crop and livestock systems presents a great potential to enhance overall productivity (Figure 3.1). The nomadic and sedentary systems in Sub-Saharan Africa have a land productivity in terms of animal protein in the same order of magnitude as ranching systems in Australia and the USA, while it can be appreciably higher under appropriate management in the transhumance system (Breman and De Wit, 1983). These animal systems face however major constraints because of the encroachment of sedentary arable farming systems on 'traditional' dry-season pastures in the Savanna (Upton, 2004; Gautier *et al.*, 2005). This prevents the optimal use of high-quality wet season pastures in the northern Sahel. A possible development strategy for animal husbandry in Sub-Saharan Africa would be integration with arable farming in the savannah. The traditional semi-nomadic systems would serve as 'delivery room', providing young animals that could be fattened in the Savanna. Such fattening stations would also be located closer to urban centres where demand for animal products is highest. This would require intensification (including the use of external inputs, such as chemical fertilizers) to improve the quality of crop residues and pastures (also through the use of leguminous forage crops). These strategies would also distress current competition for land and feed in the Savanna because of the encroachment (Van Keulen and Schiere, 2004).

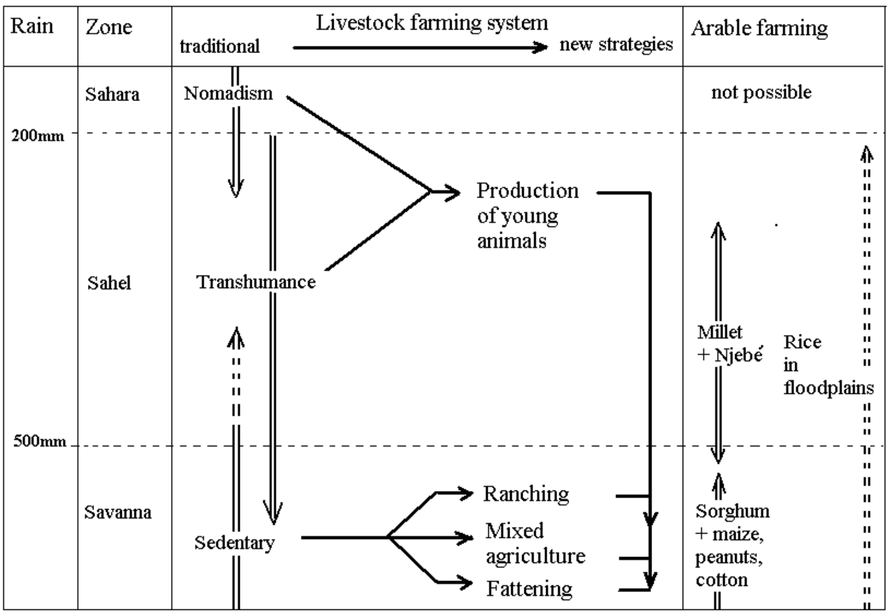

Figure 3.1. Integration of nomadic, semi-nomadic (transhumance) and sedentary systems in sSA to enhance productivity.
Source: Van Keulen and Schiere, 2004.

Box 1. Niger's agropastoral potential

Niger enjoys a comparative natural advantage for the production of cattle and small ruminants for export to the coastal countries of the Gulf of Guinea and Central Africa. Livestock rearing is practised by almost 87% of the active population as their main activity, or secondary activity after agriculture. With a pastoral area estimated at 63 000 km2 and a water-rich subsoil, the development of a small proportion of this land could already significantly increase both fodder and animal production. There is a very broad genetic potential composed of such highly productive bovine species as the Azawak zebu with its high milk yields, shorthorn cattle (Gouri) toward the Lake Chad area and the Bororo breed, which is well adapted to the arid environment of the Sahel. The know-how of Toubou, Arab and Fula herders is legendary and is a huge asset in maintaining the productivity of the various breeds of cattle. The small ruminants of Niger (Bali Bali sheep and Red Sokoto or Sahelian goats) are particularly appreciated not only in the SWA region but also in Central Africa and the Maghreb. The growing interest and organisational capacity of those involved in the beef and veal, leather and skins, dairy, and sheep subsectors are starting to be recognised within the regional trade in animal products. In view of the estimated 35% contribution of the livestock sector to agricultural GDP, the Government has recognised the sector's importance by upgrading it to a full ministry.

Statements gathered by the mission to Niamey (Ministry of Livestock Resources) on 18 September 2006.

The growing globalisation of markets and rapid urbanisation also encourage the development of 'supermarketisation' and market segmentation (Randolph *et al.*, 2004), which means that a growing proportion of urban inhabitants, even those with modest incomes, buy more animal products in urban supermarkets, at the expense of raw products sold in public places and often consumed by the poorest strata of society. Urbanisation therefore strongly influence marketing channels, increasing the need for longer commodity marketing chains, which will be in direct competition with import chains, since most large West African towns are ports - and, although the Sahel countries are land-locked, they have easy access to ports in the coastal countries.

3.2 Institutional conditions

3.2.1 Effective institutions

Institutional change is relevant in further enhancing agricultural development for most African countries and these institutional changes need to be adapted to the specifics of local (economic, environmental, cultural and political) contexts. Changing institutions therefore does not occur overnight as they may be closely connected to local circumstances (cultures, interests, etc.). Institutional change involves path-dependent processes influenced by different groups' relative power and by their perceptions (of possible opportunities and threats posed to their interests by alternative paths of institutional and technological change or stagnation) (Dorward *et al.*, 2003). Institutions themselves may pose problems in cases where necessary formal norms, such as grades and standards, are missing or when their enforcement and implementation are imperfect. Formal institutional frameworks may also be contradictory and clashes may take place between formal rules and customary norms. Politics needs to acknowledge these social norms as part of the institutional environment that bears on economic decisions and outcomes, particularly in rural settings.

Institutional change therefore requires concerted and longer term engagement of local, national and international stakeholders. Although long term, the approach needs to be flexible to allow for continued learning and adapting (Maxwell and Slater, 2003). This is a challenge as commitment to investing in agriculture by both national governments and international donors is variable. For instance, despite their pledge in 2003 under the CAAPD framework, only seven out of 53 African countries effectively spend at least 10 percent of their 2008 budget on agriculture (Somma, 2008).

Two sources of institutional failure exist, namely failure by design and failure due to improper adaptation to the wider institutional environment making two types of policy action possible: firstly to create fast-moving institutions (a formal body of law and norms for enforcement, service delivery systems and other market supporting institutions, courts and political institutions) that are in accord with the reality on the field; secondly to improve the functioning of institutions themselves. The interplay of these two policy options can be complex: indeed it is unlikely that agents will choose to use, trust and therefore grant legitimacy to a formal system that offers little certainty on outcomes. Hence attempts at formalisation or reform need to be based on institutions that offer better 'service' than customary alternatives. If customary alternatives generate good outcomes for individuals, they will require even better formal institutional performance if they are to use such formal institutions. Good policy requires not only good intentions, but also a deep understanding of the rules of the game, both written and unwritten, to be successful in generating development (De Laiglesia, 2006).

Successful institutional reforms for agricultural development require (De Laiglesia, 2006):

- Changes to formal institutions that complement cultural norms and encouragement and support for the evolution of traditional customs.
- An accessible, trustworthy way to enforce agricultural contracts that will enable farmers and traders to go beyond 'cash-in-hand' economies.
- Political institutions that allow farmers to organize themselves and address local problems collectively to give them some influence in the policy formulation.

Of key importance for the further development of African agriculture is also a system of good governance, that is of transparency, participation, accountability. Figure 3.2, based on research done within the World Bank ' Governance & Anti-Corruption' initiative (Website: www.govindicators.org), shows that this is lacking in African countries (=agriculture-based countries).

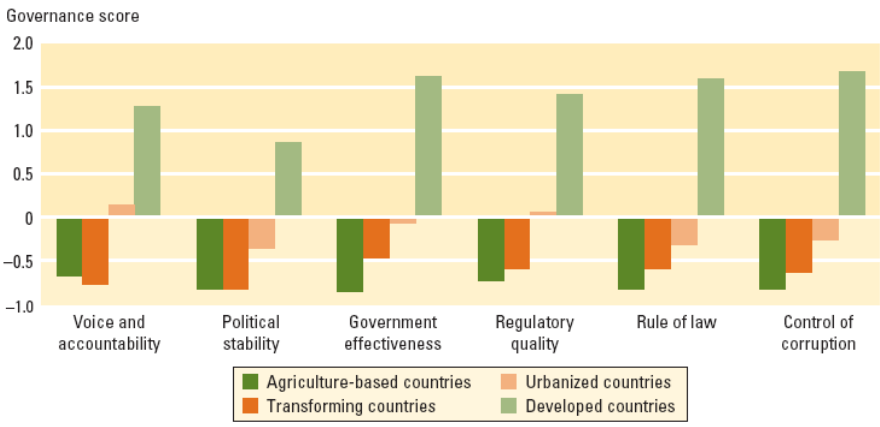

Figure 3.2. Agriculture-based and transforming countries get low scores for governance. Source: Kaufmann, Kraay and Mastruzzi, 2006.

These aggregate indicators allow to make comparisons between countries and over time as they summarise in a compact way the diversity of information (perceptions-based measures) on governance available for each country. The scores on the different indicators support the argument that many African countries still need substantial improvements in effective, efficient and participatory running of their governmental institutions.

Coordination of the many international policy and aid programmes and organizations working on African agricultural development is highly needed. There is a strong fragmentation, not only among intergovernmental institutions such as FAO, UNDP, UNEP, IFAD, GEF and the like, but also with public-private arrangements and with large private initiatives (e.g. the ISO, CGIAR, IUCN, various partnerships, HarvestPlus, the Kofi Annan Alliance for a Green Revolution in Africa). The discussion for a reorganization of all these organizations and institutions into a more effective system has been going on for some time. Some suggest reorganizing the system into three UN institutions: one related to Development, one related to Environment and one related to Humanitarian affairs.

3.2.2 Operational institutions

Adequate and operational institutions are a prerequisite for agricultural development, securing access to means of production (capital, labour, land and knowledge/technology) and to markets (infrastructure, communication and information on price and quality, etc.). In Table 3.2 several essential challenges for farmers to secure their access to markets are presented in combination with the varying roles of relevant domestic institutions (both governmental and private actors).

Table 3.2. Public and private options for strengthening farmer links to the market.

	Public sector		
Issue	**Public investments**	**Policy environment**	**Private sector**
Lack of access to markets	Invest in education, rural infrastructure (roads, markets, electricity, irrigation); support formation of producer organizations	Liberalize domestic trade; foster development of input and credit markets	Assist farmers in forming producer organizations
Weak technical capacity	Support market-oriented extension	Foster environment for private extension to emerge	Provide extension and key inputs to farmers
Meeting quality standards	Support farmer training on good agricultural practices for quality enhancement and food safety	Establish grades and standards	Supply inputs and train farmers on quality management and food safety
Meeting contract conditions	Train firms in contract design and management; train farmers on their rights and obligations	Foster institutions for dispute resolution; strengthen producer organizations	Foster trust; develop contracts that are self-enforcing
Farmer exposure to risk	Foster development of commodity and futures exchanges; train firms on use of market instruments to hedge risk	Create enabling environment for insurance market	Use contracts that share risk equally among parties; assist farmers to access insurance

Source: World Bank, 2007: 128.

Rural finance:

- all sizes of agribusiness need access to credit - not only the smallholder;
- credit is needed for the full value chain and institutions must deal with all of it;
- repayment schemes should be adapted to the real possibilities of the farmers;
- if necessary, subsidized interest rates should be considered.

'Smart subsidies' should be organized to make farm inputs available to farmers who would otherwise be unable to purchase them and delivered through the private sector. Buying fertilizers in large quantities by governments and companies may lead to lower prices farmer prices.

Land

Uncertain land tenure undermines farmers' incentives to make agricultural investments and agricultural policy must take into account the importance of farmer stability (Reardon *et al.*, 1995; Rosegrant *et al.*, 2005). The combined effects of population growth and increasing commercialization of land-based activities have increased pressure on land and raised the monetary value of land, undermining its social, cultural and spiritual significance. The process of and pressure for privatization and efficient land use have increased the individualization of tenure. Different forms of land sales also take place more and more. When indigenous forms of property undergo formalization, exclusivity of rights tends to be strengthened benefiting the primary right holder at the expense of others. When rights are formalized, some right-holders are privileged, others marginalized. At the intra-household level, youths and women tend to be marginalized relative to men in accessing and using land, which has compounded poverty in the smallholder sector. Inter-household land conflicts of a multi-dimensional nature arise as well, related to the unequal local distribution of resources, the politicisation of ethnic groups, the manipulation of religious differences and social exclusion (Havnevik *et al.*, 2007). The critical risks to tenure security come from different sources in any particular context.

However, for formal rights to be upheld and enforced, the institutions that issue or formalize them have to be seen as socially legitimate and have the power to enforce these rights. As such, formalization of tenure is a governance issue as well as a technical one. Tenure security is not only a function of ' objective' elements (content and enforceability of rights), but also of subjective perceptions - land users have to be confident that their rights will be upheld by those institutions responsible for enforcement.

Tailoring land registration to local customs

Formal land tenure registration systems, particularly titling, promoted for many years tend to be expensive, badly tailored to local contexts and inaccessible for poor groups. Yet, the innovation documented in recent land tenure reform in Ethiopia, Mozambique and Niger shows how more enabling pro-poor frameworks can be developed. These, and other initiatives, illustrate more appropriate and more flexible land tenure systems, which build on positive aspects of socially embedded rules and on group organization. In Ethiopia, Niger, Mozambique and Uganda, verbal as well as written evidence is accepted for registering land rights. In both Mozambique and Niger, collective rights may be registered and build on the principle of collective management of common property resources. Collective management options appear to be significant in reaching some of the poorest and most disadvantaged groups, such as pastoral groups in the Niger case.

Source: IIED, 2006.

Knowledge infrastructure

There is need for a variety of (information and knowledge) service providers because they can overcome constraints, such as shortages in funding, staffing, and expertise, and provide the necessary flexibility to tailor services to the needs of specific subsectors or regions (Birner *et al.*, 2006). Despite major changes in thinking concerning sustainable development of agriculture in Africa, implementation of new ideas and approaches remains problematic. Information transfer to agricultural development workers (NGOs, extension, etc.) is slow and most information available from government offices in countries of sub-Saharan Africa is decades old. The diversity of local conditions in terms of economic and infrastructural development as well as agroecology suggests the need for best fit approaches to information delivery services (IFPRI, 2005). Designing the most appropriate systems under a specific set of conditions requires an institutional learning process. The key property of an agricultural innovation system is not the strength of its component parts, but rather how it performs as a dynamic whole. Addressing the lack of technological development in African agriculture therefore can not be achieved through simple solutions such as increased financing or improved research skills. The real need is for institutional structures that permit the involvement of all actors in the value chains and the symbiosis of knowledge search with knowledge use. Deliberate policy initiatives are required to provide incentives for organizations and individuals to engage in multi-disciplinary, multi-institutional and multi-stakeholder systems of innovation (Jones, 2006).

The pluralism of extension models should be endorsed, as Eicher (2007) argues, different models provide better fits for different contexts, agricultural problems and organizational scales. Despite the availability of these options there is still need for expansion to increase the availability of more decentralized extension systems promoting feedback from clients to extension specialists, researchers, policy makers and donors (Eicher, 2007). Improving the feedback mechanisms, or learning, within the institutions for research, education and extension is urgent because new challenges emerge, such as climate change and globalisation in food provision which demand responses at the level of the individual farm, but also at the level of local and national institutions. These various responses need to include technical aspects as well as social and political dimensions and they have to be coordinated and adapted to the specific local circumstances.

We need new institutional mechanisms to secure funding and to ensure that agricultural R&D benefits the African small-holders. The role of patents, and the alternative of prizes (Masters, 2005), need further investigation.

Infrastructure to secure market access

Complementary infrastructure built by the villages, national governments, or NGOs is crucial to remove existing limitations on the participation of the private sector and increase the costs of input and output marketing. Critical investments include rural transportation; rural water infrastructure; village production infrastructure, such as threshing and drying floors, and basic village storage facilities; electricity for agroprocessing; and telecommunications infrastructure.

Social infrastructure

Improving rural associations is envisioned to provide better support to farmers and, at the same time, become a vehicle for defining and implementing rural development with farmer participation. In Africa, rural associations give assistance to farmers in terms of farm inputs and crops; credit to members (savings societies); joint production of food crops, particularly for women's groups; management of pastures; and processing of agricultural commodities. However, despite their engagement, the volume of credit, farm inputs, and crops handled by farmers' groups remains extremely small. However, probably organizations of poor rural producers can also maximize their input in the policy processes which enables them to analyse and articulate key requirements for pro-poor growth through agriculture. This way, the focus of policymaking may shift from the claims of competing vested interests, which frequently disadvantage the poor, to a more evidence-based dialogue. A stronger voice should also increase the accountability of the state to those representing the interests of the poor. In addition, small farmers, other stakeholders and their organisations should just not wait for governments to take action, but initiate actions and strategies themselves. As in other countries, also in Africa the conventional distinction between state, market and civil society is disappearing and innovative institutions and policy arrangements should be promoted as they can be more effective nowadays (Oosterveer, 2007). New opportunities appear as small farmers engage with governments, traders, and NGOs in creating new institutions and rules to improve the efficiency of the food distribution system (KIT and IIRR, 2008). These experiences could be extended to establish innovative institutions that bridge the wide gaps separating governments and the agricultural sector, farmers and traders and local supermarkets and suppliers. The rather positive experiences with (multi-stakeholder based) roundtables on particular crops (cf. on palmoil, on soybeans, etc.) could be replicated to bring together for instance local supermarket chains in different African countries and the (potential) local suppliers to discuss ways of organising local supply: addressing issues such as grades and standards, packaging and transport, financing and prices, etc.

Diversity in African agriculture could also offer perspectives for diversifying exports as niche markets may be (created and) supplied (see the biofuels option in the box below). To stimulate sustainable niche markets (public and private) labels can play a vital role, by setting and implementing specific conditionalities. Fair trade labels, certification and eco-labels form an interesting international institution which can combine agricultural niche market development with sustainable development.

Biofuels

In recent years, the production of biomass for biofuels has been suggested as an interesting new opportunity for African farmers. Particularly the EU decision to require a 10 percent share of biofuels in transport fuel by 2020 ('manadotory mixing'), as part of its climate change strategy, opens up new export possibilities for Africa as it is more efficient to grow biomass under tropical conditions than in Europe's moderate climate. However, new evidence suggests that producing biofuels for export markets is rather controversial. In particular, the mitigating impact of biofuel production on greenhouse gas emissions has been grossly overstated, and could even be negative due the carbon debts that emerge as the natural vegetation is cleared (e.g. Fargione *et al.*, 2008, Searchinger *et al.*, 2008). Large-scale production of biofuels will use scarce resources (e.g., land, finances, labour), raising food prices and threatening the continent's already weak food security. The net effect is therefore likely to be ambiguous and context-specific. Large-scale biofuel plantations (e.g., sugar cane, oil palm, jatropha) may displace people and crowd out food production (Dufey, 2006; Eickhout *et al.*, 2008; Von Braun, 2008), but could also trigger investments in infrastructure, and create job opportunities—raising and stabilizing incomes. Small-scale biofuel opportunities and local processing (e.g., jatropha, sweet sorghum, cassava, oil palm) could raise and diversify rural incomes, as well as allow technical innovation and diffusion by enabling farmers to access new sources of energy (Legoupil and Ruf, 2008). There is a need to assess the conditions under which biofuel production is pro-poor and efficient, and to elaborate transparent and equitable standards of carbon and biofuels trading. Ongoing work in Mozambique in the context of the competing claims programme intends to sort out and quantify the various positive and negative effects of biofuel production and trade for African households.

Promoting education, health, governance, communications infrastructure, and macroeconomic stability are all necessary conditions for pro-agricultural growth, but not sufficient. Markets are also institutions allocating, co-ordinating and exchanging resources, production and consumption. Acknowledging this means raising the question which institutional arrangements offers the best perspectives for agricultural growth (Dorward *et al.*, 2003).

3.3 Economic opportunities

3.3.1 Access to the means of production

Access to financial capital is critical for investment in agricultural technologies and upgrading that allow farmers to improve their labour and land productivity and move up the income ladder (Woller and Woodworth 2001). As a response, microcredit organizations have been founded in almost all developing countries aiming at providing small (agricultural) entrepreneurs that lack formal collateral with access to finance. When implementing microcredit and savings schemes it is important to take into account local institutions and other constraints to investment besides capital. With regard to the former, the experience in Ghana has demonstrated how microfinance can benefit from relying on pre-existing institutions (see box).

The informal 'susu' system in Ghana

The informal credit sector in Ghana includes a range of different actors that support households in accumulating savings and sometimes extend loans to their long-term clients. *Susu* collectors collect daily amounts of savings from their clients and return the saved amount at the end of the month. Susu associations either operate like rotating savings associations, collecting savings from their members and allocating them to each member in turn, or like savings associations, helping farmers to save capital that will be paid back as a lump sum later.

Microfinance institutions in Ghana teamed up with susu collectors and associations to mobilize savings and expand their services. The latter benefited from access to safe bank accounts where they could store mobilized savings as well as from access to capital that enabled them to provide larger cash advances to their clients. For microfinance institutions the insider information and knowledge of informal agents was an important success factor.

Furthermore, microcredit can only sustainably lift smallholders out of poverty if they successfully invest in upgrading their (agricultural) activity. Investment opportunities hinge on farmers' access to other production factors such as land and agricultural technologies that fit the local context. Therefore, the constraints faced by farmers have to be taken into account when designing or adapting a specific technology: In the absence of secure land rights farmers are unlikely to invest in soil improvements that will become profitable only in the long term (for a more comprehensive discussion of the role of land rights see section 3.2). Labour-saving techniques are needed in areas where farmers experience labour shortage during peak labour seasons. Land saving (or high-yielding) technologies are more appropriate in areas where land is scarce and population pressure is high. The availability of information and extension services that assist farmers in applying new technologies is critical for successful upgrading and for improving farmers' competitiveness. There is a need for better linkage policies between farmer organizations and research institutions to provide new research insights to farmers and provide feedback to researchers (Eponou, 1996). While farmers' access to information is important to improve their competitiveness, their feedback and participatory evaluation is the key to successful technology transfer. This can be accomplished by innovative forms of extension, such as farmer field schools that directly involve farmers in field testing and technology adaptation.

Building input markets for fertilizer

Absence of input markets is a common constraint in African agriculture that can not be overcome solely by providing farmers with credit. IFDC (International Centre for Soil Fertiliy and Agricultural Development, www.ifdc.org) demonstrates with their voucher system implemented in Afghanistan how farmers and traders can be supported in building up input markets. They provide grain farmers with vouchers that can be redeemed for fertilizer with local traders. After the grain harvest, farmers have to repay the credit (that they received in the form of vouchers) to the local town committee that invests the money in community development programs. Traders that supply the fertilizer to farmers get reimbursed in cash by IFDC through local non-governmental organizations. This way, IFDC succeeded in achieving two goals: increasing agricultural production and thus local food supply, and building sustainable input markets.

3.3.2 Development of output markets

Many authors argue that while liberalization should be a long-term goal, government interventions might be required in the short term to support the development of markets (Figure 3.3). This is based on the finding that, in the absence of investments in the institutional environment, (agricultural) entrepreneurs in the least developed African countries have been unable to respond to economic incentives (Fafchamps *et al.,* 2001, Dorward *et al.*, 2004; Morrison and Sarris, 2007). In order to reduce transaction costs that hinder effective market participation, investments in public goods such as infrastructure, telecommunication and market information systems are basic requirements. Most farmers in remote areas also lack management and marketing skills that are necessary to take advantage of new market opportunities. In countries where these 'basics' are missing, the government needs to assume a key role in developing market infrastructure and in creating an enabling environment that creates favourable conditions for investment and growth in rural areas.

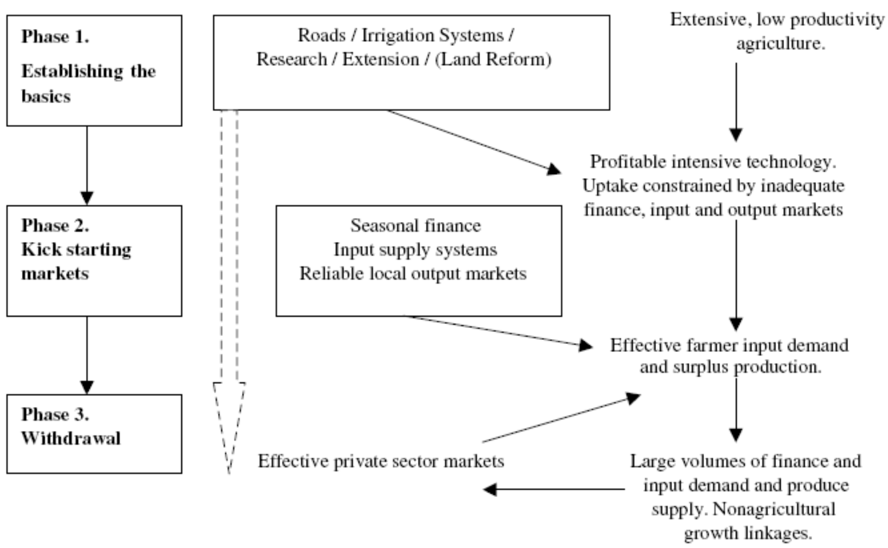

Figure 3.3. Policy phases to support agricultural transformation.
Source: Dorward et al., 2004; Morrison and Sarris, 2007.

In addition to establishing the basic requirements for effective market development, policy measures can help to 'kick-start' markets and to take advantage of new market opportunities. One example of such active market creation is the 'Purchase for Progress Program' mentioned in chapter 2.5 that aims at providing African farmers with secure market outlets and stable prices. Von Braun *et al.* (2003) discuss the role of buffer stocks managed by governments to stabilize prices for domestic farmers and consumers. Price stabilization can be especially helpful in a country that recovers from crisis, as it reduces risk and thus boosts agricultural production. With increasing market liberalization and economic development other measures will become available to deal with price fluctuations and risk, and buffer stocks should become less relevant (von Braun *et al.*, 2003). The 'pace of liberalization' needs to be determined on a country-specific basis (see box).

On the optimal level of trade liberalization in Africa

African countries differ in terms of institutions, economic structure, and geographic location. This implies that the scope for a development strategy based on labour-intensive exports, as successfully pursued by some newly industrialized Asian economies, is not within reach for all African economies. As the potential benefits from trade are country specific, it is not surprising that blanket recommendations about trade liberalization may be counter-productive.

Even for specific countries, the merits of trade liberalization may be hard to predict. While standard trade models based on comparative advantages unambiguously point to free trade as the optimal policy - even for countries with no absolute cost advantage in the production of any commodity - reality is more complex. For example, dynamic considerations may reverse the 'free trade' recommendation. Specifically, scenarios can be constructed where currently uncompetitive domestic producers 'gain an edge' by temporarily shielding them from foreign competitors on (sufficiently large) domestic markets. This can happen via scale economies, spillover effects and learning-by-doing.

This so-called 'infant industry' argument has been discredited, mainly because it has proven difficult for infant industries to grow up behind tariff walls. History is replete with examples of protected industries that successfully lobbied for continued protection, often using the threat of massive layoffs as a powerful bargaining chip. To what extent holds the same true for agriculture, where African producers have to compete with efficient producers—some of which are subsidized by national governments abroad?

When domestic markets are small, and when scale economies or spillover effects are modest or absent, clearly it is in the interest of African economies to open up for trade and import cheap food for its growing urban populations. However, cases can be constructed where 'infant crop' arguments make sense, and where temporarily restricting trade leads to long run economic benefits. In WTO trade rounds, it may be useful to recognize the context-specificity of the pro- and contra trade arguments, and allow African countries to decide on their own policy, even if that implies a departure from Washington consensus style recommendations.

With respect to international markets, new opportunities for income generation might be tapped in high-value segments. Through increasing integration of African countries into global trade patterns and high-value supply chains, new marketing and employment opportunities for the rural population are likely to emerge (Swinnen and Maertens 2007). For linking farmers to these markets, new contractual arrangements are necessary. These contracts often do not only specify the marketing terms, but also provide farmers with credit, inputs and assistance, thus overcoming missing or incomplete markets. Producer organizations can play an important role in reducing transaction costs and thus linking farmers and agribusinesses. The most important role for policy-makers, besides providing the basic market infrastructure, is the development of grades and standards to increase transparency. Besides these direct market linkages, high-value chains can create non-agricultural employment opportunities in transportation/trade and processing. Therefore, The World Bank (2008) suggests following a chain approach in agribusiness and small enterprise development and support. Possible constraints and bottlenecks need to be identified at all stages of the value chain. At higher stages of the chain, access to credit, market information systems, transparency of product standards, and quality compliance are often among the critical factors where support is needed. Value-adding can also be a lucrative option for farmers that have managed to upgrade their agricultural production and to diversify into processing activities. Here, the major limitations that call for action include the lack of adequate credit sources, (local) market outlets, linkages with other agribusiness, and technological skills.

3.3.3 Subsidiarity/optimal level of decision making

To embrace diversity, central authorities should assume a subsidiary function performing only those tasks which cannot be performed effectively at a more immediate or local level. At the international level that means, for example, that African governments served by international lending institutions should have the freedom to design the policies that best fit the current situation of their country. At the national level this entails decentralizing decision-making to local governments that know best about the local particularities and development needs. At the micro level, agricultural extension services have to redefine their role not only transferring best practice solutions that have been developed elsewhere, but also adapting them to the local conditions, for which the use of local knowledge and the involvement of farmers in field experiments is indispensable.

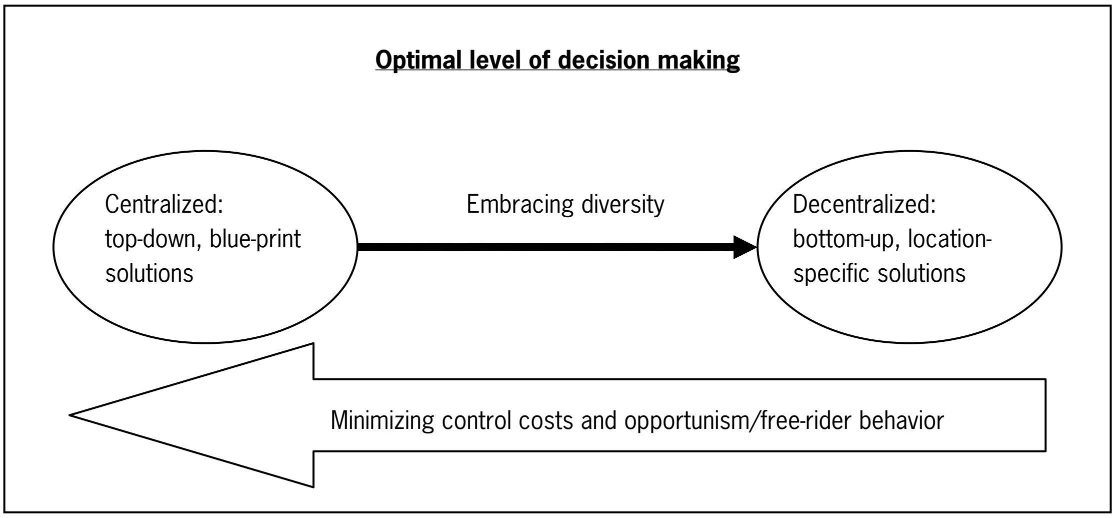

Figure 3.4. Seeking for the optimal level of decision making.

However, when delegating responsibilities to lower hierarchical levels two issues arise. One is related to determining the optimal level of decentralization. It seems rather intuitive that issues that affect the interests of a specific village should be handled by the local village authorities, who possess knowledge about the local conditions and demands. However, action at the village level may have negative externalities, i.e. impact other neighbouring villages in a negative way. An example for such externalities is the use of forest resources. If no regulation at a higher level exists, forests may be exploited because each village extracts the maximum amount of timber without taking the demand of other villages into account. Similarly, at the international level, it could be argued that each country should decide on their level of pollution depending on the state of industrial development. However, solutions to deal with climate change can only be found at the international level by means of an agreement concerned with aggregate pollution levels that tackles free riding incentives of individual countries. Therefore, if decisions that are rational at the individual level negatively affect other actors or society as a whole, solutions need to be reached at a higher level.

The same argument holds for the provision of public goods. The provision of infrastructure, for example, can more effectively be performed by national governments. If one village builds a road to the capital city, it cannot capture the full benefits of the investment, because other villages located along the road benefit from its construction as well. Therefore, there is no incentive to invest in road construction at the village level unless coordinated action is taken by all villages concerned. It is important to note that the identification of the optimal level for decision making might not coincide across different countries and regions. While in some countries forest extraction might be most effectively regulated by law, in other countries, where the enforcement of law is difficult and costly, local traditional institutions might provide a more effective solution to the problem.

The second issue is that embracing diversity and delegating decision-making to lower hierarchical levels, opens up possibilities for selfish behaviour and power abuse. Furthermore, there is no guarantee that decision makers charged with responsibilities actually have the necessary competencies and skills to solve complex problems and to achieve compromise among local interest groups. While the latter can potentially be solved through education and training, the former issue can only be avoided (or minimized) through monitoring and control. The costs of monitoring and control, however, increase with the level of diversity admitted. The obvious trade-off that arises is one between allowing as much diversity as possible, while keeping monitoring and control costs at acceptable levels. Finally, the evaluation of competencies and skills at lower levels ought not to be confounded with racism and distrust in the abilities of ethnically diverse groups. This applies at the international level, where Western leaders might distrust the ability of African governments to tackle the problems they are concerned with, but also at the regional level, where this distrust is sometimes held by urban elites against ethnic minorities and the rural poor.

Taking these trade-offs and potential challenges into account, there is a strong need to work towards an institutional framework that embraces diversity and guides its implementation. Within such a framework, the 'benefits' of decentralized decision making (bottom up, exploiting knowledge about local conditions) should be balanced against the various 'costs' highlighted above, which requires a tailor-made perspective. Future approaches to development will be more likely to focus on creating opportunities than providing pre-cast solutions. In rural areas, this may include opportunities for agricultural households to improve rural livelihoods, to exit agriculture or to move up the value chain. Given that this approach is more knowledge intensive than top-down approaches to development, the building of human capital and the provision of specific training will be critical to enable households to take advantage of the created opportunities and participate in new (market) developments. In this context, it is also important to reduce transaction costs and strengthen institutions at all levels (micro, meso, macro) to create an enabling environment that facilitates adequate information flows and functioning markets.

4. Beyond competition

In the above chapters we have made a plea for recognizing the diversity within the African continent and to embrace it in order to seek for solutions. The complexity of the matter calls for solutions that are not driven by ideology nor interests, but seek novel and innovative solutions that may leapfrog development. Agro-technical solutions to increase productivity should, in all instances, take production-ecological concepts as a basis, which includes the pursuit of integrated approaches, advanced technologies and the continued search for making most efficient use of the scarce natural resource base of the continent. Enhancing ecological literacy is a basic precondition to this avail. Both economic and institutional arrangements should fit location-specific conditions, even if, and likely so, these will deviate from international concepts and standards.

Productivity increase and resource use efficiency

It is evident that the productivity of African agriculture will have to increase drastically to meet the growing demand for food. The sSA countries are, however, not endowed with favourable biophysical conditions, nor are institutions and markets strongly developed. Doomsday scenarios for Africa need, however, not become reality as a backward position may be exploited to leapfrog development. The current collapse of various global systems, including the energy, food, mortgage, industrial and financial systems, may imply that continuation of 'business as usual' may evolve in an ever fiercer competition for resources (e.g. water and energy).

Options to mitigate adverse effects within the context of current institutional arrangements, stakeholder interests, market functioning and technological means, may only partially solve these pressing issues. Production of biofuels, for instance, does not fundamentally address emerging petrol-related problems, because of the continued use of outdated combustion technologies and because vested interest are continued to be served. Likewise, increasing resource use efficiency in rice might require a shift from traditional flooded rice systems (paddy rice) to so-called aerobic rice. Any such fundamental changes to management practices are complex and their implementation requires reconciliation of different and possibly conflicting objectives. It is this shift to fundamentally different technologies that might create new opportunities, especially for sSA, to leapfrog development.

Aerobic rice

Rice has been grown for millennia under inundated conditions, i.e. in a standing water layer of 5-10 cm. It is however, not an aquatic species. It can stand the water, while weeds do perish. Inundated soils are easier to puddle with animal traction, fields with raised bunds serve as basins for water during heavy showers, soil nutrients are more easily dissolved for uptake by plants and nitrogen fixing bacteria, living in symbiosis with ferns floating on the water layer, provide nutrients. Revisiting these agronomic arguments reveals them to have become obsolete under current technologies, certainly so with declining availability of water, land and labour. Much progress has been made in transforming inundated rice with much less water (Bindraban *et al.*, 2006), though adaptation appears to be a drawn-out process because of vested interests, social customs, ridged institutions and lack of economic incentives to save water (Senthilkumar *et al.*, 2008).

The demand and production of rice is increasing rapidly in Africa. Rather than adopting inundated rice cultivation practices, an immediate attempt can be made to develop agro-technologies for the cultivation of rice as any other cereal such as wheat. Lessons from Brazil and other nations could also appear useful. These options are already under consideration for parts of the rice-producing areas in sSA, but need particular attention.

Evolution in production systems

In agriculture, there is growing awareness of the need to stimulate integrated production systems and 'multifunctionality' in agriculture and land use, i.e. simultaneously realizing various objectives. While growing, there is still little systematic insight in production-ecological aspects of such complex systems, at both field and regional scale. This approach might enhance ecological synergies, such as the creation of refuges in non-productive areas for natural enemies of pests on crops in adjacent production fields (e.g. Douglas *et al.*, 2008). It is assumed that the combined growth of two or more crops could make more effective use of natural resources (e.g., light and water) and added resources (e.g., fertilizer) raising productivity of the entire system. The different crops would optimize sharing of resources over time and space; but then, various combinations could also exacerbate drought or disease and pest incidence (e.g. Keating and Carberry, 1993; Marshall and Willey, 1983; Morris and Garrity, 1993; Trenbath, 1993; Tsubo and Walker, 2002). Skelsey and colleagues (2005) developed only recently for instance, a model to systematically assess the impact of crop combinations on disease infestation and dissemination. Similarly, no priority has been placed on the development of machines equipped to harvest two or more crops simultaneously or to harvest a single crop in a mixture. But unless mechanization is tailored to diversified farming systems, their land and labour productivity will remain virtually stagnant at their low level.

Agricultural production systems in Europe have, for instance, evolved to integrate ever more objectives (Vereijken, 2002). The first and foremost role of agriculture remains the production of food and other primary bio-based goods. Agriculture should also generate sufficient income, except where agriculture is still practiced for 'pure' subsistence purposes. Increasingly, environmental concerns have imposed the demand on agriculture to minimize negative impact on desirable environmental characteristics, and to safeguard the health and wellbeing of both humans and animals. And finally, the importance of nature is recognized for sustaining our ecosystem as a production base, affirming the need for both the non-use and use function of biological diversity (CBD, 2003; Slootweg and Kolhoff, 2003). Related to this nature element, cultural heritage, often resulting from specific activities in the past on the land, is also valued, calling for its preservation.

These European lessons about the evolution of agricultural production systems to increasingly meet the desires of society might appear useful in search for opportunities to enhance the productivity of complex production systems, inherent to most of sSA (Bindraban, 2006). Rather than pursuing a similar path of reviving diversification in production systems after an initial decline due to specialization, the current diversity should be taken as a starting point to increase productivity and benefit from ecological synergy. This however, by no means excludes any other option, including monocultures to safeguard food security in sSA.

Advanced technologies

Embracing advanced technologies from abroad may create great benefits without capital investments for their development. Mobile phones, for instance, have eliminated the need for a costly physical infrastructure for cables. Wide access to this technology means that information, such as seasonal forecasts, early warnings of extreme events or commodity prices, can now be communicated cheaply and in time. Widespread introduction of solar panels would create similar gains and reduce the need for fossil fuel.

In the past decades, knowledge of wheat breeding and cultivation in developed nations has, for instance, been useful in improving the productivity of rice. Techniques and methodologies developed in and outside sSA, either advanced bio- and nanotechnology, information and communication technology should be embraced whenever felt necessary and effective in achieving productivity increase.
Many of the current initiatives in biotechnological improvement in Africa result from spill-over effects of activities developed outside the continent, rather than being initiated from desires and needs coming from within. Still, only a small proportion of African farmers use improved varieties for instance. Because the use of chemical inputs is limited and its future use should be kept minimal anyway, breeding should target the many and widely divergent environments. Advanced technologies might break with the need for the time-, space- and labour-consuming process of conventional breeding for specific traits and characteristics and accelerate the breeding process. Bindraban and colleagues (2006), provide some views on a breeding strategy for mixed production systems in sub-Saharan Africa.

They point to the need to make best use of the increasing number of disciplines, such as crop physiologists, statisticians and crop modellers, so as to hasten the processes of crossing, selection and testing. While they observe biotechnological approaches to recoil from this widening approach, they call for further broadening of this wide view, by introducing considerations related to the entire production system within which a crop is cultivated.

Institutional arrangements

When acknowledging the existence of diversity and variability in African agriculture, the present institutional arrangements need to be reconsidered. Institutions may or may not enable farmers' access to the means of production and the market, link agricultural production with processing and consumption, and create the macro conditions for increased productivity. More adequate institutional arrangements need to facilitate both the small-scale farming household and the large-scale market-oriented agricultural entrepreneur, which requires a flexible approach to secure land, labour, finances, inputs and market access. Typologies and scenarios for a range of different groups of people operating in different contexts should be developed to enable a modular approach, which is better oriented to and flexible in securing an adequate institutional and policy environment. Particularly smaller farming households require a balanced support promoting productivity growth and securing livelihoods, whereby the position of women still needs specific attention.

Securing access to land is essential as this constitutes the basis for actual agricultural production as well as for future sustainability. Pastoralists and farmers should be encouraged to invest in securing and increasing soil fertility and biodiversity. In certain instances this may mean guaranteeing individual land titling but in other cases shared ownership, or overlapping ownership-rights, is more effective, for instance when pastoralists demand seasonal access to cultivated areas or when climatic conditions require flexible and seasonal distribution of plots. Natural resource management needs to be local, flexible and non-exclusive (Woodhouse, 1997).

International negotiations on trade and environmental governance are already very important and will only become more so in the future. Recognising the specific position of African agriculture and farmers and defending their interests demand adequate capacity among governments. Agreements reached in multilateral fora, such as WTO, CBD and EPA, as well as private arrangements through roundtables and various certification and labelling schemes all influence the future perspectives of sSA farmers to produce and export. Governments should therefore (be supported to) invest in capacity building to be able to actively engage in these and future negotiations. Not only global regulations and inter-continental trade require their engagement, but profiting from regional trade as well. Governments should in particular, work on improving the physical and service infrastructure to accelerate trade among African countries (Njinkeu, Wilson and Fosso, 2008).

Global developments

The plea for embracing the diversity of African agriculture does not exclude options to benefit from global developments, nor from engagement in large-scale production systems. Here we analyze the role of Europe in African agriculture from the growing global demand for soybean, as an illustration to dovetail the developments of both continents. Brazil exploited the opportunity by expanding its soybean cultivation into less favourable areas through large investments in soil improvement, including lime application to increase soil pH and P fertilization, and through breeding varieties that could grow closer to the equator. The N-fixing ability of soybean also allowed this expansion, as it reduced production costs by eliminated the need for N-fertilization. Favourable institutional conditions and supporting policies have also contributed to the expansion, stimulating the migration of small soybean farmers from the southern states in Brazil, who sold their properties and purchased land 10-fold larger in the frontier areas. Hence, specific interventions were needed to enhance the productivity of soybean in Brazil. Likewise, appropriate technologies could stimulate the development of soybean cultivation in Africa, as it can eco-physiologically be grown in various parts of the continent (Stehfest *et al.*, 2007). The larger diversity in biophysical and socio-economic conditions in the different sSA countries, as compared to Brazil, will require more varied interventions, i.e. other types of (integrated) production systems.

Soybean in Nigeria

Soybean (*Glycine max*) was introduced into many African smallholder farming systems in the early 1900s, but remained a minor legume. A breeding programme at IITA was successful in developing leafy and promiscuous soybean varieties that led to a rapid increase in smallholder soybean production in the northern Guinea savannah of Nigeria (Sanginga *et al.*, 1997). These varieties had good yield potential and were multi-purpose in terms of the biomass that could be fed to livestock and had significant soil fertility benefits to cereal crops grown in rotation (Sanginga *et al.*, 2001). A local market developed for processing soybean and this led to exponential expansion of soybean production during the 1990s (Sanginga *et al.*, 1999) supporting diversification from continuous cereal cultivation and more sustainable crop production. Though local successes generally remain poorly visible at national level and FAO statistics, this development could be traced in FAO data.

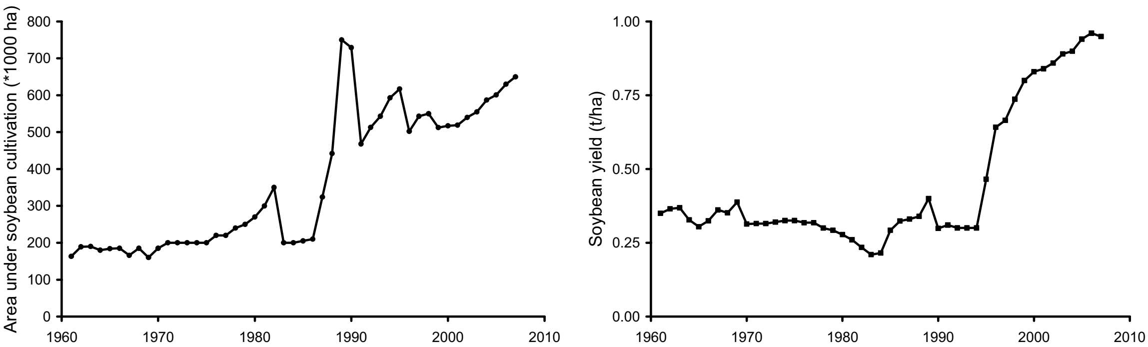

Figure 4.1. Development of soybean yield and area in Nigeria (FAO-data).

Soybean in Zimbabwe

In Zimbabwe, substantial research effort was made to increase smallholder soybean production, but the area planted remained small. There was a widely-held belief that soybean was an unsuitable crop for the sandy soils predominant in communal farming areas (Mpepereki *et al.*, 1996). An intensive extension project was established through the University of Zimbabwe from 1996 onwards, assisting farmers to access seed and inputs, on demonstrating appropriate agronomic management for soybeans, on local processing of soybeans for food and assisting farmers in marketing their surplus soybean and to obtain good prices (Rusike *et al.*, 1999). A wide range of varieties was distributed, including 'improved' varieties that had better yield potential (of 3-4 t ha^{-1}) but needed rhizobial inoculation, as well as 'promiscuous' varieties that had stable yields under less-favourable conditions, but could nodulate and fix N_2 without inoculation. These promiscuous varieties had the additional benefit of a luxuriant biomass that could be used as fodder for livestock and returned more N to the soil (Mpepereki *et al.*, 2000). Yields of maize after soybean were demonstrated to be more than double the yields in continuous cultivation. This extension programme led to an increase in sales of soybean from the smallholder sector from 350 t in 1996 to 12500 t in 2004.

In identifying options for nations to cooperate, policies and strategies of both parties should be taken into consideration. Further elaborating the soybean case suggests an option for Europe to stimulate the development of legume-based production systems in Africa. First, there is much debate and uncertainty in Europe about the sustainability of soybean production in Latin American countries, related to the concerns for deforestation of the Cerrado and Amazon biomes (Van Berkum and Bindraban, 2008). Second, the growing awareness about the excessive claims on natural resources for the production of meat may trigger a transition to an increase in consumption of plant-based proteins. Third, European consumers do not readily accept genetically modified food items, while soybean production is rapidly converting into GM-soy (Bindraban *et al.*, 2009). These drivers in Europe might be combined with the need to enhance the integration of legumes in the diversified production systems in sSA. By acquiring protein-rich crop produce for its own transition from meat-based to plant-based proteins in diets, soybean, specifically not genetically modified, could be of particular interest to meet the demand of European consumers.

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