IAASTD SSA REPORT

CHAPTER 5

OPTIONS FOR ACTION: GENERATION, ACCESS AND APPLICATION OF AKST

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1. The expected structural transformation of sub-Saharan Africa's economy is not expected to diminish the importance of agriculture to the region's socioeconomic development, both as a source of livelihoods and as a linkage to other sectors. The fostering of participatory and decentralized structures of governance inclusive of farmers, marginalized groups and regional and local authorities and enterprise is an important step toward the development of the agricultural sector. Decentralization of funding sources and market development, including an emphasis on the cross-sectoral benefits of agriculture (to health, nutrition, education, environment), regional market-chain approaches and local government funding can raise the profile and contribution of agriculture for development.

2. The presentation of a "basket" of agricultural technology options, would allow farmers the flexibility to choose among options that best match the site-specific diversity of their fields and socioeconomic contexts. This approach is in contrast to the typical approach in which only a small number of technologies are made available through extension services. Close to 90% of sub-Saharan African farmers currently practice diversified as opposed to monocrop agricultural production systems. Participatory and community-driven approaches to research and development can increase both the relevance of AKST for small-scale producers and their likelihood to adopt new technologies and practices. Research and extension efforts can improve rates of adoption by addressing concerns of language and gender.

3. Markets for agricultural products remain relatively inaccessible to sub-Saharan African farmers. Technical assistance, extension, and capacity development is needed to link producers to markets and transform farming activities into agribusiness ventures. Improvements to basic infrastructure, market information systems and levels of market integration are critical.

4. There is a large scope for increasing the role and participation of women in agricultural research, extension and development. Women account for over 70% of agricultural workers and 80% of food processors in sub-Saharan Africa, yet comprise 17% of agricultural extension workers. Increased access for women to micro-credit and education is likely to increase the involvement and adoption of AKST by women.

5. Land degradation, and poor soil fertility in particular, is a critical factor in limiting agricultural production in SSA. Options for soil, water, and nutrient management but approaches that address resource management in an integrated way are more likely to offer sustainable solutions than practices that addressing management of a single resource.

6. The full extent and long-term economic costs of environmental degradation to individual farms and agricultural landscapes is seldom clear to farmers or policy makers. Increased understanding and information flow of the full costs of environmental degradation at all scales is a critical step to the design of policies and incentives that can simultaneously support long-term sustainable development and agricultural production. Land tenure and access to credit are key elements to improving rural livelihoods in an equitable fashion.

7. Agricultural intensification, supported by conventional research, is most often accompanied by a decrease in agricultural biodiversity. ***In situ* conservation is the most appropriate means to preserve the indigenous germplasm and seed varieties that sustain the majority of small-scale rural farmers.** Conservation of biodiversity requires the involvement of local communities and can be facilitated by government-funded initiatives. Strategies for the preservation of wildlife biodiversity are significantly improved when local communities are embedded in the responsible institutions.

8. A *de facto* open access situation is typical of forested lands in SSA. The contribution of Payment for Ecosystem Services (PES) and other market-based schemes to address deforestation are as yet unknown. Agroforestry, simultaneously offering improvements in soil fertility, provision of animal fodder, and the supply of poles, timber and fuelwood holds the potential, in the short and long term, to relieve pressure on forested lands.

9. Centralized fisheries management strategies hold limited potential for addressing the poverty of fisheries-dependent populations. Current limitations in technical capacity, funding levels and management schemes have left most fisheries overexploited. Aquaculture holds some potential to relieve pressures on fish stocks and will require significant cooperation between fishers and governments and between fishing communities.

10. Agriculture policies in SSA continue to promote primary agricultural production, reducing the potential of agriculture to contribute to the improved health and nutritional status of households through the production and consumption of diverse and micronutrient-rich foods.

5.1 Governance, Institutions, and Funding

Agriculture plays a central role in the livelihoods of the majority of Africans, providing the basis for social and economic development and providing crucial linkages to environmental sustainability, peace and security. While a structural transformation of African economies is expected to see agriculture contribute relatively less to employment creation and GDP, in absolute terms agriculture is expected to contribute even more to Africa's socioeconomic development, by providing vital linkages to other sectors of African economies, especially manufacturing, industries and the service sector. AKST has a significant role to play in facilitating a viable transformation of African economies by enhancing agricultural productivity and increasing rural incomes. An economically viable and environmentally sound agricultural transformation strategy would include harnessing AKST to increase efficiency and sustainability in farm production, agro-industrial and product development, and improvements in distribution/marketing networks.

A vision for enabling the sector to reach development and sustainability goals. Increasingly there is a consensus that a new vision for agriculture in SSA is required, articulated through various organizations. The Forum for Agricultural Research in Africa's (FARA) vision is for African agriculture to become vibrant and competitive in the international market, growing at a rate of at least 6% per annum by the year 2020 (FARA, 2007). NEPAD's vision includes an agriculture-led development that eliminates hunger, reduces poverty and food insecurity and includes improving access to markets to integrate more farmers into the market economy (NEPAD, 2004).

Key tenets expressed by many individuals involved in policy making, are decentralization and the adoption of a value-chain approach, embedded within an environment of good governance. Definitions of good governance invariably include elements of democratic decentralization, enforcement of law and order- including the elimination of corruption, properly enforced legal frameworks, and participatory, transparent, and equitable processes (UNESCAP, 2007). An environment of good governance for the generation and application of AKST in SSA would therefore include empowerment of farmers to take on a larger role in agricultural research and development; activities to ensure the inclusion of marginalized groups such as women and pastoralists; decentralization of economic and political structures of governance; promotion of the principles of subsidiarity and plurality in service provision; the drawing on local and traditional knowledge, and private and public sector skills; and well defined and enforced property rights. Given that many African countries are relatively small in geographical and population size, with many having similar sociocultural and agro-ecological similarities across borders, a regional approach to value chain development has been advocated (UNECA, 2007). To African and other investors in agriculture and AKST, regional integration in the context of value chain development would allow for the much needed spatial and population sizes critical to viable production, processing, distribution and market expansion. Increased trade opportunities associated with regional integration, in particular, would help to facilitate private sector involvement, and, ultimately, market led productivity and production improvements. Given that Africa has, during the 2006 African Food Security Summit, identified regional strategic commodities, using these commodities as entry points for a regional approach to value chain development offers an opportunity to realize the benefits of this new vision to agricultural development in Africa.

The current institutional environment in many SSA countries is not always conducive to developing the agricultural sector. At the country level, AKST is often poorly represented in negotiations with finance ministers and other key players. This situation is exacerbated by agriculture often being represented in multiple ministries, which makes national coordination tricky even for the agricultural sector, let alone links between agriculture and other sectors. Countries have two broad options, to attempt to coordinate agricultural and AKST activities at the national level, or to coordinate at the level of decentralization. As coordination occurs at a more decentralized level, the complexity of developing a national strategy can be reduced.

Arguments have been put forward that the key role for governments and agriculture in SSA is not about public expenditure but rather about policy making and regulation. Agriculture is primarily market-based. Even in SSA many of the small-scale producers who are currently producing for home consumption would be involved in the market if they were not constrained by, for example, high transactions costs or lack of credit. The role of the government becomes one of correcting for market failures and distributional objectives.

[Insert Box 5.1]

The current and likely future of AKST in SSA, at least in the short term, is one of unreliable funds for AKST generation, access, development and extension and inadequate human capacity. When compared with other regions, spending on the agricultural sector in SSA does not appear disproportionately low. Indeed, total public spending on agricultural R&D as a percentage of agricultural output (agricultural GDP) – the intensity ratio – in SSA (48 countries) in 1995 was 0.79%, greater than the average for all developing countries (0.62%) though lower than the global average. However, the trend has been downward in SSA. Spending in SSA grew by only 0.82% in the 1990s as compared with 1.25% in the 1980s, and the intensity ratio in 2000 was down to 0.7%. The World Bank recommends a ratio of 2%, whereas other organizations have suggested 1% as more realistic (Beintema and Stads, 2006). There is considerable variation among countries in SSA, from 0.20% or lower in Gambia and Niger, to over 3.0% in Botswana, Mauritius, and South Africa (Beintema and Stads, 2006). To reach either recommended level requires increased spending in most countries. Given that the number of research staff in the region (sample of 27 countries) has been growing at approximately 4% per year over the past three decades, average spending per scientist has declined by about a half over this period.

Donor funds. Traditionally donors have taken an area-based approach to their agricultural activities. Yet a value-chain perspective on agricultural development naturally lends itself more to a commodity-based focus that would fit better with a value-chain approach and use limited funds more effectively. At the regional level, AKST is almost always a stand-alone activity in donor's programs rather than being part of an integrated research-development-application approach (Rothschild, 2005). Effective donor involvement is further constrained by a project-oriented approach, including limited time commitments and a lack of coordination (Tripp, 2003). The Commission for Africa has advocated for increased aid to SSA – that is untied, predictable, harmonized, and linked to the decision making and budget processes of the country receiving it – for an increased growth rate and progress towards achieving the development goals (www.commissionforAfrica.org). Indeed, as direct budgetary support through country offices of donor agencies becomes the preferred mode of overseas development assistance, the constraints to effective donor involvement may be reduced. Poor representation of agriculture at the national level may become an increasing problem (Rothschild, 2005) unless mechanisms are in place to raise the profile of agriculture and availability of funding for AKST.

Leveraging funding. The profile of agriculture can be raised through its links with health, nutrition, and environmental goals. For example, NEPAD's Comprehensive Africa Agriculture Development Programme (CAADP) was endorsed by the African Heads of States and Government Summit, as a framework for restoring agriculture growth, food security and rural development in Africa. CAADP has been receiving substantial support since agriculture was placed at the top of Africa's development agenda through the Maputo Declaration, which commits governments to allocate 10% of public investment for agricultural development (Heidhues et al., 2004).

There is potential for leveraging funding for agriculture by highlighting (and preferably quantifying) the potential positive contribution of agriculture to health, nutrition, and the environment. For example, health considerations typically play little if any role in the decisions made in ministries of agriculture, despite the large potential health benefits from joint research and action in agriculture and health (Hawkes and Ruel, 2006). Similarly, health and agriculture are rarely considered interdependent by donor agencies or even government departments when budgets and strategies are being determined. In Malawi, over half of child mortality can be attributed to malnutrition, as much as the combined so-called killer diseases (Rothschild, 2005). There is therefore scope for arguing that part of the health budget would be well spent reducing child mortality through improvements in agriculture. In Uganda, collaboration between DFID economics and environment advisers resulted in the integration of environmental issues into both policy and investment mechanisms of the Plan for the Modernisation of Agriculture (Yaron and White, 2002).

Without increased awareness and cooperation among agriculture and health ministries, AKST is likely to continue to focus on increased output, rather than also taking account of nutrition quality and diversity. The CGIAR centers have recently begun an initiative on agriculture and health that could potentially contribute to increased coordination between ministries of health and agriculture and among countries in the region. Networking national bodies with regional bodies such as NEPAD and international organizations such as FAO and WHO, also offers potential.

Networks have the potential to use scarce funding and expertise more effectively, and can address some shortcomings of low funding levels and fragmented agricultural research capacity. Despite increases in AKST capacity in the 1970s and 1980s, more than half the region's countries each employ fewer than 100 full-time equivalent researchers, and 40% of total capacity lies within just 5 countries. Increased reliance on networks brings with it problems of complexity that can negate their benefits. Further, SSA's ability to benefit from network synergies is likely to be constrained by the current lack of sufficient capacity. The question of whether or not the benefits of regional cooperation and integration outweigh the costs has not been evaluated sufficiently (Toure, 2003). The increased use of networks for AKST research and development is particularly challenging given an emphasis on farmer participation, particularly in areas where research is becoming more site specific (Burley, 1987).

The involvement of the private sector. Globally, there has been a gradual shift away from government and donor funding, a trend which is likely to continue. Although in the short and medium term, private sector investments in AKST are likely to remain small in SSA (currently less than 2% of research spending) due in part to the lack of funding incentives (Beintema and Gert-Jan Stads, 2006), funding mechanisms that are likely to increase in importance include commodity levies, internally generated resources, local government funding, and commercial contracts (InterAcademy Council, 2004).

Significant debates remain over the role and involvement of the private sector in AKST research and development. A continuing question is whether countries in SSA should rely exclusively on approaches by established science centers of excellence, or involve the private sector in public-private partnerships. Private sector R&D has tended to focus on improving crops and technologies relevant to farmers in richer countries, ignoring crops important to poor farmers because of the lower profit potential of the latter. Private public partnerships offer the possibility of a focus on poorer farmers combined with access to the better equipment and facilities that private companies often have (IFPRI, 2005). However, such approaches could draw public funds away from R&D relevant to poor farmers towards more high-return commercial crops. Findings from Latin America suggest that that partnerships work best when the parties have a shared goal or interest in a particular outcome and the benefits of working together outweigh the costs of conducting the research separately (Hartwich et al., 2007). These partnerships raise critical issues around intellectual property rights. For example:

> To develop golden rice … Potrykus and Beyer used proprietary technologies belonging to half a dozen different companies … After the initial research the first step was to arrange for free licenses for these technologies so that Potrykus and Beyer could use them to further develop golden rice varieties. Syngenta then made legal arrangements giving the intellectual property rights associated with golden rice to a group called the Golden Rice Humanitarian Board, chaired by Potrykus and made up of individuals from various public and private organizations. The Humanitarian Board grants royalty-free sublicenses to the golden rice technology to public research institutions so they can develop locally adapted varieties in places like Bangladesh, China, India, and the Philippines. For developing country farmers who generate more than US$10,000 a year from farming, a commercial license from Syngenta is required. Otherwise, the technology is free for use by farmers in developing countries. Working out such an arrangement took considerable time (IFPRI, 2005).

5.2 Generation, Access, and Application of AKST

5.2.1 Appropriate technologies

The largest productivity gains in agriculture have been from monocropping systems that benefit from specialization and economies of scale in a global setting. However, in SSA, given that almost 90% of African farmers currently practice diversified production, a more pragmatic approach may be to optimize the farming systems already in place by exploiting the particular advantages of these systems (InterAcademy Council, 2004). Indeed, many technologies in SSA remain “on the shelf”, in part because they are relevant to specialized rather than diversified systems, and in part because they are not relevant to the particular environmental characteristics of the region. For development and sustainability goals to be reached, new technologies will have to address not only the sustainability of the agricultural systems themselves, but also the impact on non-agricultural ecosystems that provide services important for improving livelihoods and the environment.

There is a growing consensus toward undertaking collaborative research with local farmers and groups, and putting local people’s perspectives at the centre of research efforts, as the best way forward, particularly for small-scale diversified farms. Yet there is little evidence as to whether such approaches are likely to be successful in the future, and just how to operationalize them (Omamo, 2003). Indeed, many of the recommendations are not evidence-based, but rather advocate new and intuitively appealing approaches. However, SSA’s poor agricultural performance relative to other regions suggests that a change is needed. Given the criticisms of earlier AKST developments (technologies that are inadequately responsive to farmer needs, and based on unrealistic results from experimental stations), more inclusive non-linear approaches may be more successful.

[Insert Table 5.1]

5.2.1.1 Participatory approaches to research and development

Participatory approaches are increasingly accepted by many stakeholders as a way of increasing the likelihood that farming solutions will be adopted by farmers (Ashby et al., 2000; Ngugi, 2005.) Participatory plant breeding (PPB) and farmer participatory research processes decentralize control over the research agenda and permit a much broader set of stakeholders to become involved in research, thereby also addressing the different needs of men and women for technical innovation. The paradigm of involving farmers in research is based on strong evidence (Pretty and Hine, 2001) that enhancing farmers' technical skills and research capabilities, and involving them as decision-makers in the technology development process results in innovations that are more responsive to their priorities, needs and constraints. This is an important strategy in making research more demand-driven and responsive to the growing needs of farmers, and contributes to the development of technologies that meet the needs and priorities of farmers. Many of the participatory approaches that have been proposed or implemented are intuitively appealing, and reflect the diversity of farmers' fields and socioeconomic circumstances, and illustrate clear differences between controlled scientific off-farm experiments and the reality of farming in much of SSA. The development and adoption of a diverse range of technologies for water harvesting and conservation in East Africa have been attributed in part to the adoption of community-based participatory approaches in place of the traditional top-down approach to technology research and extension (Lundgren, 1993).

In general, however, participatory approaches have not been proven as yet to be more effective than earlier approaches (Farrington and Martin, 1988; Bentley, 1994), and may be constrained by the existing institutional structures in many SSA countries, including the NARS system (Hall and Nahdy, 1999). A number of specific drawbacks to and criticisms of farmer-led and participatory approaches have been identified. First, there has been a tendency for these approaches to emphasize food security, with insufficient attention paid to development of the value chain through marketed and value-added goods. Increasing the involvement of the private sector and recognizing the role of the market could increase the relevance and further adoption of appropriate technologies (Heemskerk, 2003). Second, participatory approaches have typically been used for applied and adaptive research and technology transfer, and so they have not as yet been a source of significant scientific data (Probst et al., 2003). This is in part due to a lack of scientists involved in longer-term participatory research, a consequence of a rewards system based on the generation of data at meso and macro levels (Probst et al., 2003).

It may not be possible to have statistically valid results from participatory trials because of the high variance in farmers' fields. Rather, the aim might be to get results that are satisfactory within the context of a particular production system that, again, are difficult to publish in more traditional scientific journals (Mavedzenge et al., 1999). Third, participatory and integrated approaches tend to be local, often incorporating specific local and traditional knowledge, and so are difficult to scale up and are often costly relative to their impact. Where approaches have proven to be locally successful, when working with a farmer group or a community, a key issue is to understand how participatory approaches can be adapted and used with large numbers of farmers to achieve wider impact, while still retaining the expected human and social capital benefits of participation. Finally, even in situations where research benefits from supply-led approaches, the needs, demands, and circumstances of farmers in SSA can inform the research directions (Rothschild, 2005). For example, there are many examples of successful integrated pest and disease management projects, as well as work on climate change adaptation that have been led by scientists but have incorporated a participatory approach.

One outstanding factor that has received little attention in the participatory development discourse as it pertains to agricultural extension in Africa is that of language. Projects and agencies concerned with agricultural development tend to function in languages different from those that farmers and rural communities use in their livelihoods and for communicating local knowledge (Chaudenson, 2004). It is not possible to say that this is a cause for the poor performance of agriculture, but it is a factor that is under-researched. Africa is the only region where formal education and government services function formally in languages different from the first languages of almost the entire citizenry. There is anecdotal evidence that this "linguistic divide" in African agriculture leads to poor understanding of science and technology (Fagerberg-Diallo, 2002). This view suggests that changes are needed to successfully address farmers participation in local languages responsive to farmers' needs. Despite these shortcomings, a number of specific participatory approaches have the potential to improve the likely impact of AKST.

5.2.1.2 Technologies responsive to diverse farming systems

A participatory approach that is gaining support is for a basket of prototype technologies to be developed that match the diversity of farmers' fields (Weber, 1996; Wezel and Rath, 2002). Under this approach, researchers would not look to the "best" technology under relatively controlled circumstances, but rather would work with farmers to develop a range of technologies (whether those technologies are developed by farmers, scientists, collaborative efforts, or adapted from traditional and local practices) that are resilient to the high variability of weather conditions, resource availability, and market fluctuations. For example, many technologies are known only to a small number of farmers, yet may have broader potential. These can be identified, validated, and then incorporated into the baskets of technology choices including agricultural engineering hardware. This approach is in contrast to the typical approach in SSA in which a small number of technologies are identified as promising by scientists and then made available to farmers through extension activities. Using a basket approach, farmers take up the technology best suited to their own specific conditions (including soil types, water availability and variability, access to credit and insurance). Small-scale holders in many parts of the world including SSA have been shown to best operate and adopt technologies when they understand their farming systems (Hall, 2001). However, as yet there is limited evidence that such a new approach is more successful than traditional research and extension.

Learn from other regions. Over the past 20 years, CIAT has accumulated considerable experience in developing, using and promoting participatory research approaches and other innovative methods to enhance agricultural research for development that are appropriate for poor farmers (Ashby et al., 2000). The Comité de Investigación Agrícola Local (CIAL), or Local Agricultural Research Committee is one example. The CIAL is a farmer-run research service that is answerable to the local community. The community elects a committee of farmers chosen for their interest in research and willingness to serve. The CIAL conducts research on priority topics identified through a diagnostic process, in which all are invited to participate. After each experiment the CIAL reports its results back to the community. Each committee has a small fund to offset the costs and risks of research and is supported by a trained facilitator until it has matured enough to manage the process independently. There are over 400 CIALs in 8 countries in Latin America and the Caribbean. Several studies have been conducted to assess the impacts of these types of empowering approaches on technology adoption and livelihoods. Farmer participation at different design stages may affect the direction of research, identify different priorities and other beneficiaries and can impact the design of the technology, as well as the adoption or acceptance of it by the intended users (Lilja and Ashby, 2002).

Farmer participation at the early stages of technology development has been found to be important in improving the relevance and appropriateness of the technologies, and therefore enhancing their potential impact (Johnson, et al., 2002). For example, as a direct result of farmer participation in the design stage of the research process, a project shifted its focus from integrated pest management (IPM) to integrated crop management (ICM), therefore broadened the project to include not only pest management but also varietal selection, seed and plant health, nutrient management, and economics and marketing. This change had significant implications on the adoption and acceptability of the project results. CIAT is now adapting and evaluating these types of empowering participatory research approaches in East and Central Africa.

Participatory technology and product development. Community driven development (CDD) is an attempt to give control of decisions and resources to community groups, which usually work in partnership with demand-responsive support organizations and service providers, among them elected governments, central government agencies, the private sector and NGOs (Dongier, 2002). The CDD approach to development attempts to empower poor people, organize economic activity and resource management, provide social infrastructure services, improve governance, and enhance the security of the poorest members of society. The potential for CDD is greatest for goods and services that are small in scale, not complex and require local cooperation, such as common pool goods like pastures and surface water irrigation systems, public goods such as local road maintenance, and civil goods such as public advocacy and social monitoring.

Experience demonstrates that by directly relying on poor people to drive development activities, treating them as assets and partners in the development process and building on their institutions and resources, CDD has the potential to make agricultural development and poverty reduction efforts more demand responsive, more inclusive, more sustainable, and more cost-effective than traditionally centralized approaches. CDD is more likely to be effective if some conditions are met:

- Local government institutions are strengthened to provide organizational and technical support, adequate resources, decision-making authority and mechanisms for grassroots participation;
- rural communities and farmers' associations are entrusted with legal authority and are able to build their capacity to take full part in agricultural development matters (e.g., contracting loans, initiating and implementing programs and projects);
- linkages are created between research institutions, extension services, and technology users for the exchange of knowledge and experience on relevant development issues;
- legal and financial frameworks are developed that encourage local communities to claim ownership of these services and infrastructure.

Proven CDD practices have shown encouraging results in Senegal, Tanzania and India. In India, several modest experiments started in the 1990s to empower local communities with resources and authority. The outcomes have been dramatically successful in several cases and resulted in poverty reduction. A key lesson from countries' experiences is that, given clear rules of the game, access to information, and appropriate capacity and financial support, poor men and women can effectively organize in order to identify community priorities and address local problems, and work in partnership with local governments and other institutions.

5.2.1.3 Agricultural extension and capacity-building opportunities

Although rural communities in SSA have a long history of self-help and community development, top-down approaches to the development and dissemination of AKST have traditionally been the norm. As such, rural communities typically have not been empowered with resources and decision-making authority, and the voices of socially excluded groups such as women and minorities are often not heard. The typical extension organizations in the region have involved overlapping responsibilities and uncoordinated interventions between several public agencies and NGOs, with extension workers often lacking the minimum means, such as vehicles, fuel, and materials needed to fulfill their roles. In many SSA countries the linear approach of a centralized scientific organization transferring technologies down to extension agents and on to the farmers (reinforced by education systems that train scientists specifically to work in such institutions) has worked relatively well for major cash crops. However, this system has had little success for improving subsistence and food production (Hall and Nahdy, 1999). The typical linear approaches to extension that have been employed in SSA lack feedback loops from farmers up to researchers, and value “scientific” research and learning over more tacit forms of farmer learning and local and traditional knowledge (Box 5.1) (Ochieng, 2007).

[Insert Box 5.1]

Participatory Demonstration and Training Extension System (PADETES), has been the national extension system of Ethiopia. Developed after a critical evaluation of the past extension approaches practiced in Ethiopia, this system accommodates present thinking in extension philosophy including research, education and extension as part of the knowledge system. PADETES puts equal emphasis on both human resource development and the transfer of appropriate and proven technologies. Implementing extension services is entirely the responsibility of the Regional Agricultural Bureaus, while the Federal Ministry of Agriculture has the mandate to formulate and submit agricultural and related policies and, upon approval, coordinate and diffuse them through interregional development programs and/or projects, and provide technical advice and training services to increase the technical competence of the extension staff of the Regional Agricultural Bureaus (Ejigu, 1999).

A number of approaches already exist to train farmers in research and extension. Farmer field schools employ a pedagogical approach of “learning by doing”, or “interactive learning” (Ochieng, 2007) that can improve farmers’ knowledge, skills, and sense of empowerment. Farmer field schools also allow local and traditional knowledge to be incorporated into the development of new approaches. Farmer field schools, combined with efforts to generate demand, have been successful in establishing producer and consumer markets for vitamin A enriched orange-fleshed sweet potato in east and southern Africa (Ochieng, 2007). However, farmer field schools also have their shortcomings, requiring relatively high investment costs. They are expensive to sustain and to replicate, and evidence suggests that they tend to exclude relatively poorer farmers (Davis, 2006).

Farmer field schools suffer from the same problem as other forms of public extension, namely they require sustained funding. In Kenya, extension-led farmer field schools over 45 weeks cost up to $600 per group of 25-30 farmers while farmer-led schools cost $300 per group (Onduru et al., 2002). Concerns have been expressed that once grants from IFAD-IPPM run out, these FFS are likely to cease unless local self-financing initiatives are identified and put in place (Onduru et al., 2002). Farmer field schools have not been fully evaluated at the national level in Kenya. However, given the reported large increases in yields, there may be potential for FFS to be self-financed by the farmer groups themselves, as has emerged in some areas in Kenya. A further potential of FFS is for lessons from this approach to be documented in relatively simple extension messages (Onduru et al., 2002). In Uganda, there has been a move to decentralize extension services and to encourage a plurality of providers and approaches. Particularly important is that extension services are being designed to be more directly responsive to farmers' self-identified needs.

New approaches to extension that are more responsive to farmers, less top down, and more integrated with research, will require extension agents to have different skills from those they currently have and that are traditionally available. One option is to introduce mid-career training and diploma courses, as is being done in Uganda. Fee-based schemes are being introduced in part in response to a decline in public funding of extension services. This approach can expand the provision of extension services, but may exclude the poorest farmers. Increasingly, the private sector is becoming involved in the provision of extension services. Private extension services are typically linked to the provision of inputs such as seeds and fertilizer and the purchase of agricultural products.

NARS relevant to changing AKST paradigms. In many countries in SSA, most agricultural research is undertaken within the framework of the NARS and so is conditioned by these institutions (Hall and Nahdy, 1999). The adoption of participatory approaches within the NARS framework is hindered by issues of professional identity, lack of participatory research skills, and a professional reward system that makes it difficult to publish the findings from participatory research in the top academic journals (Hall and Nahdy, 1999). Extension tends to rely only on countries' official languages as working languages. Though not yet proven, moving the use of selected SSA languages up the research-extension chain could have a significant impact on participation, relevance, and results.

There are a number of processes that are currently working to improve the relevance of the NARS. The Innovation Systems Framework and Integrated Agriculture Research for Development are highlighted below. An innovation system can be defined as networks of organizations or actors, together with the institutions and policies that affect their innovative behavior and performance that bring about new products, new processes and new forms of organization into economic use (Hall et al., 2006). As an evolutionary model, the focus is on interaction between actors and their embeddedness in an institutional and policy context that influences their innovative behavior and performance. The innovation system approach emphasizes the different roles of the actors. Many actors in the public and private sectors could be involved in the creation, diffusion, adaptation, and use of knowledge relevant to agricultural production and marketing. Therefore, instead of the public research and extension agencies being regarded as the prime movers of agricultural processes, the innovation systems framework recognizes that i) a broad spectrum of actors outside the State have an important role; ii) the relative importance of different actors changes during the innovation process; iii) as circumstances change and as actors learn, roles can evolve; and iv) actors can play multiple roles - sometimes as a source of knowledge, sometimes as a seeker of knowledge, sometimes as a coordinator of linkages between others (Hall et al., 2004).

The innovation systems concept recognizes the importance of the inclusion of stakeholders and their demands which can provide important signals that can shape the focus and direction of innovation processes. They are not articulated by the market alone but can be expressed through a number of other channels, such as collaborative relationships between users and producers of knowledge or mutual participation in organizational governance (for example, board membership). This framework is now being tested in various contexts in SSA.

The Forum for Agricultural Research in Africa (FARA) is testing innovative partnership processes, or “Innovation Platforms,” which seek to better understand how processes for systemic innovation can be organized among researchers, practitioners, policy actors, market chain actors, and rural communities, in order to make innovations useful, affordable and accessible to end users. The Innovation Platforms (IP) will serve to provide a space (not necessary physical) around which stakeholders will organize around particular themes. A common IP will bring together researchers from different disciplines, private sector (input suppliers, output markets, market information systems, micro-finance institutions), practitioners (NGOs, Extension departments) policy makers, and rural communities or farmer organizations. This approach is being tested and evaluated in various countries under the SSA Challenge program (FARA, 2007) (Box 5.3).

[Insert Box 5.3]

5.2.2 Soil variability

A key challenge in SSA is the high variability of African soils, rendering blanket recommendations inappropriate for many farmers (Bindraban and Rabbinge, 2003). This high variability suggests that decision tools would complement a basket of available technologies, and would also counter some of the criticisms of participatory approaches – that they are difficult to scale up. Options for enabling such “precision agriculture” vary from high-tech satellite referencing to relatively simple scoring techniques based on farmer observations of their own fields (Gandah et al., 2000).

Linking systems modeling tools to farmer participatory research. Computer models have been developed that can be used to help resource-poor farmers in SSA determine the best use of, for example, crop residues, fertilizers, and alterative land uses (Mando, 1997; Ibrahim et al. 1988; Sissoko, 1998; Sawadogo, 2000; Slingerland, 2000; Kanté, 2001; Schiere et al., 2001). Systems modeling linked to farmer participatory research in sub-Saharan Africa can help farmers interact with scientists and speed up the research process (CIAT). Information and communications technologies (ICT), including geographic information systems (GIS), can help to increase understanding of the complex biophysical conditions of crops and animal production (Bindraban and Rabbinge, 2003). Participatory GIS provides a new set of approaches and methodologies that have potential for advancing agricultural development in Africa.

Recent advances in ICT allow the search for optimal application of inputs in time and space, often by combining GIS and close and remote-sensing technologies and increase labor productivity. In many parts of Africa, for instance in Kenya, ICT has facilitated communication and provided farmers with market information, leading to improved negotiating power. Although, in many parts of Africa these technologies have not yet been applied, success stories in countries like India demonstrated their feasibility particularly in poor regions. In addition, the use of ICT has enabled the availability of quality data sets on agricultural production particularly for disaggregated agroecological ares, with spatially defined heterogeneous production systems. In countries in SSA where ICTs are not yet capable of helping individual farmers, simple decision support tools can complement participatory approaches where farmers are encouraged to identify and adapt technologies to suit their own particular circumstances.

5.2.3 Patents for biotechnologies and GM technologies

In SSA, most food and feed crops are grown from farmer-saved seeds and farmer-developed varieties with very little intergovernmental or donor support. A key concern over agricultural biotechnology and GM in particular is that it can lead to the decommodification of the seeds that farmers use from one season to another, which would benefit developed countries at the expense of poorer countries (Fok et al, 2007). New technologies are often developed in richer countries and IPRs can claim global applicability.

Maintenance of patent exemptions. Because of this, a number of organizations – such as the WTO TRIPs Council – support the continuing of patent exemptions in SSA (Article 27.3b), and seek to protect the use of traditional AKST, such as at the World Intellectual Property Organization negotiations. SSA has also opposed attempts to restrict farmers' rights to save and exchange seeds at implementation negotiations of the Convention on Biological Diversity and the International Treaty on Plant Genetic Resources for Agriculture and Food. Such an approach is, for example, consistent with IITA and the CGIAR system. IITA explicitly states that it normally does not seek to secure patent or plant breeders' rights for germplasm, materials, or technologies developed by IITA. Moreover, IITA does not see intellectual property protection as a mechanism for securing its own funding.

Laws for patenting in SSA. An alternative approach, promoted by a number of intergovernmental institutions, foundations, and bilateral donors, is based on patenting seed varieties and other inputs that would require rewriting SSA law. Proponents of such an approach suggest that it will reduce biopiracy and foreign exploitation of local and traditional SSA knowledge. Although the costs involved in securing patents would be too high for individual small holder farmers, concessions could be negotiated by organizations such as the AATF for local communities to benefit (as for the IR maize project where seed is coated with the herbicide imazapyr to control *Striga*). South Africa has an IPR regime that proponents suggest provides a favorable environment for both local and foreign investment opportunities that could be a model for other SSA countries. Detractors suggest that an approach based on patents would protect patent holders' rights while eroding farmers' rights, and would be excessively costly in terms of development, royalty, and licensing costs.

There are alternatives to the two extreme options discussed above that can be explored in the future. Some gene and biotechnology patents are expiring and will be available for poorer countries to take advantage of. Patent protection for "global" crops that are grown in richer and poorer countries could be made weaker in poorer countries; or enforcement could be permitted in either richer or poorer countries but not both (Fok et al., 2007). CAMBIA is an open-source system for biotechnology that has the express purpose of providing free and continuously evolving IP for global users.

5.3 Enhancing Agricultural Product Value Chains

The lack of connection between the African farmer and the market has seen African agriculture remain rudimentary, unprofitable and unresponsive to market demand. African markets, which are readily available to international agricultural products, are relatively inaccessible to African farmers. With recent and expected trends relating to market liberalization, decentralization, urbanization and globalization, Africa will continue to experience dramatic social, political, economic and cultural transformations. As such, African agricultural must respond to the needs of a different type of consumer, increasingly a better informed, urban-based consumer with a demand for more processed and easy-to-cook foods. African agriculture cannot, therefore remain rudimentary but must be an integral part of the growing African market economy through a transformation geared towards increased productivity, increased agricultural incomes and employment, and competitiveness in local, regional and international markets.

Part of the reason for the current underdevelopment of African agriculture lies in the failure to transform farming activities into agribusiness ventures, key to developing the various stages of the agricultural product value chain and crucial to linking agriculture to markets. Agribusiness refers to all market and private entities involved in the production, storage, distribution, and processing of agricultural products plus the supply of production inputs, extension, administration and research. There are signs that agribusiness development is imminent in Africa. Some opportunities in this regard include: the recent growth in post-production activities; trends towards more vertically linked and concentrated organizations in agrifood systems; existing gap in agroindustries and agribusiness for value-addition; and the potential for agribusiness development to provide much needed support services.

Yet for agribusiness, especially agro-industries, to flourish, addressing the growing lack of connection between Africa's agriculture and farmers and the market, particularly at sub-regional and regional levels is crucial. This includes strengthening both backward (from input markets) and forward (from output markets) disconnects. Amidst this disconnect is a paradox with regard to African trade and marketing: Africa has continued to open its markets to traders outside the continent in response to calls for global trade liberalization, but has remained largely closed to intra-African trade. As a result, the potential for intra-African trade within and between sub-regions is largely untapped. While traders from outside the continent have continued to visualize a continent-wide market, there seem to be asymmetries in the perceptions of market and investment opportunities by the private agroindustry and agribusiness communities. Most of them perceive a national, or at best, a sub-regional market, not a common regional market. In the face of globalization, this limited scale is not optimal. Economies of scale along commodity value chains, economies of vertical coordination among the different stages and economies of complementary diversification and specialization among countries and sub-regional groupings, are critical in order to realize the full competitiveness gains and the intra-regional potential of an African common market in agriculture.

Improve the connection between farmers and markets. The link between producers and post harvest activities can be improved to increase the efficient use of production and post-harvest technologies. Technical assistance in production and post-harvesting techniques and operations, and training and capacity development to enhance farmers' management, negotiating and bargaining skills, are much needed. Other approaches include the promotion of contract farming/out-grower schemes or other forms of contracts that allow for advance payment and provision of inputs and extension services from agribusiness companies to farmers, thereby reducing the need for credit to which many farmers lack access. Farmers will also benefit from innovative methods of receiving market information and intelligence, mechanisms and guidelines that allow for accreditation of agribusiness companies, farmers organizations and co-operatives, as well as regulations on foreign investment.

Capacity development and facilitation of dialogue between farmers, distributors, agro-processors and marketing agents. This approach can be used to improve adherence to standards relating to quality and volume, as well as timeliness in the delivery of agricultural produce. Productive dialogue is key to examining agribusiness companies' pricing incentives with a view to encourage farmers to produce higher quality products in a timely manner. In addition, establishing long-term contracts and viable partnerships between farmers and agribusiness companies that ensure the provision of training, technical, extension and financial support to farmers and farmer organizations has proven to be fruitful.

Other options for improving connections between farmers and markets include increasing and sustaining government/public sector support to: develop and implement policies and guidelines that encourage investments in private agribusiness ventures while protecting producers; facilitate information generation on production and post-production technologies; provide marketing infrastructure and information systems; and put in place fiscal incentives that are supportive of research and development not only for enhancing on-farm productivity, but product development based research and innovation to facilitate off-farm growth of agro-industries and marketing.

Market development and market access. The state of underdevelopment in African markets, low levels of market integration and poor infrastructure continue to cripple the competitiveness of African agriculture. Africans, the majority of whom live in rural areas, are poorly served by both input and output markets. Without well functioning input markets, developments in AKST will not benefit African farmers, as seeds, fertilizers, tools and other inputs will remain out of reach for the majority, due to high input prices as a result of inefficiencies created by high transaction costs and information asymmetry. Similarly, low prices in output markets prevents producers from earning income conducive to poverty alleviation and stimulating a demand for non-farm products, a necessary condition for industrial growth and a structural transformation of African economies. Improving the functioning of African markets is vital to reversing the stagnant state of agricultural productivity and to increasing incomes in the largest employment sector on the continent. In addition to increasing incomes for the poor, well functioning markets can reduce the food bill of urban populations, the majority of whom are food insecure and spending a large proportion of their incomes on food.

Interventions for enhancing the performance of African markets and hence link producers to the markets must ensure that markets work for the poor, by developing markets where markets do not exist and improving infrastructure where markets do not function properly due to infrastructural related constraints (UN Millennium Project, 2005). Markets are especially rudimentary in environments characterized by low population density, dispersed rural households and a poor rural roads network. In addition to ensuring that markets exist and function, addressing challenges related to market exclusion for the poor is crucial. These constraints include inadequate productive assets and collateral; social attitudes barring women from participating in the market; and poor legal and regulatory environments. Even where markets exist and efforts have been made to provide the poor with the tools necessary for participating in them, unfavorable terms of trade including poor output prices and wages remain major challenges to the performance of African markets. The situation is exacerbated by a lack of bargaining power by the poor and poor access to information. Some options for addressing these challenges are offered below.

Improving basic infrastructure. African trade and marketing is constrained by the rudimentary state of Africa's infrastructure. More innovative approaches are necessary to create, through policy, legal and institutional reforms, an incentive environment that is conducive to mobilization of initiatives and resources from rural communities, farmers' associations and other private-sector stakeholders for investment in basic production, market and social infrastructure (e.g., irrigation, rural roads, rural water supply and electricity systems, health and education facilities). African governments must be encouraged and supported to develop national policy frameworks that identify priorities for rural investments as part of a national network of services and infrastructure, and specify the roles and responsibilities of various actors in delivering services. With decentralization taking root in many Africa countries' governance structures, it is vital to encourage greater involvement of decentralized rural communities in direct investment and maintenance of roads. But the support of governments and the donor community in support of investments that would increase the density of rural and feeder road networks cannot be underestimated. Lessons must be drawn on innovate public-private partnership (e.g. through taxation and public financing) for feasible domestic action in this regard.

Improving the performance of domestic markets. This calls for an understanding of current realities and future trends in the structure and magnitude of effective demand for agricultural products. In this regard, African governments must intensify and complete agricultural policy reforms and market restructuring processes, most of which are underway with a view to putting in place institutional, legal and financial frameworks that promote private investment in agribusiness and agro-industrial enterprises. It would be practical to put emphasis on small-scale industries, capable of diversifying food and agricultural products, supplying effectively agricultural inputs, and providing basic transport and marketing services. Responding to consumers and other marketing agents requires the enactment of appropriate regulations on product standards to improve the quality and increase the competitiveness of food and agricultural products. And finally, viable strategies to promote the development of strong and effective market information systems would help to complement other strategies to facilitate market access, including the provision of financial support and the mobilization of private participation for strengthening national market information collection systems. Africa must take advantage of ICTS work towards putting in place functional sub-regional and regional networks of Agricultural Market Information Systems (AMIS).

Regional integration to facilitate intra-African trade. The potential benefits of regional integration in Africa have been accepted by African governments as demonstrated in their adoption of the Lagos Plan of Action in 1980 at the OAU Extraordinary Summit. The Lagos Plan of Action highlighted the goal of regional integration, which was further concretized in the signing of the Abuja Treaty, establishing the African Economic Community (AEC) in 1991and ratified in 1994. The Abuja Treaty outlined a gradual process for establishing regional economic communities (RECs) to act as the building blocs for the AEC as follows: AMU (The Arab Megreb Union), ECCAS (Economic Community of Central African States), COMESA (Common market for Eastern and Southern Africa) SADC (Southern African Development Community) and ECOWAS (Economic Community of West Africa). The Treaty envisaged a process that would culminate in the establishment of the AEC by 2008, including the strengthening of the RECs, removal of tariff and non-tariff barriers, the establishment of free-trade areas and the formation of an African common market. African governments, by signing the Treaty, committed to promoting the integration of production structures, processing, trade and marketing systems in order to speed up agricultural development and food production. A renewed commitment by African States under NEPAD, and trends toward strengthening regional integration under the existing sub-regional commissions are a welcome sign, but more needs to be done to ensure a successful integration of Africa's market. Some alternative adaptations include: implementing existing regional integration agreements and targets set within each agreement; improving procedures for customs and harmonizing national taxation and support policies for more efficient cross-border trade; creating, through public-private partnerships, sub-regional marketing mechanisms and institutions to develop marketing strategies for African products; removing infrastructural and institutional barriers (both legal and illegal) to investment promotion and free movement of commodities across borders; and rationalization of the regional economic communities.

Current efforts are being made by the African Union (AU), Economic Commission for Africa (ECA) and African Development Bank (ADB) to assist in the rationalization of the Regional Economic Communities. It would be useful for the three continental institutions to also support these efforts by putting in place a mechanism for peer review and learning, as well as monitoring the implementation of various commitments with regard to market integration, within the framework of the African Peer Review Mechanism.

Increasing access to global markets. Improving the access of Africa's agricultural products to global market calls for action at the national and sub-regional levels. Capacity for policy research on the impact and implications of the various requirements of WTO agreements for African agriculture could be strengthened with a view to providing vital information for African trade negotiators and forming common platforms that improve the outcomes of these negotiations. To better meet both WTO requirements and the needs of African countries the establishment of technical committees (or standards bureau) involving key stakeholders would be helpful to ensuring the development of appropriate regional and international product standards and technology regulations. With current trends in globalization and trade liberalization calling for high quality standards, the selection of appropriate means (technical seminars, training workshops, ICT, extension networks, etc.) for informing and educating farmers and private agribusiness entrepreneurs in on acceptable product standards becomes important. At the global level, African governments could benefit from high-level forums (e.g. ministerial workshops) in which African countries collectively develop institutional capacity to engage in multilateral trade negotiations, including phytosanitary and other agricultural trade regulations. This can be done under the aegis of AU and with support from the ECA and ADB. In such a case, OECD policies regarding subsidies and market access, which constrain trade opportunities for major agricultural commodities and products from Africa, would likely become prominent issues.

5.4 Enhancing the Contribution of Women to Agriculture

Women account for approximately 70% of agricultural workers and 80% of food processors in SSA, are more likely than men to be managers of natural resources, and often maintain and share traditional practices. Yet women typically are disadvantaged relative to men in terms of access to education, to extension services, to credit (due in part to women's higher illiteracy rates), to irrigation, and to land ownership rights. Moreover, women are poorly represented in the supply of AKST, whether as researchers or extension agents – for example, in 2000, just 18% of African agricultural researchers in a 27-country sample were female (Beintema and Gert-Jan Stads, 2006).

The gap between the importance of women in agricultural production and processing and their weak representation in and access to agricultural services suggests that there is scope for enhancing their contribution to the agricultural sector. Improving women's general education has been shown to have a positive impact on agricultural yields. In countries where modern agricultural technologies have been introduced, returns on an additional year of women's education range from 2% to 15%, more than the returns for the same educational investment in men. Further, policy experiments in Kenya have suggested that primary schooling for women agricultural workers raises their agricultural yields by as much as 24%.

[Insert Box 5.2]

Though it has not been proven, increasing the proportion of women extension agents is likely to increase the number of women attending extension meetings and talking with extension agents and increase the relevance of AKST for women. Extension officials are typically men (only 17% of extension agents in SSA are women) and, depending on particular country and regional norms, may not be able to, or may choose not to speak to women farmers (Das, 1995).

In much of SSA women have "secondary" rights to land, obtained through their husbands or other male kinsfolk (Toulmin and Quan, 2000). They often have access to their own plots of land that may be of a lower quality than those available to men, on which they may cultivate different crops than their husbands. The extent to which women are less likely than their husbands or other male farmers to invest in their plots differs from country to country. For example, women's level of inputs in Burkina Faso has been found to be similar to men's, but in Uganda women are less likely to plant trees and make other long-term investments in productive assets because they are not confident of being able to control any ensuing profits (Sawodogo et al, 1998; Toulmin and

Quan, 2000). Hence the likely impact on agricultural production, particularly long-term investments, of more formalized access to land for women will also vary from country to country.

Women's access to land and their degree of land tenure security on private and communal lands can be improved through the implementation of land policies and laws oriented towards equal rights for men and women. Yet, although many countries are at an advanced stage in the formulation of gender sensitive policies, laws, and other instruments, implementation is slow (for example, women received only 20% of land under the recent Zimbabwe land reforms). To catalyze implementation, reforms can be accompanied by mechanisms such as the harmonization of laws related to inheritance, marriage and property rights. In addition, political will and clear guidelines and benchmarks for monitoring implementation to allow appropriate authorities, including citizens, to hold governments accountable in this regard (Box 1) are more likely to lead to successful implementation of land reforms .

Women farmers access only 10% of credit allocated to smallholders and only 1% of available agricultural credit. These data could reflect either a lack of supply of credit to women, or a lack of demand. For example, women who feel insecure about their land are less likely to choose to invest in that land and so less likely to demand credit. Evidence for men and women suggests that a focus on micro-credit rather than improving women's security of land tenure is likely to improve women's access to credit.

Although the following options have not been proven to increase the likelihood of achieving the assessment goals, they can increase the profile of women in agriculture. Quantifying the role and value of women's knowledge and contribution to agriculture and natural resource management, particularly with respect to local and traditional knowledge, can emphasize the importance of women in agriculture and subsequently the cost of not fully mainstreaming them in all aspects of agricultural development.

Protocols that ensure that women are involved in the design and enumeration of any questionnaires and surveys that are undertaken, and that women are fully represented in any sample that is taken, can be introduced relatively easily and at low cost. Data collection that deals particularly with issues of natural resource management can ensure that the role of women is determined explicitly – for example, questions can identify the roles of men and women in different activities and in decision making with respect to agriculture and resource management at the household and village levels. Involving women in enumeration may, in some cultures, make it easier to document fully women's activities with respect to natural resource management. The findings from such studies can be incorporated into university curricula. In particular, agricultural sciences, agricultural economics, and agriculture-oriented sociology courses could include specific modules that address the role and contribution of women with respect to natural resource management and knowledge.

Gender-specific roles and the current status quo in many African countries can hinder the process of mainstreaming women into the above activities. The likelihood of successful mainstreaming can be increased with commitment from government and universities, combined with monitoring and assessing over time the numbers of women applying for positions, and being accepted.

Options for mainstreaming women in AKST development include efforts to encourage women to study agricultural science, natural resource management, and forestry at school and university, and to include the role of women in agriculture in studies both at primary and university level. Although the costs and returns to these strategies have not been assessed, and there is in theory no reason why men should not be as capable as women in addressing the needs of women in agriculture, there is a general consensus that better mainstreaming of women throughout education, training, and extension, is likely to improve the relevance of AKST to women and therefore have a positive impact on the assessment goals.

5.5 Sustainable Use of Land and Water Resources

Africa faces a number of specific challenges with respect to the sustainable use of its natural resource base. These include the increasing degradation of natural resources due to inappropriate resource use; increased competition for resources; climate change; and the loss of agricultural biodiversity including animal genetic diversity. These challenges are exacerbated by the low commitment to integrating environmental concerns into AKST-related strategies; the low capacity for the development of AKST to address natural resource issues; and the low support for women in the management of natural resources.

Addressing the enhancement and sustainability of the natural environment through AKST is particularly challenging in SSA. The emphasis for agriculture in the region has been to increase crop production and reduce malnutrition through arable land expansion and increased cropping intensity. This pressure to increase output will continue over the period of the assessment given the continuing chronic malnutrition and low incomes within the region. Most of the increased food production in SSA has been in expansion of agricultural land area thereby putting pressure on marginal land and the non-farm natural resource base outside of the farm (FAO, 1996). These pressures will be reduced if agricultural productivity increases on existing arable land. However, increasing cropping intensity will put more pressure on on-farm natural resources, particularly soils.

Complex biological interactions exist between different resources such as soils and water, suggesting that integrated solutions are required. NRM practices are typically more knowledge intensive than agricultural production technologies, which often embody the technology in inputs such as seeds or chemicals (Barrett et al., 2002). Local and traditional knowledge about the environment is embedded in languages that are typically not formally used in extension except ad hoc in the field, nor in research, except to mine information. This hinders the ability to leverage local knowledge and link it with exogenous AKST.

Problems associated with missing markets (externalities) and common pool resources are common. The actions of an individual farmer with respect to the resources on her farm, for example, may have a negative impact (externality) on resources outside of her farm that she does not take into account in making decisions. Individual farmers' incentives therefore may not align with sustainable farming activities at the community level and so incentives and institutions are required to ensure the resource base is managed sustainably.

If farmers do not see direct benefits to themselves from natural resource management activities, they have little incentive to adopt the technologies (Dejene, 2003). When environmental degradation is gradual it may not be noticeable for several years or more (though soil erosion can occur even over a few hours). Solutions may have high upfront costs but take time to have an impact and so may not be compatible with resource-poor farmers with high discount rates.

Private enterprises may not have a "long-term interest in creating the type of long-term, strategic, public goods research products that are required to ensure a continuous stream of benefits from natural resources to society at large" (Ashby, 2001), and little interest in issues such as water conservation techniques (Scoones, 2005). However, whereas the private sector lacks incentives, the public sector lacks capacity (Scoones, 2005), suggesting potential for private-public partnerships. Finally, the natural biological and institutional linkages among resources and resource users are often in contrast to the lack of appropriate organizational linkages among different government ministries and research organizations that would improve the likelihood of environmental degradation being tackled effectively. Particularly in SSA, providing technical solutions to environmental degradation is therefore far from sufficient.

5.5.1 Land: Limiting conditions and available alternatives

Land degradation, and poor soil fertility in particular, is widely accepted as the most critical factor in limiting agricultural production in SSA (Stoorvogel and Smaling, 1990; Smaling et al., 1997; Hilhorst and Muchena, 2000; Baijukya, 2004). The natural resource base in SSA is, in many areas, highly degraded, due in part to increased competition for resources, inappropriate pricing of those resources, and – increasingly – climate change. There are numerous estimates of the costs of this degradation – irrigated lands 7% below their potential productivity, rain-fed crop lands 14% below, and rangelands 45% below (Donovan and Casey, 1998), resulting in, for example, an estimated cumulative productivity loss over the past 50 years of 13% for cropland (Scherr, 1999).

Increasing degradation of natural resources is already having a negative feedback effect, reducing the potential of agriculture and any new innovations, and making the task of increasing productivity and reducing malnutrition all the harder. For example, soil degradation reduces the potential of agricultural initiatives such as improved water management (IAC). Current policies and priorities have not, in the main, slowed down this degradation. And despite the existence of many technologies for the improved management of soil fertility in SSA, there has been a poor uptake of these existing technologies by smallholder farmers.

Though contentious, increased applications of synthetic fertilizers are seen by many practitioners as essential for SSA, as reflected in the resolution by AU members to increase fertilizer use significantly by reducing its cost through national and regional level procurement, harmonization of taxes and regulations, the elimination of taxes and tariffs, output market incentives, and access to credit from input suppliers (Chude, 2007). The AU's recommendation to remove all taxes and tariffs from fertilizer and fertilizer raw materials could increase fertilizer use. However, farmers are unlikely to increase their use unless they have access to markets for the output, they are confident that the expected returns are sufficiently high to justify the cost, they have access to affordable credit to purchase fertilizer and the risks of crop loss (or revenue loss from adverse market conditions) are sufficiently low.

Recommendations for fertilizer use typically involve unsophisticated "blanket high dose" applications while research focuses on fine-tuning high-input recommendations that are particularly inappropriate for the region, given the cost of fertilizer in SSA and the understanding that higher doses of fertilizer are more likely to result in environmental pollution (Snapp et al., 2003). More appropriate, particularly for resource-poor farmers in SSA, are approaches and recommendations that enable farmers to maximize returns from smaller input purchases (Snapp et al, 2003). Further, as the following discussion on integrated approaches to water and soil management highlights, given the poor state of soils in much of SSA, mineral fertilizer alone may have little impact on yields and therefore the economic justification for increasing fertilizer use.

Pollution and health hazards from agrochemical use including fertilizer and pesticides in SSA are currently less of an issue than in other regions because most farmers cannot afford to apply any, let alone high levels of fertilizer, particularly given its relatively high cost. However, experience from other regions suggests that in parallel with encouraging increased fertilizer use, efforts will be needed to reduce the negative associated health and environmental impacts including soil acidification and water pollution that particularly come from excessively high levels of fertilizer (Weight and Kelly, 1998). Farmers are more likely to minimize the negative environmental effects of fertilizer use if they have access to technologies that enable technically efficient application, typically specific to local soil conditions (Weight and Kelly, 1998). Biological control is an option for integrated pest management and involves augmentation or conservation of local, or introduced natural enemies to pest populations. There are several examples of where staple and important crops have been saved by biological control over wide areas.

Fifty-seven percent of SSA's land is “marginally sustainable”, meaning poorly buffered soils with very low soil organic matter and poor water retention (Weight and Kelly, 1998). Addressing one of these problems without addressing the other in parallel is likely to have very little impact on output, and indeed there is a growing consensus that gains in productivity in SSA require an integrated approach to soil, nutrient, and water management rather than undertaking separate research. On farms with low soil moisture and low fertilizer-use efficiency, the addition of chemical fertilizer is likely only to be profitable where there is regular rainfall or irrigation, and already relatively high organic matter in the soil (Masters, 2002). A combination of organic and inorganic sources of nutrients – integrated nutrient management – has been found in many situations to be more effective than using just one approach (Murwira and Kirchmann, 1993; Swift et al., 1994; Ahmed and Sanders, 1998; Bationo et al., 1998; Murwira et al., 2002; Ahmed et al., 2000). Green manure crops can be grown in farmers' own fields, and there is evidence in West Africa that they can help to revive degraded lands. Yet although green manure technologies have been successfully developed for west Africa, and even though some farmers have adopted them, many farmers see green manure crops as competing with edible and cash crops, and having little observable impact on yields and soil fertility in the short term, and so are reluctant to adopt them.

In some areas of SSA, such as western Kenya, phosphorus deficiency is a critical limiting factor for crop yields, such that without application of phosphorus, investments in nitrogen or nitrogen-fixing legumes has little impact (Sanchez, 2002; Smalberger et al, 2006). Phosphorus can be added in several ways: phosphorus fertilizers; phosphate rock (such as Minjingu rock in Kenya);

and phosphate released from biomass such as from Tithonia leaves. Phosphorus fertilizers are relatively costly in SSA and are scarce in some countries, due in part to poorly developed markets, a lack of domestic production, or limited foreign exchange, and so, not surprisingly, phosphorus application in SSA is low (1kg ha^{-1} compared with 14.3kg ha^{-1} in Asia) (FAO, 2002a; Smalberger et al, 2006). The use of relatively small applications of phosphorous has been found to be effective at increasing vegetative cover in Nigeria (CGIAR). However, in water excessive phosphorous can over-stimulate the growth of algae thereby depleting the water of dissolved oxygen and harming aquatic life. The addition of phosphorous combined with improved soil erosion management techniques is likely to reduce the potential negative externalities of its application. Further, phosphorous fertilizers may contain cadmium which can enter certain crops including potatoes and leafy vegetables and which is toxic to humans.

5.5.1.1 Integrating approaches

Encouraging more integration requires alternative approaches to the “transfer of technology” model that has been common in SSA. There has been criticism of natural resource related research approaches that are predominantly undertaken on research stations rather than collaboratively on farmers’ fields. For example, most information on the contribution of legume nitrogen is from research stations where soils have sufficient P and other nutrients and is sometimes is irrigated (Mafongoya et al., 2006). Most soil fertility research in East Africa has concentrated on recommendations for monocrop systems despite the fact that most smallholder farmers use intercropping and mixed cropping systems (Bekonda et al., 2004). Evidence suggests that involving farmers in soil fertility research improves the likelihood of recommendations that are more relevant to farmers’ situations (CIAT, 2002; Bekonda et al., 2004). On-farm experiments are more likely to provide realistic rates of return to different technologies and therefore those that would best suit the farmers; and farmers may be more likely than on-station researchers to identify green manures with food or forage uses that are more likely to be adopted.

A number of approaches naturally lend themselves to farmer-oriented research. Production ecological approaches and conservation farming have both been promoted as approaches to reversing on-farm environmental degradation that take account of soil-water-nutrient interlinkages. A production ecological approach is one way to take account of complex biological linkages such as those between water retention and soil fertility, and between pest management and soil fertility. It requires an understanding of what is happening in the fields to orient research towards technologies that enhance productivity and profitability in an environmentally sustainable way. For example, integrated soil management requires a combination of improved soil hydraulic measures, organic fertility maintenance, and inorganic fertilizer and soil amendments (Batjes, 2001).

Conservation tillage (in which crops are grown with minimal cultivation of the soil) directly affects water infiltration and water retention in the soil, and so improves the efficiency of rainwater use, and may contribute to yield stability and food security in drought prone regions (ACT). However, more studies of sufficient size are required to determine the true benefits and constraints to the adoption of conservation farming. For example, conservation tillage has high labor requirements that may deter farmers from adopting the approach (ACT). The effectiveness of conservation tillage most likely depends on specific agro-climatic conditions – for water-conserving conservation tillage – and access to draft power influences profitability (and hence the likelihood of uptake). Moreover, the benefits of conservation tillage occur gradually over time, suggesting that poor credit-constrained and risk-averse farmers (a typical SSA farmer) will find it difficult to adopt such techniques without confidence as to their benefits and the ability to make upfront investments – such as through access to credit.

Currently the capacity for integrated soil fertility management in many countries in SSA is limited by insufficient numbers of professional personnel and the essential laboratory facilities required (World Bank, 2002). More integrated approaches require interdisciplinary teams working together, more complex institutional arrangements, and increased coordination among different agencies and organizations, particularly given that governments often separate, for example, agriculture, natural resources, and wildlife agencies. Integrated approaches may also imply new approaches to training and extension. Previously, efforts to undertake research at the level of large complex systems have tended to result in excess amounts of costly effort to collect data, yielding few results that are of immediate practical value (Campbell and Sayer, 2003).

Livestock. The role of livestock in land degradation has been controversial: Livestock grazing and pastoralism in SSA have often been viewed as a critical factor in the interaction between agriculture and the natural resource base, and overstocking has long been blamed for the cause of extensive land degradation in rangeland areas. For example, some state that overgrazing causes 49% of soil degradation in dryland SSA, while agriculture causes 24%, and overexploitation and forest degradation 27% (Dejene, 1997). Many previously proposed solutions to perceived overstocking are now considered to have been misguided. For example, in Tanzania, officials have viewed large herd size and overgrazing as major causes of land degradation and so attempted to enforce destocking and also introduced zero-grazing of improved dairy cows for milk. Yet livestock were moved to other areas (rather than numbers being reduced), thereby transferring the problem to different locations and also leading to increased malnutrition (Dejene et al., 1997). A lack of understanding of the social, cultural, and economic roles of livestock most likely led to misguided solutions that did not have the intended effect, and had overall negative consequences.

[Insert Box 5.2]

There is increasing evidence that climate, rather than overgrazing, is the key cause of land degradation in rangelands. Climate change is likely therefore to exacerbate the problem of land degradation. For example, long-term monitoring by ILRI (International Livestock Research Institute) in East and West Africa has provided evidence that climate has been the main determinant of changes in arid and semi-arid environments and that rangelands are resilient and capable of recovery. Indeed, strong seasonality of rangeland production in the Sahel appears to limit the environmental damage of overgrazing to short periods and confined areas (Ellis, 1992; Hiernaux, 1993).

Recent rethinking of “range ecology” suggests that the opportunistic range land management practiced by pastoral livestock farmers is indeed the appropriate response to natural conditions (Behnke et al., 1993; Scoones, 1995; Homann and Rischkowsky, 2001). Local and traditional management strategies have evolved naturally in response to knowledge of the spatial and temporal availability of natural resources, “and include mobile resource exploitation, flexible stocking rates, and herd diversification, sustained by a system of communal resource tenure” (Sandford, 1983). These strategies, however, may not be able to evolve as rapidly as needed given changing climatic conditions. Nonetheless, they can be integrated into AKST research and development if they are first documented and understood within pastoral livelihood constraints (Oba and Kotile, 2001).

In general, there is insufficient understanding of the role of livestock in livelihoods and the motivations behind pastoralist practices. Better knowledge can be incorporated into the development of technologies and approaches that enable pastoralists to manage their resource base more effectively. For example, approaches that simply encourage lower stock levels may not be sufficient, in part because of farmers’ and pastoralists’ reasons for keeping livestock, and in part because of the role of climate. Similarly, rangeland degradation is unlikely to be addressed effectively unless the underlying motivations for environmentally destructive practices are understood. For example, the use of fire is widespread as many livestock owners consider it the best means of reducing the incidence of livestock disease, encouraging regeneration of grass and pasture for livestock, and clearing new land. However, the use of fire has negative environmental effects that include the destruction of vegetation cover and soil organic matter, lowering the diversity of soil fauna, and increasing erosion. AKST efforts that address livestock diseases could, under these circumstances, help to reduce environmental destruction by reducing deliberately started fires. These findings are an example of how understanding the motivations behind livestock owners' actions and integrating this knowledge into AKST development can help lead to identifying the causes (disease) of environmentally destructive actions rather than dealing with the symptoms (burning).

Developing ways of conducting more research in pastoralists' native languages using participatory methods can present opportunities for achieving better understanding of the above mentioned subjects. Herders generally understand well the environment, their animals, and strategies for survival and production. A substantial challenge exists in developing (or matching) terminologies for exogenous AKST, animal science and range management concepts, not to mention educating outside researchers in the languages. There is, therefore, the potential for combining knowledge and generating new understandings in the vernaculars of the people most directly involved in this mode of production.

Pastoralists' use of rangeland is often more conducive to conserving wildlife than more intensive alternative land uses. However, there is a natural tension and therefore conflict between pastoralist land management techniques and wildlife needs. Given the growing importance of nature-based tourism in many SSA countries, particularly in east and southern Africa, there are likely to be increased economic benefits from supporting the dual use of rangelands.

5.5.2 Water: Limiting conditions and available alternatives

In semi-arid areas, the probability of light, moderate and severe droughts ranges from 43-55%, 32-43%, and 13-30% respectively, made worse because droughts come in runs of 2-5 seasons (SOURCE). Under such conditions, risk-averse farmers tend to adopt low external inputs crop production systems rather than high yielding technologies and management practices. AKST has a direct role in terms of the development and adaptation of new technologies for more efficient water use. There is scope for improved irrigation techniques, water harvesting technologies, and developing approaches for using water more efficiently in rainfed areas. Improved water efficiency of crops can also be embodied in seeds – in particular through drought-resistant seed varieties.

Drought resistant species will be increasingly important in SSA, especially for regions that are negatively affected by global warming and climate change – rainfall and higher temperatures are predicted to be particularly problematic for southern Africa. A key question is whether these drought-resistant species will be developed by the private sector, and whether they will be cost effective for small-scale and poor farmers, or whether such species will be prioritized sufficiently in the international research centers. There are examples of drought resistant species that have been successfully developed, such as open pollinated maize, a result of intensive breeding efforts between the international maize centre CIMMYT and national researchers (Scoones, 2005). Such a development required long-term funding and research commitment within the public sector.

Technologies for increased water productivity exist for both rainfed and irrigated systems, including water harvesting and drip irrigation, which have been shown to be technically effective. Advances in AKST offer low cost technologies that can reduce the uncertainty farmers face. Despite scope for considerable increases in irrigation, there is strong support for a focus on integrated rainwater management and improved understanding of farmers' motivations and ability to adopt the requisite technology. An alternative to large-scale irrigation projects that is particularly relevant for resource-poor farmers is the promotion of rainwater harvesting. Water harvesting can reduce risk by 20-50%. Once output risk is reduced, farmers are more likely to adopt improved seeds and high yield varieties, and apply more fertilizer and manure. Many farmers could benefit from these technologies, no major infrastructural development is needed, and the benefits are more equitable than large-scale irrigation projects. One possible drawback of these approaches is that they often have a high labor demand and that may deter adoption particularly where HIV/AIDS rates are high.

In SSA, unlike most other regions, water resources typically are not over-exploited (a key exception being South Africa). Most countries have enough water to meet their near-future needs – though these resources are often as yet untapped. Yet, though there is considerable scope for increased exploitation, most countries in SSA are not currently making the necessary investments to exploit the water resources (Molden and de Fraiture, 2004). Therefore an immediate challenge for many countries in SSA is to exploit the existing water resources more fully. Water scarcity is likely to become a much larger issue in the future, and is already causing localized conflicts in some countries (for example, the Ewaso Ng'Iro North Basin in Kenya) (Weismann, 2000) and so mechanisms are required to ensure that water exploitation is technically and economically efficient and that equitable access to water resources is taken into account.

Irrigation. In the past, there was a considerable focus of AKST on the use of large-scale irrigation for agricultural systems. Although such irrigation systems can have a positive impact on poverty reduction, they have at the same time often proven incompatible with environmental concerns where water off-take for agriculture has a negative impact on water-related ecosystems and ecosystem services. Moreover, research from Asia suggests that research into rainfed areas offers greater productivity increases and greater reductions in poverty than similar investments in irrigated agriculture (Fan et al., 2000a; Fan et al., 2000b; Bindraban and Rabbinge, 2003).

Therefore, the potential for irrigation needs to be considered in the context of alternative water management strategies, external costs imposed by an irrigation scheme and distributional considerations. Investment in irrigation requires coordination among a number of farmers and significant upfront funds. NEPAD proposes that countries set up public-private partnerships for managing basic irrigation infrastructure, and encourage the private sector to invest in irrigated agriculture in parallel. These investments are only likely to occur however if the legal framework is sufficiently transparent and credible for the private sector to be willing to make long-term investments.

Water resources in SSA have typically been managed within administrative boundaries. A more logical approach is for water resources to be managed within the boundaries of a river basin (UNEP 1999). Such an approach requires institution building and sharing of information. Further, organizational structures most likely will need to be adapted to reflect realities such as the increasingly artificial divide between rainfed and irrigated agriculture (Molden and de Fraiture, 2004). The development of water harvesting techniques and small-scale irrigation are likely to be hindered by the current sectoral distinction between rain fed and irrigated agriculture, reinforced by the current professional divide between, for example, agronomists who work on rain-fed agriculture and irrigation engineers (Molden and de Fraiture, 2004), and institutional divide – these two areas typically fall under different government ministries. Either new explicit institutional linkages are required, or the merging of responsibilities within one particular ministry. In parallel, those involved with separate research into rainfed or irrigated agriculture can be provided with opportunities to work more closely both with villagers and each other.

5.5.3 Incentives and motivation for change

Farmers and researchers rarely consider fully the costs of environmental degradation. Farmers themselves may not be sufficiently aware of the costs on their own farms, or the damage that they are causing occurs on land other than their own and they do not bear the costs. In Cameroon many farmers do not regard soil fertility as a problem (despite a general consensus that in west Africa soil degradation is the biggest problem for the sustainability of agriculture), in part because there are still opportunities for more extensive slash and burn agriculture (Sanchez, 2000). Similarly, researchers developing new approaches to crop intensification or pest management, for example, may not take into account environmental costs, as these may be cumulative over time, external to the individual farmer, or resources may be priced at below their “social cost” (subsidized water and electricity).

Ultimately, farmers are more likely to undertake long-term investments in improving the resource base on their farms if they face the true cost of any environmentally destructive practice (polluter pays principle), if they produce cash crops and have good access to markets for outputs and inputs, access to credit, and access to extension services (Reardon et al., 1995). Machakos in Kenya is a much cited example of an area where land degradation has been reversed and agricultural production increased, despite increases in population. Factors that contributed to this success include good transport infrastructure to markets, secure land tenure, and above average rural education and health (Toure and Noor, 2001).

Unless the full costs of environmental degradation and resource exploitation to farmers themselves (on-farm degradation), to the community (degradation of common pool resources such as forests), or to other sectors (pollution of down-stream water supplies) are quantified (both for current practices and proposed new practices) it will be difficult to persuade policy makers or farmers to adopt technologies and approaches that reduce the degradation.

The enabling and institutional environment is particularly important with respect to increased water exploitation. For farmers to choose to adopt efficient water techniques, not only must they be affordable for farmers, but appropriate institutions and incentives need to be in place, and farmer motivations and the links between water use and soil fertility better understood.

In the long run, realigning farmers' incentives over their water use is essential for improving water efficiency and water equity. This entails appropriate mechanisms for allocating water – whether pricing, allocation of property rights, regulation, social pressure, or negotiation. The appropriate approach in a particular country will depend in part on existing institutions, the ability to enforce rights through formal systems, and social cohesion within a particular area. Market mechanisms are one approach to improving the efficiency of resource use by ensuring that users pay the true cost of their actions (making the polluter pay; charging for water taken from rivers or aquifers). However, given that many farmers in Africa are poor, there are considerable equity issues to be considered. Further, the costs of establishing and monitoring such market institutions could be high. Ensuring the appropriate institutions also entails ensuring that farmers are able and willing to choose water-efficient technologies and drought-resistant plants. Hence issues of risk and risk aversion, and access to credit are relevant.

A key problem to tackle with respect to improving water efficiency in agriculture is that typically individual farmers do not currently bear the true costs of the water that they use (many of these costs are externalities to the farmers), whether in terms of resulting downstream pollution, or in terms of taking water away from other more socially efficient uses. When water is relatively readily available this is not a problem. However, all forecasts are that water scarcity will become an issue in SSA in the future.

There is a natural tension between water for agriculture and water for ecosystem services. For example, farmers taking upstream water may harm downstream ecosystems. If water is free at the point of access as it typically is in SSA –farmers can pump water from an underground aquifer or divert water from a river without paying for the water – then farmers will typically use more water than is socially efficient because they do not have to bear the costs of the water use – these costs are borne by the downstream communities and ecosystems. Moreover, farmers will likely not have an incentive to adopt relatively costly but efficient drip irrigation or water harvesting techniques. In these circumstances efforts to increase productivity through the greater exploitation of water may be at odds with the assessment goals with respect to ecosystems and biodiversity. Yet more efficient water use also requires markets other than those for water to function efficiently. For example, farmers may need access to credit to afford more efficient water harvesting and water use technologies, access to insurance if they are exposed to higher risk, or better access to markets given expected increased outputs and higher input costs. South Africa has explicitly addressed the problem of competing claims for water between agriculture, industry, human use and ecosystems by introducing a "reserve for the environment" in the 1998 National Water Act that reduces available water for other uses by 15-20% (Inocencio, Sally, and Merry, 2003).

Typically in SSA, there are few formal mechanisms for allocating water efficiently among different users and needs, though local and traditional mechanisms naturally tend to develop, at least among farmers, as water scarcity increases in the absence of formal rules. If these local mechanisms are ignored, the likely result will be conflict and a reduced likelihood of any new initiatives working. For example, in Tanzania there has been a focus on the use of the statutory legal system to allocate water that ignores the plurality of systems operating in the country and the prevalence of customary arrangements, which has resulted in conflicts between traditional water users and new water regulations (Maganga et al., 2004).

Approaches to "internalizing the externalities" associated with water use include pricing (such that the price reflects the marginal benefits to different users – though tricky to implement, even in richer countries), regulation (such as assessing and regulating environmental flow requirements to sustain specific ecosystems and the services that they provide), allocation of property rights enabling private markets to develop, and negotiation. Without changes in the current system (water typically being free at the point of access for those with de facto access rights), the appropriate incentives for farmers to adopt more efficient water technologies will not be in place, and water will continue to be used inefficiently. That is, getting the regulatory and institutional environment right is critical before attempting to introduce new technologies. There are also equity considerations – poorer households may simply not be able to afford water if it is priced at its true cost.

5.5.3.1 Fiscal incentives

In South Africa, the 1998 National Water Act attempts to balance efficient and equitable water allocation using what is termed a pro-poor “some for all” approach. Improving the productivity of water use in the agricultural sector – the biggest user of water – was seen to determine the extent to which the efficiency, equity, and sustainability objectives could be reached (Kamara and Sally, 2004). In 2000 the government decided that households would receive 6000 liters per month free. Remaining water would be allocated to domestic uses such as small-holder livestock and small-scale gardening. After these needs were fulfilled, compulsory licensing was introduced to allocate water among other needs including larger-scale agriculture and forestry. Further, rather than considering conventional measures of agricultural water productivity such as “crop per drop” or “monetary value per crop”, other measures are included such as “jobs per drop” (Kamara and Sally, 2004) (Box 5.4).

[Insert Box 5.4]

Whether pricing, regulation, property rights, or negotiation is chosen as a route to allocating water in a more efficient (and possibly equitable) way, a better understanding of the value of water for different competing users is required, as is research into new institutions for allocating water more efficiently and thereby creating appropriate incentives for farmers to adopt water-efficient technologies. Most likely this research will recommend changes in access to water, either through pricing or regulation. But it must also link to technology developments such that the conditions for farmers to adopt the technologies are appropriate.

A lack of credit and risk sharing institutions reduces the likelihood that farmers will adopt technologies that conserve the natural resource base. In SSA rainfall is highly unpredictable, resulting on average in complete crop failure once every ten years in semi-arid lands. Farmers are typically unable to insure themselves against the risky environment within which they farm and so would benefit from technologies that reduce the risks of farming such as improved water harvesting techniques. However, farmers also often lack access to credit to make such investments, and taking on debt also increases farmers’ risk. Hence in parallel to introducing new technologies for water management and harvesting, credit, insurance and other risk-sharing institutions would improve the enabling environment for farmers and increase the likelihood that they would be willing to adopt the new technologies.

Farmers in SSA typically need improved access to credit and microcredit is relatively well established. However, most is provided through NGOs and may not be sustainable without the injection of funds to cover the relatively high administrative costs. Recently, commercial retail banks have become involved by providing capital to organizations at commercial rates that then provide the microcredit directly to farmers. This involvement of commercial banks may offer a more sustainable longer-term route for providing capital for microcredit. Although in the literature there is a focus on microcredit, access to formal credit is and will remain an important issue for larger-scale farms. The use of formal credit requires banks to be willing to supply the credit, which is more likely to occur in an institutional environment where farmers have collateral (such as land or fixed assets), property markets are efficient (such that land and property offered as collateral has sufficient value to the bank), and there is an efficient and effective legal system that enables banks to take action if farmers default.

Weather insurance is mentioned in the literature as a potential mechanism for reducing farmers' financial exposure to highly variable rainfall and hence crop yields. However, problems of moral hazard (farmers may put less effort into their farming activities if they are insured against losses), the difficultly in monitoring farming effort and output, the problem that negative weather shocks to farmers tend to be correlated, and the possible unwillingness of farmers and likely inability of poor farmers, to pay the insurance premiums, mean that the provision of crop insurance is likely to be limited. So far, weather insurance has not been successful (Dercon et al, 2004). However, some initiatives are being piloted by the World Bank in SSA and Latin America that payout depending on rainfall rather than crop output, thereby eliminating moral hazard (Devereux, 2003). Such insurance may be more relevant to drought than to climate variability, and the problem of covariance remains (if one farmer is negatively affected the likelihood is that most farmers in the local will be), suggesting that private companies may not be willing to provide such insurance (Devereux, 2003).

5.5.3.2 Land tenure

In many SSA countries, inadequate land tenure structures are perceived to be a major obstacle to sustainable agriculture, rural development, and equitable access to resources. In general, exploitation (and over-exploitation) of natural resources is inextricably linked to the institutions surrounding access to land, pricing, and regulation. Land reform has often been cited as an approach to reducing environmental degradation (in addition to other benefits) – a way of allocating property rights such that individuals internalize the negative impacts of their actions on the environment, so that farmers can access credit for appropriate investments in managing soil and water, and so that farmers have the confidence to make these investments without concern that they will lose access to the land. However, local institutions have evolved in SSA in response to the lack of formal property rights over resources and need to be understood in this context before costly land reform is undertaken.

Long-term investments in natural resource management have been found to be correlated to secure land tenure and short-term investments to insecure tenure, suggesting that formal land titling would benefit the adoption of investments in natural resource management (Gebremedhin and Swinton, 2003). However, land tenure reform alone rarely brings all the hoped for benefits. Land titles have also been shown to have little impact on reducing environmental degradation and there is plenty of evidence in the literature that land titling does not in crease credit transactions, improve production, or increase the number of land sales (Seck, 1992; Melmed-Sanjak and Lastarria-Cornhiel, 1998). Indeed, many benefits from land titling appear to be offset by increased risk of small holders losing their land if titled, high transactions costs of titling land, the reality that with or without title, small farmers rarely access formal credit, and that rural land has little value as collateral to financial institutions.

Indeed, it is not necessarily formal land tenure per se that is important for farmers’ long-term investments, but whether individual farmers perceive their claims to the land that they are farming to be sufficiently secure to make the required investments. That is, secure land tenure is important for providing an appropriate incentive for farmers to adopt technologies that, for example, enhance natural resources, but this security can be obtained without formal land titles. However, women’s weaker rights to land and tenure security do appear as a constraint to meeting sustainability and development goals and more research is needed into how land tenure systems and property rights can be developed that benefit women and minority groups such as pastoralists.

Another impact of formal land titling could be that farmers have an opportunity to consolidate land holdings through buying and selling land, thereby increasing the average size of land holdings (Scott, 2007). In Tanzania the area of land used by individual households has leveled off over the past decade to approximately 2 hectares per household, though over three quarters of households farm less than two hectares (Nagayets, 2005) – in other countries including Lesotho, DR Congo, and Ethiopia, the area per household is decreasing (Nagayets, 2005) making it increasingly difficult for individual farm households to commercialize. If land holdings in SSA do start to be consolidated, understanding and dealing with increased rural unemployment and rural-urban migration will become particularly important.

5.6 Crop and Livestock Diversity

Two types of agricultural biodiversity are identified by the Convention on Biological Diversity (CBD): a managed portion that is manipulated by people for their own needs; and an unmanaged portion such as soil microbes, natural enemies, pollinators and their food plants that supports production (Biodiversity International, 2007). Farmers naturally play a role in conserving agricultural biodiversity, a role that can be exploited and incorporated into more formal conservation approaches. However, there is a general consensus that agricultural intensification has been accompanied by decreasing agricultural biodiversity. Industrialized agriculture has tended to promote a small number of species, and scientific research has typically been focused on these species (MA, 2005; FAO, 2002b), resulting in a decline in genetic diversity for agricultural crops.

Genetic erosion of indigenous germplasm for both forage and livestock species is increasing in SSA. This is of particular concern for the region because many countries have a wide range of crops that are considered relatively unimportant on a global level, but are important as local staples (Engels et al, 2002). Further, over 95% of Africa's ruminant population is indigenous, supporting the majority of small-holder rural farmers for whom these genetic resources are critical as a source of food, income and secure form of investment. The causes of this genetic erosion include human population growth, increased pressure for land development, urbanization, climate change; and controlled breeding and development of livestock breeds with a narrow genetic base to meet the demands of modern production systems. There also appears to be a loss of local and traditional knowledge concerning species diversity, including loss of local language terms, in part a natural consequence of changes in cropping systems.

There are two key linked responses for conserving agricultural biodiversity, as identified by the Millennium Ecosystem Assessment and recognized elsewhere: in situ conservation (conservation of important genetic resources in wild populations in natural habitats, whether farmer fields or within existing agroecosystems), and ex situ conservation (conservation of genetic resources in off-site gene banks).

5.6.1 Safeguarding and maximizing potential of genetic resources

Changing climatic conditions, the importance of livestock in SSA, clonal propagation, and the high costs of ex situ conservation suggest an emphasis on in situ conservation to be most appropriate for SSA. In situ conservation is essential for conserving animal genetic resources, and most relevant for hard to store tropical species and for those that are clonally propagated, and therefore particularly relevant to SSA. It also helps maintain evolutionary processes (preserving the process of crop evolution) and may have a positive impact on equity (Brush, 1992; Meilleur and Hodgkin 2004; Jarvis et al, 2000; FAO, 2007). Although ex situ collections substitute imperfectly for the evolution of crops on farmers' fields, storing genetic resources as back-up seed stocks in ex situ collections is a key element of conserving genetic diversity (Drucker, 2005). However, ex situ collections are costly, involve considerable losses, and – due to climate change or genetic drift – genetic resources held in long-term storage may no longer be suitable for cultivation in the areas where they were collected (Biodiversity International, 2007). Specific challenges for Africa include the difficulty of storing many tropical seed species (Pardey et al, 1999), and that many crop plants are clonally propagated. Additional issues include how to ensure sufficient long-term and reliable funding; how to ensure sharing (in particular with IPR issues and the involvement of the private sector); and how to ensure that biodiversity being protected today is relevant to predicted climate changes (for example, drought-resistant varieties are likely to be more important in many parts of SSA in an environment of climate change).

Genetic resources have public good characteristics – farmers who cultivate crops and keep livestock with valuable genetic traits do not reap the full benefits of their conservation efforts, suggesting that the private on-farm provision of genetic resources will typically be lower than optimal (Brush, 1992) and that therefore there is a role for government.

Governments can intervene in genetic conservation in a number of ways that include setting up protected areas where human activity is excluded or limited; subsidies to particular agricultural sectors or direct payments to farmers; empowering villagers to conserve species diversity at the community level, such as in community forests; and developing markets and creating market incentives. These interventions can broadly be divided into market and non-market interventions and each has different implications for funding and sustainability of that funding. Subsidies for particular sectors or direct payments to farmers do not naturally respond to evolutionary changes and are susceptible to rent seeking behavior and so are not considered further in this assessment. Protected area systems that exclude human activities have been established throughout many countries in SSA, although the reality of many is that they are simply "paper parks," where little enforcement occurs due to lack of funding and so degradation and loss of diversity is prevalent. Yet, where protected areas are effective at keeping out people, nearby communities are often harmed as they tend to rely on common areas of land, particularly forests, for nutrition and livelihood activities.

The Millennium Ecosystem Assessment (MA, 2005) concluded that working with local communities is essential to conserve biodiversity in the longer term. A number of prerequisites are required for in situ conservation, particularly with respect to common pool resources (such as village-level forests). Well-defined property rights in favor of local villagers (land tenure security), or at the least legal recognition of the villagers as forest managers, are a pre-requisite for getting villagers to participate in protecting the nearby village forests and hence the genetic diversity contained within the forests (Wiley, 1997; Wiley et al., 2000). Participatory rural appraisals can help decision makers and local communities with communally owned land to determine their own priorities for tree genetic resources and thereby increase the likelihood of successful community in situ conservation responses (FAO, 2007). Although in some countries and some cultures social norms protect common resources – for example sacred groves are often respected by local communities and not used for extractive purposes – typically enforcement activities are required, whether undertaken by villagers or the government.

At the individual farm level, governments can help to develop institutions and policies that create incentives for local in situ conservation of agricultural diversity. This will be particularly important if farmers increasingly purchase limited varieties rather than using retained seeds. Specific options include the development and promotion of markets including specialty markets that attract premium prices.

The conditions for ex situ collections can be improved through better funding, investigation into new storage technologies, and prioritization. The current understanding of the costs of maintaining ex situ collections and the use of materials from these collections is limited. Key actions that are required therefore include exploring new technologies to improve the possibilities for ex situ conservation policy and methods. Because of the high cost of ex situ conservation, priority setting and sub-regional collaboration to pool resources and expertise and avoid duplication is seen as essential (Biodiversity International, 2007).

The System-wide Genetic Resources Programme (SGRP) of the CGIAR is a new facilitation unit that aims to promote and facilitate research collaboration worldwide so that biodiversity in agriculture can play a much greater part in sustainable development. BioNET is an international not-for-profit initiative that aims to promote taxonomy, particularly in biodiversity rich but economically poor countries, working with local partnerships – LOOPs. Other coordinating mechanisms, like Tree of Life, coordinate research, without the strong emphasis on local capacity development.

Livestock diversity is a particularly important aspect of agricultural biodiversity in SSA. Conserving livestock biodiversity is costly and complicated, and hence priority setting is critical in an environment of limited funding. Ex situ conservation is not practical for conserving animal genetic resources, hence the focus must be on in situ, with a priority being to conserve diversity across species and breeds or strains given that as yet there are no validated breed definitions across species and insufficient application of standardized evaluation protocols for genetic or phenotypic studies in Africa (Wollny, 2003). Measures of breed genetic distances and conservation costs are lacking for many species/breeds (Drucker et al., 2005), and there is little information on the population sizes of existing indigenous animal genetic resources (AGR) and the changes in the sizes of pure breeding herds/flocks over time in most SSA countries.

Characterizing livestock diversity will offer insights into genetic relationships that help ensure that conservation maintains the greatest amount of diversity. Because livestock diversity is being lost relatively rapidly, both short-term and long-term strategies are required. In the short term, rapid surveys and the estimate of population sizes by species and breed, with the identification of distribution patterns within agroecological zones can provide initial information for policy makers to obtain an overview of the national livestock herd and formulate initial plans to conserve the existing farm animal populations in their habitat (Wollny, 2003). Inadequate valuation of livestock genetic resources may be contributing to genetic erosion, suggesting the need, therefore, for national policies that promote and enable the valuation of genetic resources in order to provide appropriate incentives, and to support efficient allocation of funds for in situ conservation (Wollny, 2003).

In the long run, breed genetic distances and conservation costs and phenotypic data are required, including biological, performance, and economic data and molecular information. Molecular genetic technology and GIS are techniques that can provide information on unique traits and population dynamics.

The development of policy decision-support tools has been proposed as part of wider AnGR conservation and sustainable use projects in Africa and Asia that are being funded or considered for funding by BMZ (Germany) and the Global Environmental Facility (GEF). However, such tools have not yet been implemented and so their effectiveness is not known.

Sub-Saharan African livestock breeds will most likely only be conserved as a result of their adaptation and commercialization. This commercialization can be in terms of the end product – meat and livestock products – or in terms of the livestock genes. Once biotechnology has derived identifiable products from indigenous farm animal resources, commercialization of genes will become a possibility and the discussion of intellectual property rights – and hence the potential for revenue generation– will be made possible (Wollny, 2003). The different possible interventions need to be prioritized, taking into account the cost-effectiveness of each intervention, and market possibilities, thereby enabling a framework to be developed for the marketing of indigenous livestock and products. It is also important for systems to be developed that monitor and control the importation of animal germplasm, given the possible negative impact on diversity of cross-breeding.

Community and village breeding schemes have not been well documented, resulting in insufficient information on how farmers make livestock selections and the cost of community-based solutions to genetic erosion. Site-specific approaches taking into account the specific resources and constraints are most likely the only sustainable solutions (Wollny, 2003). And prioritization can only occur if there is adequate monitoring of changes in genetic diversity. Biodiversity International (formerly IPGRI) is increasingly working with local communities to encourage in situ conservation.

5.6.2 Managing agricultural and wildlife diversity

The conservation of wild biodiversity in SSA is threatened by the negative interaction between wildlife and agriculture. Farmers typically bear the costs of damage from them, such as the destruction of field crops by elephants, without gaining any of the benefits from the wildlife. Farmers' natural response is often to reduce the costs that wildlife impose on their livelihoods by killing the wild animals that cause damage. There are a number of options that can reduce conflict between agriculture and wildlife and therefore minimize loss of wildlife and wildlife biodiversity. These options include keeping livestock and wildlife apart using physical barriers; paying villagers compensation for damage done to their crops and livestock; and "internalizing the externality" such that farmers bear the costs of wildlife damage but also get control over and therefore benefits from the wildlife and so have an interest in their conservation. Giving the property rights to the local community to manage the resource also provides a mechanism through which outside agencies concerned with biodiversity conservation can negotiate with the community, and through which the community can have the legal backing to protect the resource from ''outsiders'' and thus derive the benefits from them (MA, 2005).

The use of physical barriers around protected areas is used in some specific areas but tends to be highly costly, not always effective, and can have negative impacts on the ecological equilibrium of a region, including interfering with natural migration routes. An alternative, less costly barrier approach is for individual households to fence their homesteads, putting their livestock in corrals overnight (Distefano, 2005). Whether households would adopt coralling depends on the costs, perceived benefits, and cultural norms.

Financial compensation tends to be highly contentious, rarely effective in practice and depends on external funds. In theory there are compensation schemes in Kenya, but no payouts have been made since 1989, and the official compensation rates are insufficient to cover most costs of damage by wildlife (Distefano, 2005). Paying compensation for wildlife damage does not guarantee that wildlife will be optimally managed, that farmers will refrain from killing wild animals, or that farmers will be honest about the extent of damage by wildlife, and so in tandem with such payments are required conservation incentives and a monitoring and enforcement system (Wells, 1992; MA, 2005).

Schemes that pay compensation or involve communities in wildlife protection are likely to be undermined where property rights are weak. Without strong property rights, farming communities are unable to restrict external access to wildlife; and have little incentive to adopt long-term strategies to manage these resources (MA, 2005). For example, in the francophone territories in West Africa, forest residents have no authority and hence no ability to restrict the exploitation of game by ‘‘outside hunters’’ (MA, 2005; Bowen-Jones et al., 2002), and so any schemes to compensate the local community for wildlife protection would be rendered ineffective.

Devolving responsibility and control over wildlife is being undertaken in a number of countries. In Ghana, encouraging local community management of wildlife resources has involved the proposal that the government Wildlife Division devolve property rights over wildlife to certain local communities, thereby providing an incentive for the community to conserve and manage the natural resource base as the local community now has hunting rights to the wildlife, also an important source of animal protein in their diet (MA, 2005). It is too early to determine whether or not this approach has been a success in terms of reducing farmer-wildlife conflict and improving wildlife numbers and diversity. In Tanzania, community wildlife management strategies feature in the 1998 Wildlife Policy in which locals are granted usufruct rights to the wildlife (Nelson, 2007). In practice, however, there appear to be political and institutional conflicts over the control of the resources, in part a consequence of poorly implemented devolution processes (Nelson, 2007).

The most successful and well-documented cases with respect to improving wildlife conservation and reducing conflict with farmers in SSA come from Southern Africa, particularly the dry savanna zone, where property rights over wildlife are well defined and enforced and where the tenurial context is much more favorable (MA, 2005). The best known is CAMPFIRE, Communal Areas Management Programme for Indigenous Resources, in Zimbabwe. In South Africa, animal viewing and hunting tourism has resulted in 18% of farmland being converted into game ranches that allow local people to capture non-local values (Heal, 2002; MA, 2005). Wildlife conservation has also increased on the remaining farmland because farmers have property rights to capture wild animals found on their land and sell them to game ranches rather than kill them (Heal, 2002; MA, 2005).

Two key lessons emerge from the literature. Without well-defined and enforced property rights, it is difficult to implement sustainable strategies for the conservation of wildlife where there are natural conflicts between wildlife and livestock and crops. This implies that community-based wildlife management cannot be introduced as a project or as part of a technical assistance package, but needs to be embedded in institutions that build local rights to control and access nearby resources (Nelson, 2007). Further, villagers are unlikely to have the incentive to be involved in community-based schemes unless the wildlife are sufficiently valuable or the villagers are otherwise compensated. In East and Southern Africa there are many charismatic wildlife species that have sufficient value to outsiders, whether for tourism or so called “trophy hunting”. The challenges are greater in West and Central Africa where these outside sources of revenue are not available. Indeed, wildlife management options that have proven successful in the savannahs of East and Southern Africa may not be applicable in West and Central Africa (Bowen-Jones et al, 2002). Finally, in situations where villagers’ incentives cannot be aligned with conserving key species, and for species where even low levels of off-take may cause loss of populations (most likely for large-bodied charismatic species such as gorilla and elephant), such that even ‘by-catch’ is a problem, separation of people and wildlife and strict enforcement may be the only option (Bowen-Jones et al, 2002).

5.7 Forests and Agroforestry

Rural populations rely heavily on forest resources that can complement or substitute for food and income from agriculture. Large and small-scale enterprises extract timber and local communities collect both timber and non-timber forest products (NTFPs), including building materials, fuelwood, charcoal, bushmeat, fruits and vegetables, of which fuelwood is particularly important in SSA. Playing multiple roles, forests also provide ecosystem services and support the conservation of biodiversity. Agroforestry has the potential to offer wealth-creating opportunities for individual households and communities and also provide alternative products from natural forests, and so its development has the potential to take the pressure off of the natural resource base and reduce environmental degradation while also improving livelihoods. In SSA there is a broad range of tree species that are suitable for domestication and commercialization (Leaky, 2001). Yet forests in SSA are typically poorly protected and therefore over-exploited, and budgets allocated to develop the agroforestry sector in SSA tend to be small, particularly so in countries with significant tracts of natural forest that are being rapidly exploited, such as in DR Congo, Gabon, Cameroon, and Congo-Brazaville.

Many of the institutional challenges for natural forests and capture fisheries in SSA are similar and revolve around the challenges of developing institutions to manage common pool resources.

Forests are often over-exploited because property rights have not been allocated, or because these property rights are not enforced, resulting in the forests being treated as de facto open access resources. But defining, allocating, and enforcing property rights is costly and so governments need to determine the most cost effective approach. They also need to take into account equity considerations, particularly where local communities have relied on these natural resources.

A typical situation in SSA is that the government owns and controls most of the forested lands and villagers living near these forests do not have legal right to use them or to extract resources from them. The government does not have funds and villagers do not have incentives to protect the forests, and so a classic de facto open access situation arises in which villagers collect from the forests with few institutions in place to ensure sustainable use of them. The forests degrade and villagers must spend more time collecting ever more scarce resources, venturing further into the forests and causing more environmental damage. Recognizing this reality of poor management and enforcement, a number of countries are introducing participatory forest management (PFM) in which local communities are given some level of control over the forest resources. For example, in Tanzania, depending on the forest classification, villagers might only be responsible for protecting the forest with few direct benefits in return, or might be given full control over a forest, including rights to extract timber and non-timber forest products, and to exclude outsiders from using the resource (Robinson, 2006). To enable PFM, national laws governing forest ownership and access typically have to be changed. In Tanzania, the 1998 National Forest Policy and the Forest Act of 2002 have enabled PFM to be introduced (MNRT, 1998, 2002a, 2002b). The factors that determine whether or not PFM is likely to be successful have not been assessed rigorously. However, PFM is more likely to be successful if the community receives sufficient control over the resources and benefits to make engaging in the process worthwhile. If communities are sufficiently well informed, PFM activities are based on traditional management systems and PFM is seen as a priority by the community, the chances for conservation increase.

5.7.1 Creating market incentives

Certification tends to be seen as appealing because certified timber can attract higher prices and access to premium markets in richer countries. However, certification requires significant organizational and technical expertise from the producers and direct costs in obtaining certification; there is some evidence that although certified producers gain market access, higher prices are typically not realized (MA, 2005; Belcher and Schreckenberg, 2007). Further, certification is largely document-based, and is predicated on formal, structured means of planning and monitoring, and so is biased against traditional societies and the complex land use systems of indigenous and community groups (Bass et al. 2001; Eba'a and Simula, 2002, MA, 2005). This far, less than 1% of certified forests are in SSA, with over 90% in Europe and North America (Schulte-Herbruggen and Davies, 2006). Therefore, although there remains scope for certification, the potential in the short to medium term in SSA remains small.

A number of innovative market-based options for improving the contribution of agriculture to the assessment goals are little tested in SSA. These options, some of which are addressed below, could be important over the next decades, particularly for the forestry sector, though their likely contribution is as yet unknown.

Payment for environmental services (PES) schemes are part of a new and more direct conservation paradigm that explicitly recognizes the need to bridge the interests of landowners and outside beneficiaries through compensation payments. PES schemes exist mainly for four services: carbon-sink functions, hydrological protection, biodiversity, and landscape aesthetics/ecotourism. Conditionality – only to pay if the service is actually delivered – is the most innovative feature of PES when compared with traditional conservation tools, but also the one which real world initiatives struggle hardest to meet. New markets for environmental services and approaches in SSA are few and although there appears to be interest and potential for PES there is little evidence to measure its impact.

Although only afforestation and reforestation projects are eligible for credit under the CDM during the first five-year commitment period of the Kyoto protocol, soil carbon sequestration and broader sink activities could become eligible in the future. The CDM involves African countries in selling or trading project-based carbon credits with more industrialized countries thereby combining increased carbon sequestration in agricultural soils with reducing soil degradation, improving soil quality, and preserving biodiversity. However, as yet there is no data concerning the potential for soil carbon sequestration in Africa, suggesting long-term field experiments and pilot projects are needed.

Agroforestry offers multiple benefits for farmers and the broader landscape that are not always clearly articulated in agricultural initiatives. Three key benefits are improvements in soil fertility, provision of animal fodder, and the supply of poles, timber, and fuelwood that both benefit households and reduce the pressure on natural forests (van Noordwijk et al., 2004; Young, 1999). Additional benefits include improvements of microclimates, enhancing water conservation, and the production of non-timber forest products including tree fruits. However, although the high demand for home-consumed fuelwood can in part be compensated for through tree planting and agroforestry, in many countries in SSA the demand for charcoal comes from urban areas (MA,

2005; SEI 2002; Ninnin 1994). Agroforestry may have particular potential in dryland areas of SSA which have until recently been relatively ignored by research and development agencies (Leaky, 1999; Roy-Macauley and Kalinganire, 2007).
A cluster of challenges have been identified by a number of organizations and working groups including the Southern African Regional Agroforestry 2002 conference. These challenges include the emergence of second generation issues such as pests and diseases, declining investment from national governments, lack of improved planting materials, weak linkages with the private sector and therefore markets for agroforestry products, and uncertainties over climate change, biotechnology, and globalization (Roy-Macauley and Kalinganire, 2007). Further, men and women in SSA typically prioritize different agroforestry products and so are likely to have different preferences for tree varieties and management practices.

In SSA, unlike, for example, South-East Asia, markets for non-timber forest products are small (Leakey et al., 2005). There is currently little value added with respect to products from natural forests and from agroforestry, in part because of the lack of focus on post-harvest issues including processing and certification, in part because of poorly developed domestic and international markets. There are opportunities to expand market opportunities locally, regionally and internationally that would provide incentives for the development of agroforests. In most of SSA (with the exception of East Africa), many of the potential tree products have potential use in the growing ethnic food industry in Europe and the US (Leakey, 1999). East and southern Africa have the greatest potential to produce indigenous medicinal products for a worldwide market (Leakey, IFR). Increasing market opportunities increases the scope for private sector involvement in research (Leakey, IFR).

5.7.1.1 Forests and energy

Men and women in SSA typically prioritize different agroforestry products and so are likely to have different motivations for adopting particular agroforestry innovations (Gladwin et al., 2002). For example, men are more likely to plant trees in croplands whereas women typically plant trees for fuelwood (Gladwin et al., 2002), reflecting women's role in collecting fuelwood for cooking and heating. Women, are likely to benefit significantly from research into rapidly growing tree species that supply fuelwood whereas men might be less likely to support research into fuelwood but more likely to support the development of revenue-generating species. One approach is to identify trees with multiple purposes that can be introduced into an agroforestry system. For example, fruit trees offer market opportunities for farmers, if markets are available for the output, and can improve households' nutritional status.

A number of preconditions enable the scaling up of agroforestry research and extension: national and regional peace and security; good and transparent governance; demand for products and market access; sound national and global economies; legislation regarding intellectual property rights; an active process of democratization; functional rural infrastructure; decentralization of decision-making; and resource availability (Cooper and Denning, 1999). International efforts will aid scaling up (Leaky et al, 2005) such as developing skills for domestication of indigenous species, processing and storage, and expanding community training.

SSA countries meet more than 50% of their total primary energy consumption from biomass which predominantly consists of unrefined traditional fuel such as firewood and crop and animal residues. Use of biomass as a source of energy in its traditional forms results in inefficient energy conversion, environmental and health hazards, is time-consuming in terms of collection, and contributes to the degradation of forests. For example, in Tanzania, over 80% of energy consumption is fuelwood.

AKST has played a role in improving traditional bioenergy technologies, such as in the design and supply of efficient cooking stoves. However, so long as fuelwood is free to collect from nearby forests, poor villagers are unlikely to pay for fuel efficient stoves, even when these villagers, predominantly women and children, spend many hours each week or even each day collecting it. Therefore, in the short to medium term, the pressure on forests is more likely to be reduced through the development of village and individual woodlots.

Some SSA countries, e.g., Malawi, South Africa, Ghana, Kenya, Nigeria, Benin and Mauritius have initiated programs for cogeneration of electricity and heat and the production of biofuels from biomass. The supply of bio-electricity to rural households and rural enterprises is particularly important in rural areas where communities are not connected to the national grid. Saw mills in countries including Tanzania are already using some residues for power and cooking though much is burned thereby causing air pollution. Some residues could be converted to charcoal, and heat gasifiers are relatively simple, though electricity generation is more complex.

Any strategy to promote biofuels needs to be aware of the pressure to expand onto forested and marginal lands, which has the potential to create competition for water, and displacement of people. Large scale monocropping could result in biodiversity loss, soil erosion, and nutrient leaching. Many biofuels benefit from economies of scale and so the benefits of biofuel promotion could bypass poor farmers. To include small-scale farmers requires effort to, for example, supply them with seeds and identify biofuel crops that are appropriate for small areas of marginal land.

5.8 Fisheries and Aquaculture

The poor in SSA are highly dependent on marine and inland capture fisheries and fish from aquaculture for their protein requirement and for their livelihood; fish protein constitutes about 22% of overall animal protein. Inland fisheries (lakes and rivers) have played a particularly important role in meeting the increased demand for fish in SSA and currently supply the majority of fish consumed in many SSA countries.

Rural fishing communities in SSA generally have a higher percentage of people living below the poverty line than the national average (Whittingham et al., 2003), Catch levels are generally above their maximum sustainable yield levels which further exacerbates the loss of economic rent from the fishery, increases poverty and loss of livelihoods and decreases food security. (Fisheries Opportunities Assessment. 2006). Increasing demand for fish, and the relatively low levels of investment required to earn at least enough to feed a family, is likely to attract new entrants into fisheries. Indeed, in 1996, the FAO estimated that artisanal fishing on the continent had doubled in the past decade and that most freshwater fisheries were intensively exploited (FAO, 1996).

Aquaculture has the potential to improve livelihoods and reduce the pressure on capture fisheries yet so far has been under-exploited. Although the practice has been around since the 1850's and 1920's in South Africa and Kenya respectively, aquaculture is fairly new to many SSA countries. Therefore, unlike in other regions, aquaculture currently makes a very small contribution to total fish production and capture fisheries will, at least in the short to medium term, remain key in SSA. In many SSA countries, capture fisheries have ill-defined use rights. The resource is usually owned by the state but managed as a "regulated open access", meaning fishers can harvest any quantity of fish if they comply with regulations set by central or local authorities (Akpalu, forthcoming). This typically results in over-exploitation.

It has been argued that community-based resources are not generally overexploited as predicted by Hardin's "tragedy of the commons". However, if the group using the resource is relatively unstable, if the members of the group do not have adequate information about the condition of the resource, and if information about the expected flow of benefits and costs is not available at a low cost to the resource users, there may be little incentive for the community to design rules to manage the resource optimally (Ostrom, 2000). The situation is exacerbated as there is free mobility of fish stocks across communities and countries. Moreover, some fisheries are characterized by unpredictable seasonal growth rates due to upwellings.

In some cases, state institutions have enacted conflicting policies at different points in time, which inevitably created mistrust between the fisheries departments and fishers. Furthermore, inadequate policies by regulatory authorities provide opportunities for self-interested fishers to use illegal fishing technologies. For example, mesh size regulations in multi-species fishery, with small and large pelagic species, are considered illegitimate by many fishers and therefore heavily violated in many fishing communities (Akpalu, 2006.)

Moreover, capture fisheries regulations are generally poorly enforced as a result of limited state budgets of institutions responsible for enforcing the regulations, corrupt enforcement officers who solicit bribes from violators and unenthusiastic judiciaries that assign minimum or no punishment to violators of fishing regulations. Commercial fishers who use fishing vessels compete with local fishers for inshore fish stocks, degrade habitat and interrupt the fish food chain which often leads to conflicts and resultant loss of property (Sterner, 2003).

Knowledge of fish stocks and aquatic ecosystems dynamics is important for designing sustainable fishery management policies. Nevertheless, SSA countries lack the relevant data and as a result formulate ad hoc policies to address problems of complex fishery systems. A typical example of such an ad hoc policy is the use of a uniform mesh size regulation to curtail overexploitation of a multi-species fishery that is characterized by seasonal upwellings and transboundary movement.

Fishing regulations are required that cover both small-scale fishers and industrial fleets. However, with the limited budgets of state institutions responsible for enforcing regulations coupled with the widespread corruption among fishery officers and the fact that fishers consider some regulations illegitimate, paints a gloomy picture of the industry. Also state institutions in Africa are generally weak and unable to cope with the activities of industrialized fleet (Fisheries Opportunities Assessment, 2006). The judicial systems in most countries are reluctant to enforce fishery regulations, which they generally consider less important.

Although improved fisheries management has been called for, what is considered as appropriate fisheries management is highly debatable. In the past proper fisheries management has implied management for equilibrium production targets such as maximum sustainable yield, with measures to achieve these targets enforced by the state (Tweddle and Magasa, 1989; FAO, 1993). However, centralized fisheries management strategies on the continent, like equivalent systems in the North, yield little evidence of actually working, particularly in environments characterized by low levels of funding, low staff expertise, and poor technology.

In SSA it is not only that the necessary context for the adequate functioning of centralized management systems is absent, but also that the internal machinations of these systems appear to be flawed. As a result, new management styles are being developed to achieve a range of management objectives. Many of these advocate an increased participation of communities of resource users. A good example is the GTZ initiative that examines how the management of traditional fisheries can be enhanced to increase their production (Lohmeyer, 2002). Some of the benefits of this management style are that they reduce management costs, improve monitoring of the resources, are democratic, and promise greater regulatory enforcement than do centralized, state based management strategies. In general, the appropriate models to achieve better management will vary, as do the fisheries to which they are applied, and there is still little consensus on an appropriate model for managing Africa's fisheries.

Policy options that are available to address stock recovery may yield results in the long term, but in the short to medium term, depending on the state of the fishery, will require restricted access. But small-scale fishers who are generally poor have immediate needs, and so even though policies such as seasonal closure in the short-term yield increases in food availability, in the long run, fishers are usually reluctant to participate in implementing or accepting such policies (Akpalu, 2006). The provision of food subsidies to fishing communities in the very short run might be appropriate, followed by creating alternative employment opportunities and encouraging fishers to take up such opportunities in the medium term. After the fish stock recovers, the resource rent could be taxed to recover the food subsidy in the long run.

A key challenge is how to design a local or community based policy instrument that can address trans-boundary capture fisheries characterized, in some cases, by unpredictable seasonal stock growths. Due to the potential resource-use externality, any community based fishery management strategy including co-management, without inter-community collaboration, may not be accepted by fishers. Therefore, although it is important that management decisions are decentralized to communities with support from state institutions, communities must be encouraged to synchronize their institutions to minimize free-rider behavior

Aquaculture has the ability to complement wild fish production and thereby take some of the pressure off the wild stocks. SSA's Regional Economic Communities and NEPAD have prioritized aquaculture and are leading regional efforts to direct investments, with clearly defined roles for research and capacity building.

The development of aquaculture is challenged by the costs and technology required for certain aquaculture activities such as hatcheries and grow-out ponds for fish farming. Communities are also challenged by management costs (Ngwale et al. 2004). In some cases, there have been conflicts between aquaculture activities and fishing activities near shore. For example, prawn farming projects in Rufiji and Mafia in Tanzania have met with resistance as it was feared that clearing of mangrove areas to build ponds would cause erosion that could affect seaweed farmers and fishermen (Juma 2004).

There has been some success in aquaculture technology development based on local species, training of researchers and extension agencies, capacity support for producer organizations in small-scale fisheries and aquaculture, and knowledge support for policy makers and planners. Still, many challenges remain, including the need for post-harvest technologies, value chain and product development, regulations and standards for international trade, provision of information and training to potential farmers, provision of credit to farmers, the availability of fishmeal and fish oil for cultivation of the fish and how to mitigate the likely environment impact of semi-intensive aquaculture.

Integrated farming systems have the advantage of being relatively efficient at converting feeds into fish and typically have lower negative environmental impacts.
Aquaculture can have a potentially negative impact, particularly if wild-caught fish are used as feed, if coastal resources such as mangroves are converted to fisheries, or if excessive chemical inputs are used – intensive aquaculture requires the use of compound feeds, pesticides, and antibiotics the spillage of which into natural aquatic systems can negatively affect the ecosystems. Potential negative effects can be reduced through the use of integrated farming systems that avoid using human foodstuffs as an input to aquaculture, strengthening capacity for impact monitoring, and taking lessons from countries such as Thailand that have experienced considerable negative effects from intensive aquaculture. Effort can also be directed towards farming high valued fish such as tilapia, catfish and milkfish which have relatively low fishmeal and fish oil content ratios. However, there is some evidence that substituting vegetable protein for fishmeal may result in higher mortality rates and low rates of growth in several aquatic species and so further research is needed into this area (Delgado et al., 2003). Extensive aquaculture, which relies on natural stocking and feeding of the species, or intensive aquaculture that uses advanced technology to recycle water and other waste, can also reduce negative environmental effects.

5.9 Health and Nutrition

Agriculture and health are closely linked in sub-Saharan Africa. Malnutrition is increasingly becoming an urban problem and so the focus must be on both rural and urban areas. More specific options to target micronutrient deficiency includes increasing research into the nutritional value of local and traditional foods, particularly fruits and vegetables, the extent to which they contribute to diets, and the conditions under which farmers would cultivate and market these traditional food sources. Other options, particularly relevant to the urban population, include product development to increase the variety and quality of foods, including fortified foods, as well as targeted information campaigns to increase awareness and encourage the adoption of more nutritious foods. The empowerment and increased involvement of women can help to emphasize the development, adoption, and demand for more nutritious foods, such as orange-flesh sweet potato (Ipomoea batatas), rich in starch, dietary fiber, vitamin A, vitamin C, and vitamin B6. Given the contribution of agriculture to health and nutrition, a strategy of integrated planning and programming among ministries of health, agriculture, livestock, and fisheries, would provide opportunities for joint funding of and better synergies among programs.

Nutritional deficiencies are wide spread in SSA. The human diet requires that major macronutrients such as carbohydrates, fats and proteins are available for energy production, body maintenance and other physiological needs. In addition, diets require micro minerals such as iron, calcium, and iodine. Vitamin requirements are also crucial for human health. Deficiencies of major food molecules, vitamins and minerals leads to disease manifestations that include Protein Energy Malnutrition (PEM); kwashiorkor (deficiency of protein energy intake); niacin deficiency (pellagra); and Vitamin C deficiency (scurvy). Yet agricultural policies in SSA continue to emphasize primary agricultural production to the exclusion of micronutrient rich products. Such foods include fruits (of which consumption is lower in SSA than all other regions) and vegetables and local and traditional foods. As a consequence the potential for agriculture to improve the health and nutritional status of households in SSA has been reduced. There are a number of approaches to ensuring that individuals have improved diets. These approaches include research into the nutrient value of local and traditional foods, breeding crops that supplement micronutrients, and ensuring that individuals have access to relevant information.

Traditional food sources are diverse in SSA. What lacks is adequate research on the nutrient values of these various types of food and the extent to which they contribute to diets. There is also a long way to go on the promotion and popularization of traditional dishes. Many communities eat plant sources that have dual uses as food and also as medicine. Some research has proved the multipurpose use of various plants. *Moringa stenopetala*, for example, is deciduous plant, whose fresh cooked leaves are widely used in some western and eastern parts of Africa and the roots and leaves of the plant are used for medicine (Mekonnen and Gessesse, 1998). Food value analysis has shown that the leaves of the plant contain some valuable minerals like calcium and iron. A variety of infectious diseases deplete the human body from minerals and vitamins. Thus it is one step ahead if the nutrient value of traditionally consumed food items is popularized for inclusion in diets.

The empowerment of women in agricultural development strategies has been shown to shift the emphasis towards the development and adoption of more nutritious crops (such as orange-flesh sweet potato, Hawkes and Ruel, 2006). Establishing the needed infrastructure for research on the health value of foods is one strategy to address the problem of nutrition deficiencies. This requires the concerted effort of governments through NARS, health institutes and other related organizations within the continent.

An alternative approach to identifying crops with particular nutrients is to breed crops that supplement micronutrients. Biofortification is an innovative approach that links agricultural and nutritional scientists together to breed crops with higher levels of micronutrients. Examples of research being undertaken in SSA include the Africa Biotechnology Sorghum Project that is attempting to develop a “super sorghum” that is resilient to harsh climates, contains more essential nutrients, and is easier to digest when cooked (www.supersorghum.org). However, this approach is controversial. In part this controversy is due to general concerns in SSA over biotechnology, including its impact on health and the environment. Others feel that available funds could be better spent developing existing highly nutritious crops and improving general access to calories.

Individuals can be encouraged to consume a variety of foods with needed nutrients and micronutrients through the development of programs that encourage awareness and develop the habit of choosing foods for nutritional value. Awareness of better nutrition and health can be addressed through efforts such as developing country’s farm radio network, which disseminates radio scripts in local languages. The scripts are used as teaching and development tools by agriculture extension staff, teachers and community workers. The information in the scripts helps people to understand the conditions that contribute to the alleviation of poverty and hunger through possibly improved nutrition and better health conditions, thus giving the community the tools to take action for change.

In SSA millions of people succumb to tropical diseases such as malaria, tuberculosis and HIV/AIDS that exacerbate and worsen the nutrition status of the population. In many SSA nations, basic nutrition is not fulfilled. Some countries suffer from recurrent drought, forced migration due to conflicts and political instabilities. Malnourished children and the labor available for agriculture are heavily affected due to these unique problems.

In severely AIDS-affected communities of SSA there has been a change in the volume and kinds of crops produced in farming systems. Partly as a result of this, levels of nutrition are falling due to the reliance on starchy staples like cassava and sweet potatoes in Eastern Africa, compared with other more nutritious but labor-intensive traditional crops or protein from animal products. In addition there is lack of understanding of the nutritional value of foods. Lower levels of nutrition result in the increased vulnerability of people to disease and thus to an overall decline in health.

Studies indicate that better nutrition could play a role in prolonging life following HIV infection, and the nutritional status of people living with AIDS plays a large part in determining their current welfare with respect to morbidity (Haddad and Gillespie, 2001). People with endemic diseases such as malaria and tuberculosis also benefit from better nutrition.

At the crop and ecosystem level, nutritional intake is a function of the array of crop and livestock species available in the community basket. For example, researchers are increasingly curious about an apparent geographical convergence of the use of aflatoxin-vulnerable crops, groundnut and maize, and the severity of both malaria and HIV/AIDS in East and Southern Africa. Aflatoxins confer a short-term advantage on people through increased resistance to malaria, but can induce immuno-suppression, which may be linked to a weakening of the immune system even before infection by HIV (CORAF/WECARD, 2003). Therefore, cautious approach to adopting food items is important.

[Insert Box 5.5]

In working to assess the nutritional status of a community, it is important to decide on the objectives of the assessment, how the analyses will be done and what actions are feasible. It is important to draw from experience and to design the most appropriate data collection exercise. For example, in an assessment in a large, newly established refugee camp, it might be advisable to collect more than just anthropometric data; in the past, when nutritional status in refugee camps was judged only on anthropometry, deficiency diseases such as scurvy and pellagra were missed.

In many countries, large and expensive surveys, in which a wide variety of nutrition-related data are collected, have been carried out and little action has followed. It has been suggested that ten times the amount spent on a survey should be available for programs aimed at overcoming the deficiencies identified by it. It is, therefore, important that the information collected be kept to the minimum required to assess or monitor the situation, and that surveys be simplified as much as possible. Some information used for the assessment of the nutritional status of a community can also be used for evaluation of programs and for nutritional surveillance.