Agrarian Science for Sustainable Resource Management in Sub-Saharan Africa
FOREWORD

AGRARIAN SCIENCE FOR SUSTAINABLE RESSOURCE MANAGEMENT IN SUB-SAHARAN AFRICA

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The world is facing a new food crisis, due to a higher demand of animal proteins, climate change, the increased cultivation of energy crops and speculation in the raw material market. In the past decades, world agriculture has undergone severe changes. The production of raw materials and agricultural goods is industrialised, centralised, energy- and resource-intensive and far from being ecologically and socially sustainable. In the rich countries, these developments already have alarming consequences: increased food prices, crop shortages, land deprivation and negative ecological and social impacts, to mention only a few of them. But the developing countries will be impaired even more.

Land shortages, resource scarcity, population growth and environmental depletion is often said to encourage violent conflicts in developing countries. Robert Kaplan argued in his essay The Coming Anarchy already in 1994, that the violence and wars in Somalia, Liberia and Rwanda were highly influenced by these factors.

But the problems of resource and food shortages are not emerging from these African countries themselves – they are largely made by an unfair world trade system and the enormous demand for food and raw materials by the industrialized world. Valuable land is devastated by huge mono-cultural crop cultivations and the related excessive use of pesticides. Tropical forests, which play a crucial role in combating global climate change are slashed and burned in order to grow soy and other high-protein plants for the giant animal factories in Europe and the U.S.

Meanwhile, the local population of the developing countries suffers from hunger and malnutrition. Worldwide, 860 million people are currently starving. And 80 percent of the poorest live in Africa. On the G8 summit 2008, one main objective for future development aid was to forward rural development in Africa. And indeed, the reconstruction and development of rural communities and small-scale agriculture is urgently needed.

Small-scale agricultural production can ensure regional food security in the long term. The daily production serves the self-supply of the farmers and their families; the surplus is sold at local markets. Also, small-scale production and
family businesses are sustainably managed – simply because the farmer has to look ahead and guarantee future earnings for the generations to come. Hence, there is no better way to implement generational justice in the agricultural sector than by supporting subsistence agriculture.

Also, unlike industrialized production which mainly focuses on export, small-scale agriculture is ecologically and socially compatible.

The global developments not only call for a more differentiated and regionally adapted developmental aid; they also show the need for altered political strategies in the concerning countries when it comes to land distribution, ownership regulations and subsidies.

Self-supporting farmers and their families must be kept able to sustainably manage their land. They need direct and unbureaucratic support in times of drought and food insecurity. Also, the government has to protect these families against foreign investors and landlords. This is fundamental in order to insure food security and to pacify conflict zones.

An interesting discussion paper of the Humboldt University Berlin, Department of Agricultural Economics and Social Sciences, on small-scale agro-pastoralist households in Somali, Ethiopia, showed, that resource sharing offers asset-poor households opportunities to stabilize and enhance their asset-base in drought years, providing incentives for co-operative rather than confictive relations with intruding pastoralists. Hence, political structures and incentives are needed in order to ensure food security and peaceful coexistence in the concerning regions*.

Future objectives must not focus on short-term gains and economic profit for some few large international companies, but building up the necessary political framework and infrastructure for a nationwide food supply for the local people. It is not tolerable, that urgently needed crops are cheaply produced in the developing countries and exported in order to fatten animals in rich countries.

In order to stem these threatening developments and search for feasible alternatives, Support Africa International e. V. and the Schweisfurth-Foundation are encouraging African scientists to conduct some research which aims at a sustainable, regionally adapted agriculture. Every year, the best scientific papers are rewarded with the Research Award and published in our serial “Studies in Sub-Saharan Africa”.

This year, the contest was themed “Agrarian Science for Sustainable Resource Management in sub-Saharan Africa”. Therewith, we intended to highlight the great importance of science in order to face resource scarcity, and to figure out alternative and applicable models for sustainable resource management.

The studies received show, that there exist useful theoretical frameworks in agrarian and animal sciences which can help establishing and implementing
practical solutions for resource management in sub-Saharan Africa. Another major focus of the studies this year was on soil science, which is tremendously important in order to combat desertification and erosion, and conserve soil fertility. Furthermore, the papers offer outstanding examples of applications for different resource-sustaining methods.

References

AGRARIAN SCIENCE FOR SUSTAINABLE RESOURCE MANAGEMENT

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Abstract
The productivity and intensification of agricultural systems require a broad-based participatory research and adoption of resource enhancing agricultural technologies by various stakeholders. The conservation of natural resources in the face of growing poverty, food insecurity and population growth requires an integration of agro-biodiversity, socio-economic variables and implementing environmentally friendly policies capable of boosting food security, alleviating poverty and ensuring sustainable resource management.

Introduction
Agriculture has changed dramatically, especially since the end of World War I. Food and fibre productivity soared due to new technologies, mechanization, increased chemical use, specialization, and government policies that favoured maximizing production.

Although these changes have had many positive effects and reduced many risks in farming, there have also been significant costs prominent among these are topsoil depletion, groundwater contamination, the decline of family farms, continued neglect of the living and working conditions for farm labours, increasing costs of production, and the disintegration of economic and social conditions in rural communities.

Continued agricultural growth is a necessity, not an option, for most developing countries. Further, this growth must be achieved on a sustainable basis so as not to jeopardize the underlying base of natural resources and it must be equitable if it is to contribute to the alleviation of poverty and food insecurity. Government policies, institutional development, agricultural research and projects at local, regional and national levels need to be designed and implemented with these objectives in mind. Productivity has grown fastest in irrigated agriculture, because of the increased use of modern inputs in irrigation, fertilizer, pesticides high-yielding varieties and machinery.

However, this intensification has also increased the potential for the inappropriate use of modern inputs, particularly when inappropriate incentives prevail. The following major environmental problems are associated with intensification in irrigated areas (Pingali and Rosepant, 1994), where poor drainage can lead to waterlogged soils and a rise in the water table. In arid and
semi-arid areas, this in turn causes salt to build up in the soil. Salinisation reduces yields and can eventually lead to abandonment of land.

- Perennial flooding of rice paddies and continuous rice culture lead to a build up of micronutrient deficiencies and soil toxicities, formation of hard pans in the soil and a reduction in the nitrogen-carrying capacity of the soil. Work at the International Rice Research Institute shows that farmers have to increase the amount of fertilizer they use over time simply to maintain existing yields in intensive paddy fields (Pingali, 1992).

- Excessive and inappropriate use of pesticides deteriorates the quality of water, poses health hazards for humans and leads to resistance of pests to pesticides. Farmers can become trapped into using more and more frequent sprays to control pest damage.

- An increasing reliance on a few carefully bred crop varieties contributes to a loss of genetic diversity and to a common vulnerability to the same pest- and weather-related risks.

In some cases, millions of hectares of land have been planted of the same wheat or rice varieties and widespread losses have occurred because of the outbreak of a single pest or disease. The loss of traditional varieties also reduces the pool of genes available for breeding plants capable of resisting evolving plant pests.

Some dramatic changes will be needed in the ways that people raise crops and livestock if much biodiversity is to survive the next 50 years. How agriculture is transformed and intensified in a sustainable manner will be the key to how many species and how much genetic variation are still around in the next century. A focus on conserving biodiversity in "protected areas" alone will not work. Protection of a sample of natural habitats is neither sufficient nor desirable to conserver biodiversity for two simple reasons:

- Most of the world's biodiversity exists in human-managed or modified systems and
- land use patterns and socio political factors in areas adjacent to parks and reserves that have major implications for the integrity biological diversity in 'protected' areas (Pimentle et al., 1992).

Given the ultimate importance of biodiversity in its broadest sense to agriculture, a strategy for main streaming biodiversity in agricultural development needs to address the off-site impacts of land use systems. Steps in this direction are outlined in the call for a new agricultural research and development paradigm. Work is already underway to addresses a range of issues related to off-site impacts, including the reduction or elimination of agricultural
pollutants in groundwater, and in runoff and the placement of greater emphasis on integrated pest management (1pm) strategies. How and why rural people conserve, enhance and use biodiversity have rarely been taken into account when designing management interventions and devising policy for agricultural development and natural resource management. But the active participation of farmers, ranchers, and pastoralists - and especially resource-poor operators - is essential in the design and implementation of biodiversity and agricultural development projects. (Thrupp, Cabarle, and Zazueta, 1994; Wilcox and Duin, 1995).

The evolving agricultural research paradigm includes, but is not restricted to, the adopting integrated pest management. 1pm strategies includes the release of bio-control agents, deployment of genetically resistant cultivars and breeds, more judicious use of pesticides and herbicides, alteration of cropping patterns to thwart the building of pests and disease, and placement of greater emphasis on crop rotation, where economically feasible to retard soil degradation and reduce pest pressure.

The use of participatory approach with farmers, two types of on-farm research are typically found: demonstration plots on farmers' land and experimental work that involves farmers and other stakeholders in the design of models from the "ground up". Much more of the second type of on-farm research is needed that involves farmers, pastoralists and other "clients" of agricultural research and development from the inception of the study design. In this manner, research would be more demand driven. Improve the use of indigenous knowledge. How and why local people use natural resources can provide important information for more appropriate agricultural research and development efforts.

Support research, development, and dissemination of lesser-known crops and animal neglected traditional varieties and breeds, many of which are particularly well suited to difficult environments, would be included in this broad research effort. But sustained support for research on the major food and industrial crops as well as livestock remains essential. Support research on new crops and livestock scope exists for new crops and livestock to fill specially market and environmental niches. In some cases, natural vegetation communities could be managed for the production of new domesticated animals. A deeper commitment to research on crop and livestock candidates would thus underscore the value of conserving biodiversity and natural habitats.

Biodiversity in managed landscapes often best served by promoting a mixture of land uses that provides varied habitats for wildlife adapted to altered areas. Achieved a greater diversity of habitats within land use systems, biodiversity within a land use system, such as intensive cereal cropping, can be achieved by allowing for a variety of habitats, such as riparian butter strips, shelter belts,
windbreaks, strip cropping and wetlands. Diversity of habitats on the landscape creates more niches for wildlife, some of which are beneficial in controlling crop pest. More diverse habitats, including managed ones, also promote the more efficient use of nutrients and create microclimates that butter crops from inclement weather.

Recycle organic matter through measures such as incorporating livestock or grain manure-no-till or minimum-till farming, help to sustain the diversity of soil micro-organisms, which are so important in nutrient recycling.

Focus research on lifetime and herd productivity characteristics. Deterministic simulation models and live animal experimentation can be used in some cases to achieve these goals. Determine the critical number of breeds for conservation purposes. Analysis of genetic "spacing" between breeds and to identify those breeds that are significantly different or unique from others. Learn more about genetic components of adaptation in livestock. A better understand of traits such as resistance to ticks and use of body reserves would aid breeding efforts and would likely underscore the importance of safeguarding so called "minor" breeds.

Many national agricultural research and extension systems have yet to integrate environmental concerns successfully into their agenda. Too little consideration is given to the sustainability features of recommended technologies, to broader aspects of natural resource management problems of more fragile rain-fed areas where resource degradation is considerable.

This research paper is aimed at addressing the issues of poor resource management through sustainable agricultural practices and proper integration of environment-friendly technologies needed to boost food production, alleviate poverty and conserve natural resources.

**Managing natural resources sustainable agriculture**

Sustainable agriculture integrates three main goals: environmental health, economic profitability and social economic equity. A variety of philosophies, policies and practices have contributed to these goals. People in many different capacities, from farmers to consumers have shared this vision and contributed to it. Despite the diversity of people and perspectives, the following themes commonly weave through definitions of sustainable agriculture.

Sustainability rests on the principle that we must meet the needs of the present without compromising the ability of future generations to meet their own needs. Therefore, stewardship of both natural and human resources is of prime importance. Stewardship of human resources includes consideration of social responsibilities such as working and living conditions of labourers, the needs of rural communities and consumer health and safety both in the present and the
future. Stewardship of land and natural resources involves maintaining or enhancing this vital resource base for long term.

A systems perspective is essential to understanding sustainability. The system is envisioned in its broadest sense, from the individual farm to the local ecosystem and to communities affected by this farming system both locally and globally. An emphasis on the system allows a larger and more thorough view of the consequences of farming practices on both human communities and the environment. A system approach gives us the tools to explore the interconnections between farming and others aspects of our environment.

A system approach also implies interdisciplinary efforts in research and education. This requires not only the input of researchers from various disciplines, but also farmers, farm workers, consumers, policymakers, and others. Making the transition to sustainable agriculture is a process. For farmers, the transition to sustainable agriculture normally requires a series of small realistic steps.

Finally, it is important to point to the fact that reaching the goal of sustainable agriculture is the responsibility of all participants in the system, including farmers, labourers, policymakers, researchers, retailers, and consumers. Each group has its own part to play, its own unique contribution to make to strengthen the sustainable agriculture community. When the production of food and fibre degrades the natural resource base, the ability of future generations to produce and flourish decreases. The decline of ancient civilizations in Mesopotamia, the Mediterranean region, pre-Columbian Southwest U.S., and Central America is believed to have been strongly influenced by natural resources degradation from non-sustainable farming and forestry practices. Water is the principal resource that has helped agriculture and society to prosper, and it has been a major limiting factor when mismanaged.

Sustainable production practices involve a variety of approaches. Specific strategies must take into account topography, soil characteristics, climate, pests, local availability of inputs and the individual grower’s goals. Despite the site-specific and individual nature of sustainable agriculture, several general principles can be applied to help growers select appropriate management practices.

Properly managed, diversity can also butter a farm in a biological sense. For example, in annual cropping systems, crop rotation can be used to suppress weeds pathogens and insect pests. Also cover crops can have stabilizing effects on the agro-ecosystem by holding soil and nutrients in place, conserving soil moistures with moved or standing dead mulches and increasing the water infiltration rate and soil water holding capacity. Cover crops in orchards and vineyards can butter the system against pest infestations by increasing beneficial
arthropod populations and can therefore reduce the need for chemical inputs. Using a variety of cover crops is also important in order to protect against the failure of a particular species to grow and to attract and sustain a wide range of beneficial arthropods. Optimum diversity may be obtained by integrating both crops and livestock in the same technology and government policy.

Common philosophy among sustainable agriculture practitioners is that a 'health' soil is a key component of sustainability, that is, healthy soil will produce healthy crop plants that have optimum vigour and are less susceptible to pests. While many crops have key pest that attack even the healthiest of plants, proper soil, water or nutrient imbalance. Furthermore, crop management systems that impair soil quality often result in greater inputs of water, nutrients, pesticides and/or energy for tillage to maintain yields.

In sustainable systems, the soil is viewed as a fragile and living medium that must be protected and nurtured to ensure its long-term productivity and stability. Methods to protect and enhance the productivity of the soil include using cover crops, compost and/or manures, reducing tillage, avoiding traffic on wet soils and maintaining soil cover with plants and or matches. Conditions in most California soils (warm, irrigated and tilled) do not favour the build-up of organic matter. Regular additions of organic matter or the use of cover crops can increase soil aggregate stability, soil tilth and diversity of soil microbial life.

Many inputs and practices used by conventional farmers are also used in sustainable agriculture. Sustainable farmer, however, maximize reliance on nature renewable and on-farm inputs. Equally important are the environmental, social and economic impacts of a particular strategy. Converting to sustainable practices does not mean simple input substitution. Frequently, it substitutes enhanced management and scientific knowledge for conventional inputs, especially chemical inputs that harm the environment on farms and in rural communities. The goal is to developed efficient biological systems which do not need high levels of material inputs.

Thorough integration of natural processes such as nutrient cycling, nitrogen fixation and pest-predator relationships into agricultural production processes ensure profitable and efficient food production. Minimization of the use of those external and non-renewable inputs, with the potential to damage the environment or harm the health of farmers and consumers and targeted used of the remaining inputs used, minimize the costs.

The full participation of farmers and other rural people in all processes of problem analysis and technology development, adaptation and extension lead to an increase in self-reliance among farmers and rural communities, so a greater productive use of local knowledge and practises, including innovative
approaches not yet fully understood by scientists or widely adopted by farmers, and also the enhancement of wildlife and other public goods of countryside.

Sustainable agriculture seeks the integrated use of a wide range of pest, nutrient, soil and water management technologies. It aims for an increased diversity of enterprise within farms combined with increased linkages and flows between them. By-products or wastes from one component or enterprise become inputs to another. As natural processes increasingly substitute for external inputs the negative impacts on the environment are reduced and positive contributions are made to regenerate natural resources.

Increasing evidence shows that regenerative and resources-conserving technologies and practices can bring both environmental and economic benefits for farmers, communities and nations. The best evidence comes from countries of Africa, Asia and Latin America, where the concern is to increase food production in the areas where farming has been largely untouched by the modern packages of externally supplied technologies. In these lands, farming communities adopting regenerative technologies have substantially improved agricultural yields, often using only a few or no external inputs. (Bunch, 1990, 1993; GTZ, 1992; UNDP, 1992; Krishna, 1994; Shah, 1994; SWCB, 1994; Balbarin and Alcobre, 1994; de Freitas, 1994 and Pretty, 1995b).

The high-inputs and generally irrigated lands, farmers adopting regenerative technologies have maintained or improved yields while substantially reducing their use of inputs (Bagadion and Korten, 1991). The basic challenge for sustainable agriculture is to make better use of available physical and human resources. This can be done by minimizing the use of external inputs, by regenerating internal resources more effectively, or by combining two in various ways. This ensures the efficient and effective use of what is available and keeps any dependencies on external systems to a reasonable minimum.

Implementing sustainable agrarian policies that reduce resources degradation Policy interventions that seek to overcome environmental problems in agriculture need to be based on a proper understanding of why farmers degrade natural resources. For example, farmers often seem to overgraze rangeland depleting soil nutrients and organic matter and overuse irrigation water, pesticides and nitrogen, whereas these actions cause health problems and reduce future incomes for themselves, their children and the communities in which they live.

The answer lies with incentives including discount rates. Farmers are not irrational. To the contrary, they maximize income and minimize risks in a dynamic context and often wider harsh conditions and serious constraints. For example, they degrade resources when there are good economic and social
reasons for doing so. If the management of natural resources is to be improved, these economic and social incentives will need to be changed in appropriate ways.

Current policies often do not reflect the long-term social and environmental costs of resource use. The external costs of modern farming, such as soil erosion, health damage, or polluted ecosystems, generally are not incorporated into individual decision making by farmers. In this way, resource-degrading farmers bear neither the costs of damage to the environment or economy, nor those incurred in controlling the polluting or damaging activity (Pretty, 1996).

In principle, it is possible to imagine pricing the free input to farming of the clean, unpolluted environment. If charges were levied, in some way, then degraders or polluters would have higher costs, would be forced to pass them on to consumers, and would forced to stitch to more resource-conserving technologies. This notion is captured in the polluters-pays principle (OECD, 1989).

However, beyond the notion of encouraging some internalisation of costs, it has not been of practical use for policy formulation in agriculture. Although a growing number of policy initiatives are oriented specifically toward improving the sustainability of agriculture, most have focused on input reduction strategies. Only a few as yet represent coherent plans and processes that clearly demonstrate the value of integrating policy goals. A thriving and sustainable agricultural sector requires both integrated action by farmers and communities and integrated action by policy makers and planners. This implies both horizontal integration with better linkages between sectors and micro and macro level.

Integration has been the policy buzz of the 1990s. But putting this desired integration into practices has been much more difficult. There have been substantial differences in the views of major policy actors, such as those representing the interests of farmers, environmentalists and treasuries.

In addition to strategies for preserving natural resources and changing production practices, sustainable agriculture requires a commitment to changing public policies, economic institutions and social values. Strategies for change must take into account the complex, reciprocal and ever-changing relationship between agricultural production and the broader society.

The "food systems" extends far beyond the farm and involves the interaction of individuals and institutions with contrasting and often competing goals including farmers, researchers, input suppliers, farm workers, unions, farm advisors, processors, retailers, consumers, and policymakers. Relationships among these actors shift overtime as new technologies spawn economic, social and political changes.
Governments can do much with existing resources to encourage and nurture the transition from modernized systems toward more sustainable alternatives, declaring a national policy for sustainable agriculture. This would help to raise the profile of these processes and needs as well as give explicit value.

Finally, for sustainable agricultural to spread widely policy formulation must be enabling and create the condition for sustainable development based on locally available resources, local skills and knowledge.

**Managing natural resources through participatory research**

Agricultural research has greatly increased the yields of important staple food crops and livestock products, yet many people have meant more food availability and trade opportunities. But some people in rural areas in developing countries still live in abject poverty. Therefore, policy makes, donors and researchers are refocusing their priorities away from simply producing more food to make sure that agricultural research benefits the poor in particular.

How agriculture can be intensified without damaging biodiversity is a critical question for rural development. Environmentally inappropriate intensification of agriculture has led to eutrophication of lakes and estuaries, loss of soil microorganisms, accelerated soil erosion, contamination of groundwater, and draining of wetlands. All of these activities trigger a potentially dangerous loss of biodiversity. But wild species are essential for agricultural improvement, because they are the source of new economic plants and animals and provide important services such as pollination and pest control.

Possible remedial measures can be adopted to address the loss of biodiversity associated with agricultural development such as minimizing habitat fragmentation by providing wildlife corridors along "bridges" of natural habitat. By shifting to integrated pest management (IPM) strategies, such as rotating crops and relying on bio-control agents to check crop and livestock pest and eliminating fiscal and regulatory measures that promote homogeneity in crop and livestock production.

The new vision for agricultural research adopts a holistic approach that is more sensitive to environmental concerns, while still addressing the need to boost the yields and incomes of rural producers and caretakers of the land. This includes, but is not restricted to:

- Integrated pest management
- A participatory approach with farmers
- Better use of farmers knowledge
- Greater support for research, development and dissemination of lesser-known crops and animals.
- Support for research on new crops and livestock.
- Greater sensitivity to the value of a mosaic of land uses
- Greater diversity of habitats with land use systems
- Greater reliance or recycling of organic matter
- The shift of the research focus from individual traits to lifetime and herd productivity characteristics.
- Determination of the critical number of breeds for conservation purposes and an effort to learn more about the genetic components of adaptation in livestock.

This notion of a new research paradigm has implications for institutional development and the exploration of new ways of doing business. Innovative institutional arrangements would include more effective partnerships among agricultural research centres, NGOs, growers, associations, private companies involved in the manufacture and sale of agricultural technologies, universities and agricultural extension agencies, and development lending institutions. To some degree, all of these partnerships are being explored and tested.

Generating the gains in agricultural productivity necessary to secure food availability and livelihoods in the developing world over the coming decades requires an approach in which the intensification of agricultural systems is consistent with the conservation of natural resource base. This approach requires less reliance on the intensive use of external inputs and greater dependence on management skills and location-specific knowledge of agro-ecosystems. Integrated pest management constitutes one of such an approach and is critical to sustainable rural development. (Pingali and Gerpacio, 1997).

The research processes should begin with the careful identification of socio-economic and environmental problems affecting the agricultural productivity, followed by a research strategy aimed at improving the genetic resources, crop/livestock farming systems as well as natural resource management. The research priorities should be based on agro-ecological, biophysical and demographic parameters so as to ensure a sound and sustainable research result.

Agricultural research can help to alleviate poverty in many ways farm household that adopt resulting technologies can benefit from higher yields and incomes, but benefits are not just felt by the adopting households. The indirect impacts of research (such as cheaper food and more jobs) can also improve the living standards of wider populations. Impact can also be negative. All are important, and all should be included in assessment of impacts. Technology should be tailored to fit people’s livelihood strategies, and it should be targeted at areas where agriculture still plays a significant role in the lives of poor farmers.
Finally, to increase the impact of agricultural research on poverty, research organizations need to embrace a culture of institutional learning and change (ILAC). This can be fostered by a spirit of critical self-awareness among professionals and an open culture of reflective learning within organizations.

**Conclusion**

The sustainability of natural resources in the developing countries could be achieved through implementing sound resource-building policies and by a holistic participatory research approach built on agro-ecological, socio-economic, demographic and biophysical framework.

**References**


