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Context, Conceptual Framework and Sustainability Indicators

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Key Messages

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1. Agriculture is multifunctional. It provides food, feed, fiber, fuel and other goods. It also has a major influence on other essential ecosystem services such as water supply and carbon sequestration or release. Agriculture plays an important social role, providing employment and a way of life. Both agriculture and its products are a medium of cultural transmission and cultural practices worldwide. Agriculturally based communities provide a foundation for local economies and are an important means for countries to secure their territories. Agriculture accounts for a major part of the livelihood of 40% of the world's population and occupies 40% of total land area; 90% of farms worldwide have a size of less than 2 hectares. Agriculture includes crop-, animal-, forestry- and fishery-based systems or mixed farming, including new emerging systems such as organic, precision and peri-urban agriculture. Although agricultural inputs and outputs constitute the bulk of world trade, most food is consumed domestically, i.e., where it is produced.

2. Agricultural systems range across the globe from intensive highly commercialized large-scale systems to small-scale and subsistence systems. All of these systems are potentially either highly vulnerable or sustainable. This variability is rooted in the global agrifood system, which has led to regional and functional differences around the world—the social, economic and ecological effects of which have not yet been assessed and compared. The global agricultural system faces great challenges today, as it has to confront climate change, loss of biological and agrobiological diversity, loss of soil fertility, water shortage and loss of water quality, and population growth. Sustainable agricultural production is dependent on effective management of a range of interdependent physical and natural resources—land, water, energy, capital and so on—as well as on full internalization of currently externalized costs. The sustainability of production also depends on the continuing availability of and generalized access to public goods. Finding ways of dealing with these challenges is a highly contested matter: strategies differ because they are based on different visions of agriculture, different interests and diverging values. However, while agriculture is a strong contributor to the most critical problems we face today; it can also play a major role in their resolution.

3. Agricultural Knowledge, Science and Technology (AKST) can address the multifunctionality of agriculture. It plays a key role in shaping the quality and quantity of natural, human and other resources as well as access to them. AKST is also crucial in supporting the efforts of actors at different levels—from household to national, sub-global and global—to reduce poverty and hunger, as well as improve rural livelihoods and the environment in order to ensure equitable and environmentally, socially and economically sustainable development. On the one hand, tacit and locally-based agricultural knowledge has been, and continues to be, the most important type of knowledge particularly for small-scale farming, forestry and fishery activities. On the other hand, the development of formal agricultural knowledge has been enormously successful particularly since the 1950s, and forms a dominating part of agricultural knowledge today. Challenges ahead include the development and use of transgenic plants, animals and microorganisms for increased productivity and other purposes; access to and use of agrochemicals; the emerging challenges of biofuel and bioenergy development, and in a broader sense, the political, social and economic organization of agriculture as a component of rural development. All these challenges have implications (both positive and negative) on the environment, human health, social well-being and economic performance of rural areas in all countries. The combination of community-based innovation and local knowledge with science-based approaches in AKST holds the promise of best addressing the problems, needs and opportunities of the rural poor.

4. The majority of the world's poorest and hungry live in rural settings and depend directly on agriculture. Over 70% of the world's poor live in rural areas. These 2.1 billion people live on less than US$2 a day. This is not inevitable, and an improved economic environment and greater social equity at local, national, and global scales have the potential to ensure that agriculture is able to provide improved livelihoods. Inextricably linked to poverty are vulnerabilities relating to production and consumption shocks, poor sanitation, and lack of access to health care and deficient nutrient intake, placing many in agrarian societies at risk. AKST may help mitigate these negative effects by supporting appropriate interventions, but it may also increase the vulnerability of poor farmers if no attention is paid to the risks and uncertainties to which these farmers are exposed. The livelihoods of many poor farmers are oriented towards meeting basic needs, particularly food. With insufficient income, households have little money to invest in increasing the productivity or sustainability of their production systems. The global trend has been towards a decapitalization of poor farmers and their resources (as well as rural areas), as they experience declining terms of trade and competition with low-cost producers. AKST offers opportunities to contribute to recapitalization of such farming households.

5. A vicious circle of poor health, reduced working capacity, low productivity and short life expectancy is typical, particularly for the most vulnerable groups working in agriculture. All persons have a right to sufficient, safe, nutritious and culturally acceptable food. Good nutrition is a prerequisite for health. Although global production of food calories is sufficient to feed the world's population, millions die or are debilitated every year by hunger and malnutrition which makes them vulnerable to infectious diseases (e.g., HIV/AIDS, malaria and tuberculosis). In many developing countries hunger and health risks are exacerbated by extreme poverty and poor and dangerous working conditions. In contrast, in industrialized countries, overnutrition and food safety issues, including food-borne illnesses affecting human health as well as diseases associated with agricultural production systems, are predominant concerns. Notwithstanding, in industrialized countries there is also a significant incidence of undernutrition among the poor, and a higher burden of both infectious and noncommunicable diseases associated with metabolic syndromes. AKST has an important role to play in both moving towards food security and food sovereignty, and breaking the malnutrition–poor health–low productivity cycle.

6. A range of fundamental natural resources (e.g., land, water, air, biological diversity including forests, fish) provide the indispensable base for the production of essential goods and services upon which human survival depends, including those related to agricultural ecosystems. During the last 50 years, the physical and functional availability of natural resources has shrunk faster than at any other time in history due to increased demand and/or degradation at the global level. This has been compounded by a range of factors including human population growth, and impacts have comprised unprecedented loss of biodiversity, deforestation, loss of soil health, and water and air quality. In many cases, such negative impacts can be mitigated; and in some cases, they are. Given the multifunctional nature of agriculture, it is critical to consider links across ecosystems in which agricultural systems are embedded, as these have important implications for the resilience or vulnerability of these systems. Linkages between natural resource use and the social and physical environment across space and time are an important issue for AKST, with significant implications for sustainable development and the mitigation of adverse impacts.

7. Social equity issues, including gender, are major concerns in agriculture, as they relate to poverty, hunger, nutrition, health, natural resource management and environment, which are affected by various factors resulting in greater or lesser degrees of equity. As a majority of the world's poor and hungry live in rural settings and are directly dependent on agriculture for their livelihoods, political, economic, cultural and technological factors contribute to mitigating or reinforcing inequality. Women and men have differing roles and responsibilities in productive households, and they can derive varying degrees of benefits from AKST and innovations. Gender-based patterns are context-specific, but a persistent feature is that women have a key role in agricultural activities, yet they have limited access to, and control of, productive resources such as land, labor, credit and capital. Agricultural development sometimes strengthens patterns that are unfavorable to women, such as male bias of the agricultural extension system in many countries. Societies can develop governance institutions, legal systems, social policy tools, and social/gender sensitive methods (e.g., gender analysis) that seek to minimize disparities and even opportunities out among women and men.

8. Agriculture today is faced with several emerging challenges and opportunities; the evaluation of those relating to climate change, land degradation, reduced access to natural resources (including genetic resources), bioenergy demands, transgenics and trade require special efforts and investments in AKST. About 30% of global emissions leading to climate change are attributed to agricultural activities. Climate change in turn affects all types of agricultural production systems, from farming to forestry, livestock production and fishery; it particularly affects resource-poor agriculture. Current as well as future damage due to temperature increases and more extreme weather events and their consequences on the hydrology of watersheds and groundwater resources are yet to be detected in detail. Agricultural households and enterprises need to adapt to climate change but they do not yet have the experience in and knowledge of handling these processes, including increased pressure due to biofuel production. Bioenergy is seen as a potential to mitigate the impact of using fossil fuels as a source of energy, thereby mitigating the impact on climate. While on-farm bioenergy production is emerging as a possibility to make better use of farm residues and excrements, the substitution of fossil fuel through biofuel plantation for transport and mobility is under contention and thus a matter of concern for AKST. The development and use of transgenics is seen very differently by the different stakeholders, ranging from a purely positivist view of genetically modified organisms (GMOs) as the solution to the problems of agriculture, to a purely negativist view that considers GMOs to be uncontrollable and life threatening. Finally, agricultural trading conditions, rules and standards are changing; together with emerging alternatives, they offer challenges and opportunities.

1.1 Setting the Scene

1.1.1 The IAASTD

IAASTD, *the International Assessment of Agricultural Knowledge, Science and Technology for Development*, comes at a time of rapid change that is affecting both rural and urban areas, as well as the climate and other natural resources—in ways that present unprecedented threats. However these changes also provide opportunities for sustainable development and poverty alleviation, and require increased knowledge, science and technology in conjunction with appropriate policies, institutions and investments.

The main goal of IAASTD is to provide decision makers with the information they need to reduce hunger and poverty, improve rural livelihoods, and facilitate equitable, environmentally, socially and economically sustainable development through the generation of, access to and use of agricultural knowledge, science and technology (AKST). IAASTD uses a conceptual framework that enables systematic analysis and appraisal of the above challenges based on common concepts and terminology.

The development and sustainability goals of the IAASTD are to:

(1) reduce hunger and poverty,
(2) improve rural livelihoods, human health and nutrition, and
(3) promote equitable and socially, environmentally and economically sustainable development.

Sustainable development is crucial to meet the needs of the present without compromising the ability of future generations to meet their own needs (see WCED, 1987). Using AKST to achieve development and sustainability goals will depend on the choices of different actors related to AKST development and application.

Agriculture plays a prominent role for human well-being on Earth; the IAASTD concentrates on how knowledge, science and technology can contribute to agricultural development. This assessment is a specific step among several global efforts to achieve sustainable development that have emerged in follow-up processes and policies of the World Conference in Rio de Janeiro in 1992. AKST will contribute to the achievement of these goals. Specifically, the IAASTD will contribute to knowledge-based decision making for future sustainable development by assessing: (1) those interrelations within AKST relevant to sustainable development; (2) knowledge and scientific development, technology diffusion, innovation, and adaptation of ecosystem management; and (3) the integration of AKST within international, regional, national and local development policies and strategies.

What is an assessment?

International assessments are very useful when they address complex issues of supranational interest and dimensions. A number of assessments have been undertaken by many organizations and individuals in the past two decades: the Global Biodiversity Assessment (GBA), the Ozone Assessment, the Intergovernmental Panel on Climate Change (IPCC) reports, the Millennium Ecosystem Assessment (MA), the Comprehensive Assessment of Water Management in Agriculture (CA), the Global Environment Outlook (GEO), and now, the International Assessment of Agriculture, Knowledge, Science and Technology for Development (IAASTD).

The evidence-based analyses that underpin the outcomes of the various assessments have common characteristics. A key point is that an assessment is not simply a review of the relevant literature; it can be based, in part, on a literature review, but also needs to provide an assessment of the veracity and applicability of the information and the uncertainty of outcomes in relation to the context of the identified questions or issues within a specified authorizing environment (Table 1-1).

To be effective and legitimate, the assessment process was designed to be open, transparent, reviewed, and widely representative of stakeholders and relevant experts, and the resulting documents to be broadly reviewed by independent experts from governments, private and nongovernmental organizations, as well as by representatives of the participating governments. Obtaining a balance of opinions in a global assessment based on a literature review and relevant expertise is an ongoing and iterative challenge to ensure that it encompasses a broad range of disciplinary and geographical experience and different knowledge systems. The IAASTD has been designed in a way that attempts to ensure effectiveness and legitimacy.

The role of Agricultural Knowledge, Science and Technology (AKST). Agricultural knowledge, science and technology are seen as key factors and instruments for future adjustment of indirect and direct drivers of agricultural outputs, as well as of ecosystem services. Assessing AKST sets the stage for an informed choice by decision-makers among various options for development. It indicates how policy and institutional frameworks at all organizational levels might affect sustainability goals. Specifically, it provides the basis for designing AKST in a way that mitigates detrimental development dynamics such as growing disparities, the decreasing share of agricultural value-added and the degradation of ecosystems. In other words, the assessment draws lessons about what conditions have led AKST to have an impact on development that has been positive for human and ecosystem well-being, and where, when and why impacts have been negative. Moreover, it explores the demands that are likely to be made on agricultural systems (crops, livestock and pastoralism, fisheries, forestry and agroforestry, biomass, commodities and ecosystem services) in the future, asking what agricultural goods and services society will need under different plausible future scenarios in order to achieve the goals related to hunger, nutrition, human health, poverty, equity, livelihoods, and environmental and social sustainability, and whether and how access to these goods and services is hindered. The result is an evidence-based guide for policy and decision-making.

IAASTD commitment to sustainable development. IAASTD sees the assessment of AKST and its implications for agriculture as a prerequisite for knowledge-based decision-making for future sustainable development portfolios. Specifically, IAASTD aims to contribute to knowledge-based, decision-making for future sustainable development by:

1. Identifying interrelations between agricultural knowledge, science and technology in view of sustainable development;
2. Exploring knowledge and scientific development, technology diffusion, innovations and adaptations of ecosystem management;
3. Supporting the integration of agricultural knowledge, science and technology (AKST) within international and national development policies and strategies.

IAASTD's relationship to the Millennium Development Goals (MDGs) and the Millennium Ecosystem Assessment (MA). The MDGs and the MA are cornerstones for development policy and serve as major references for the IAASTD. In addition to these frameworks, the IAASTD assesses AKST in relation to the objective of meeting broader development and sustainability goals. It is generally assumed that AKST can play a major role in efforts to achieve the MDGs, particularly that of eradicating extreme poverty and hunger (MDG 1) by improving the productivity of agriculture in general and the competitiveness of smallholders and marginalized groups in the expanding global, national and local markets in particular, as well as by creating employment among poor rural people and making food available to consumers everywhere. AKST can also contribute directly or indirectly to improving primary education and social and gender equity, reducing child mortality, improving maternal health, combating HIV/AIDS, malaria and other diseases (MDG 2-6), and ensuring environmental sustainability (MDG 7) by delivering a variety of supporting, regulating and cultural services (MDG 8). The IAASTD assessment enables a more adequate consideration of the linkage between poverty reduction and environmental change.

Key questions for the IAASTD. The major question for this assessment is: "How can we reduce hunger and

Table 1-1. **Differences between a review and an assessment.**

	Scientific Reviews	Assessment
Audience	Undertaken for scientists	Undertaken for decision-makers from a specified authorizing environment
Conducted by	One or a few scientists	A larger and varied group based on relevant geographic and disciplinary representation
Issues/Topics	Often deal with a single topic	Generally a broader and complex issue
Identifies gaps in	Research issues generally driven by scientific curiosity	Knowledge for implementation of outcomes; problem-driven
Uncertainty statements	Not always required	Essential
Judgment	Hidden; a more objective analysis	Required and clearly flagged
Synthesis	Not required, but sometimes important	Essential to reduce complexity
Coverage	Exhaustive, historical	Sufficient to deal with main range of uncertainty associated with the identified issues

Source: Watson and Gitay, 2004.

poverty, improve rural livelihoods, and facilitate equitable, environmentally, socially and economically sustainable development through the generation of, access to, and use of AKST?" Three questions recur throughout the global and sub-global assessments of IAASTD. They concern:

1. *Social disparities:* How have changing markets and changing access to markets affected development and sustainability goals, and how has this been influenced by AKST? How and by what have cultural values, traditions and social equity (including gender equity) been influenced? What are projected implications of market changes in the future, and how can AKST contribute to informed decision-making?
2. *Ecology:* How has availability of, access to and management of natural resources (particularly water and soil resources, as well as plant, animal, genetic and other resources) affected the development and sustainability goals of IAASTD? How can AKST enhance knowledge of natural resource management?
3. *AKST:* What have been, and what are projected to be, the implications of institutional and policy changes and funding (e.g., private versus public investment; intellectual property rights [IPR]; legislative frameworks) on access to AKST, on innovation systems and on ownership of knowledge? How will AKST influence social, environmental and economic outcomes of agricultural and food systems?

Other central issues relating to hunger, nutrition, human health, poverty, livelihoods and the economy, as well as productivity and technologies are part of the sustainability goals and thus further emphasized in the document.

Diversity of views and value systems represented in the IAASTD

AKST is not an entity; it is a diverse field of knowledge and values. Achieving development and sustainability goals requires probing and experimentation, negotiation, and learning among diverse voices and interpretations, as well as taking into account place-based and context-relevant factors and voices to address the multiple functions of agriculture. The IAASTD has made clear how contested AKST are among the hundreds of professionals involved, especially formal AKST. Conflicting perspectives on AKST have led to different options for policy-making, and understanding the competing interpretations of AKST does not guarantee a consensual outcome. IAASTD focuses on AKST issues most relevant to development and sustainability goals.

1.1.2 Agriculture and its global context

Importance of agriculture. Agriculture as the source of human food, animal feed, fiber and fuel plays a key role in efforts to achieve global sustainable development. It is a major occupational sector in developing countries, with the poorest countries being those with predominantly agricultural economies and societies (FAO, 2000). Approximately 2.6 billion people—men, women and children —rely on agricultural production systems, be it farming, livestock production, forestry or fishery. Food security for a growing world population is positioned to remain a challenge in the next few decades. Most food is produced in Asia and other densely populated poor regions, and most of that food is consumed domestically. Because of the high diversity of agricultural systems across the world IAASTD decided to carry out five sub-global assessments in addition to the global one, in order to adequately address issues in the major agricultural regions of the world. These regions have developed to their current state for a variety of reasons, and a more specific reorientation of AKST is likely to be more effective if it addresses region-specific issues in agriculture, development and sustainability. The IAASTD has put particular emphasis on addressing issues relevant to tackling poverty reduction, which is central to the Millennium Development Goals to be achieved by 2015, though these issues are also expected to remain important long beyond that date.

In parallel with the spread and growth of human population, particularly during the last 300 years, but at a particularly impressive rate since 1950, the transformation of natural ecosystems into agriculturally used and managed land has accelerated, which coincides with the time when formal AKST began to have a significant impact. The world population grew from about 2.5 billion people in 1950 to 6.5 billion in 2005, i.e., by a factor of 2.6; in most countries, growth rates have just recently begun to decrease. Trends indicate that the global population will reach between 7.5 and 11 billion people by 2050, depending on the expected average number of children per women (Figure 1-1).

World agricultural output, or more specifically, food output as measured in cereal and meat production, in turn, increased even more during the same period, due to large increases in fertilizer use, herbicides, plant and animal breeding, and extension of irrigated area (Figure 1-2). The total cultivated area increased much less, i.e., from 1.4 to 1.5 million ha between 1950 and 2005 (Wood et al., 2000, based on FAO data), although fallow systems were greatly reduced.

For similar figures indicating equally moderate growth of crop area see also the Millennium Ecosystem Assessment (MA, 2005a). However, more land was converted to cropland in the 30 years after 1950 than in the 150 years between 1700 and 1850 (MA, 2005a). More than half of all the synthetic nitrogen fertilizer ever applied on the planet has been used since 1985, and phosphorus use tripled between 1960 and 1990 (MA, 2005b). Globally, agricultural output has been growing at about 2% per year since 1960, with higher rates in developing countries because area productivity, particularly in sub-Saharan Africa and Latin America, is still much lower than in industrialized countries and in Asia (FAO, 2006a). Along with an increase in agricultural output, water use in agriculture has increased to 7,130 cubic kilometers today and is expected to double by 2050 (CA, 2007). Another form of competition has recently been observed between the use of crops for food and feed and the use of the same crops (e.g., maize) for biofuels; moreover, a competition at the world level is rising for the supply of protein-rich animal feeds.

Today's land use patterns in general reveal the importance of agriculture as a major land management system transforming and making use of natural ecosystems. Given a global land surface (without Antarctica) of 13,430 million ha (FAOSTAT, 2006), there are still about 30% forest ecosystems (nearly 4,000 million ha), part of which are the least converted in a biological sense. About a further 26% (3,400 million ha) are pastureland (FAOSTAT, 2006), of which about half was converted from natural grassland and the rest from forestland or woodland. About 11.5% are cropland (1,500 million ha) (FAOSTAT, 2006), most of which was also converted from forestland. The remaining share of the global land surface are deserts, shrubland and tundra (about 25%), inland water surfaces and wetlands (about 4%), and built up land for human settlements and other infrastructure (about 5%). In sum, more than half of the earth's land surface is intensively used for agricultural purposes such as cultivation, grazing, plantation forestry and aquaculture; and since 1950 one third of the soil has been profoundly altered from its natural ecosystem state because of moderate to severe soil degradation (Oldeman et al., 1990).

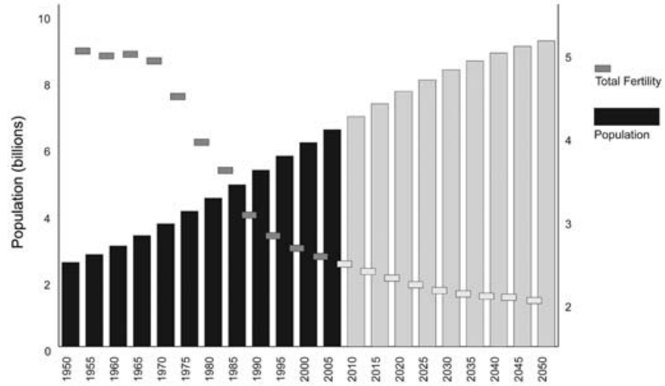


Figure 1-1. *Total world population 1950-2050 and average number of children per woman (total fertility).* Source: UNFPA, 2007

Multifunctionality of agriculture. As an activity, agriculture has multiple outputs and contributes to several ends at the same time (Abler, 2004). Agricultural resource management thus involves more than maintaining production systems. Services such as mitigating climate change, regulating water, controlling erosion and support services such as soil formation, providing habitats for wildlife, as well as contributions to cultural activities such as use and preservation of landscapes and spiritual sites are some of the positive functions that agriculture provides. The OECD identifies two key elements of multifunctionality: externalities and jointness (OECD, 2005). Agriculture uses public goods—natural resources (landscapes, plants, animals, soils, minerals, water and atmospheric N and C) for the production of public services, common goods, and private goods (food, feed, fiber, fuel). These natural resources are controlled and distributed partly through public entities and partly via privately producing and marketing entities; hence the issue of externality of costs are borne by the public. Agriculture is embedded in local and regional contexts and is always bound to particular, socially defined relationships and interdependencies between the production of private goods and the use and production of multifunctional public goods, which leads to the issue of jointness (Abler, 2004).

Globalization in agriculture

Globalization in agriculture, aided by information and communication technologies (ICT), has resulted in economic opportunities as well as challenges, particularly in developing countries. Globalization is typified by the increased interlinkage and concentration at almost all stages of the production and marketing chain, with functional and regional differentiations, and includes transnational corporations that are vertically and horizontally integrated in globalization and their increasing power over consumers and agricultural producers. Globalization is also characterized by growing investments in agriculture, food processing and marketing, and increasing international trade in food facilitated by reduced trade barriers (FAO, 2003). The creation of intellectual property rights has become an increasingly important source of competitive advantage and accumula-

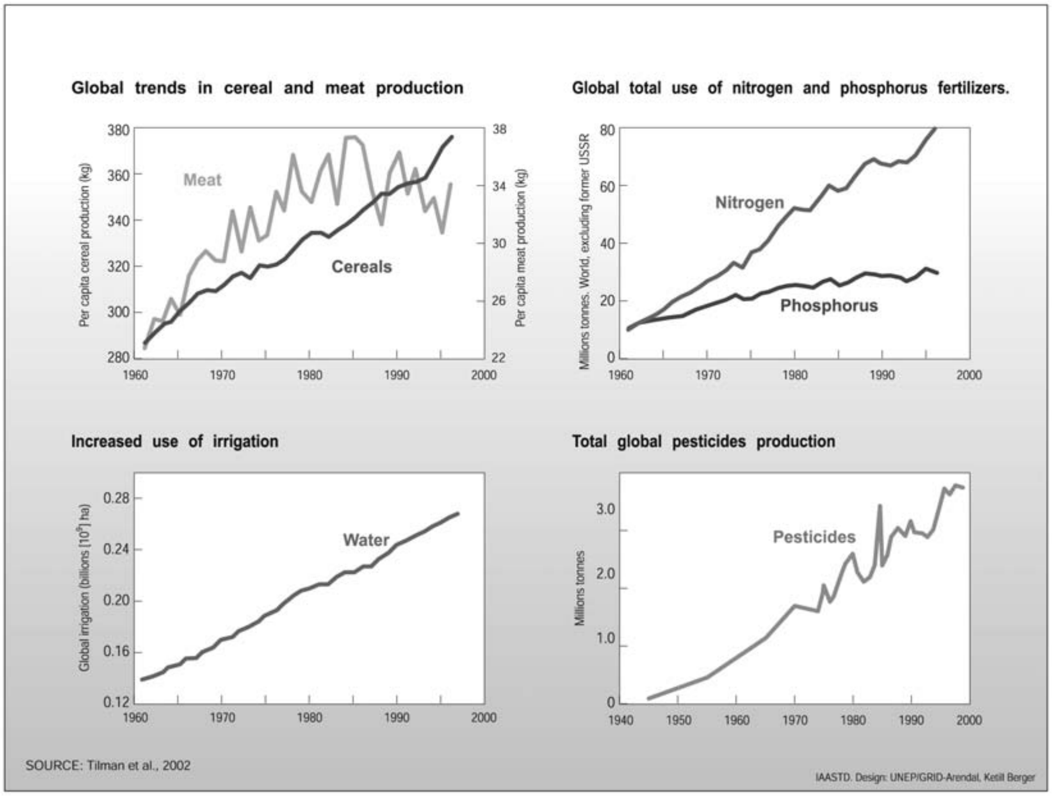


Figure 1-2. *Global trends in cereal and meat production; nitrogen and phosphorus fertilizer use; irrigation, and pesticide production.*

tion in the production and trade of agricultural goods. Globalization has resulted in national and local governments and economies ceding some sovereignty as agricultural production has become increasingly subject to international agreements, such as the World Trade Organization's Agreement on Agriculture (WTO, 1995).

The progressive expansion of commercial-industrial relations in agriculture has put further strain on many small-scale farmers in developing countries who must also contend with direct competition from production systems that are highly subsidized and capital intensive, and thus able to produce commodities that can be sold more cheaply. Newly industrialized countries like India have increasingly subsidized inputs in agriculture since the early 1980s (IFPRI, 2005).

Competition, however, does not only originate in subsidies from agricultural policies of richer countries; it may also derive from large entrepreneurial holdings that have low production costs, which are primarily but not exclusively found in developing countries. Three phenomena related to globalization are specific for a number of countries: the growing impact of supermarkets and wholesalers, of grades and standards, and of export horticulture, have substantially favored large farms (Reardon et al., 2001, 2002, 2003) except when small farmers get special assistance through subsidies, micro-contracts or phytosanitary programs (cf. Minten et al., 2006), for example. A steady erosion of local food production systems and eating patterns has accompanied the net flow of food from poorer to richer countries (Kent, 2003).

While average farm sizes in Europe and North America have increased substantially, in Asia, Latin America, and in some highly densely populated countries in Africa, average farm sizes have decreased significantly in the late 20th century, although they were already very small by the 1950s (Eastwood et al., 2004; Anriquez and Bonomi, 2007). These averages conceal vast and still growing inequalities in the scale of production units in all regions, with larger industrialized production systems becoming more dominant particularly for livestock, grains, oil crops, sugar and horticulture and small, labor-intensive household production systems generally becoming more marginalized and disadvantaged with respect to resources and market participation. In industrialized countries, farmers now represent a small percentage of the population and have experienced a loss of political and economic influence, although in many countries they still exercise much more power than their numbers would suggest. In developing countries agricultural populations are also declining, at least in relative terms, with many countries falling below 50% (FAO, 2006a). Although, there are still a number of poor countries with 60-85% of the population working in small-scale agricultural systems. The regional distribution of the economically active population in agriculture is dominated by Asia, which accounts for almost 80% of the world's total active population, followed by Africa with 14%. Although the overall number of women in agriculture is falling, the relative share is rising, i.e., women make up an increasing fraction of the labor force in agriculture, especially in sub-Saharan Africa where hoe agriculture is practiced extensively (Spieldoch, 2007). While the agrifood sector *in toto* may still account for a large portion of national economies, with the production of inputs, industrial transformation and marketing of food, and transport becoming more important in terms of value and employment, agricultural production itself accounts for a diminishing share of the economy in many countries while the other sectors are expanding. Average farm sizes vary greatly by region (see Table 1-2).

Trade and the agricultural sector

International trade and economic policies can have positive and negative effects on different development and sustainability goals. In addition, AKST can have substantial roles in the formation of better policies. Poverty-affected agricultural producers in particular have been poorly served by trade; unless they have better access to efficient and equitable market systems, they cannot easily benefit from AKST initiatives (IFAD, 2003). Trade policies and market dynamics are thus key determinants of whether and how AKST systems can effectively address poverty, hunger, rural livelihoods and environmental sustainability. Although most agricultural production is not traded internationally, national agricultural planning and AKST investment is increasingly oriented towards export markets and designed to comply with international trade rules. Agricultural trade has been increasing in developing country regions particularly since the 1970s (FAO, 2005a).

The focus on export has left many small-scale producers, i.e., the majority of the rural poor, vulnerable to volatile international market conditions and international competition, often from subsidized producers in the North. The globalization of agriculture has been accompanied by concentration of market power away from producers into the hands of a limited number of large-scale trade and retail agribusiness companies. Corporate concentration along the agrifood value chain can have a significant impact on international commodity prices, which have recently risen but have generally been low relative to industrial and manufactured goods (FAO, 2005a). In addition, increased international trade in agricultural commodities has often led to overexploitation of natural resources, and increased energy use and greenhouse gas (GHG) emissions. Overall the impact of trade liberalization has been uneven in industrialized and developing countries.

Table 1-2. **Approximate farm size by world region.**

World region	Average farm size, ha
Africa	1.6
Asia	1.6
Latin America and Caribbean	67.0
Europe*	27.0
North America	121.0

Source: Nagayets, 2005; von Braun, 2005.

*data includes Western Europe only.

Small-scale farming as a particular challenge for agriculture

Despite the crucial role that agriculture has for rural populations in transition and developing countries, agriculture-based livelihoods and rural communities are endangered by poverty worldwide. Based on FAO census data, it has been estimated that about 525 million farms exist worldwide, providing a livelihood for about 40% of the world's population. Nearly 90% of these are small farms defined as having less than two hectares of land (see e.g., Nagayets, 2005). Small farms occupy about 60% of the arable land worldwide and contribute substantially to global farm production (Figure 1-3). In Africa, 90% of agricultural production is derived from small farms (Spencer, 2002). If a high percentage of a country's population is engaged in agriculture and derives its livelihood from small-scale farming, the whole sector is predominantly subsistence-oriented, which makes livelihoods extremely vulnerable to changes in direct drivers such as diseases, pests, or climate, even though its sensitivity to indirect drivers such as markets, infrastructure and external inputs is less pronounced. Not surprisingly, subsistence farmers tend to be very aware of their multiple vulnerabilities and therefore adopt diverse risk-minimizing and mitigating strategies.

Poorly developed market infrastructure such as rural roads and postharvest facilities are among the factors that have limited market access for outputs and inputs (e.g., fertilizer) for the majority of small-scale farmers (FAO, 2005a) (Figure 1-4).

Growing disparities have developed over the last 50 years between small-scale farming that follows local practices and industrial agricultural systems that have incorporated formal AKST. A key factor is the tremendous increase in labor productivity in industrialized agriculture and the stagnating labor productivity in most small-scale systems

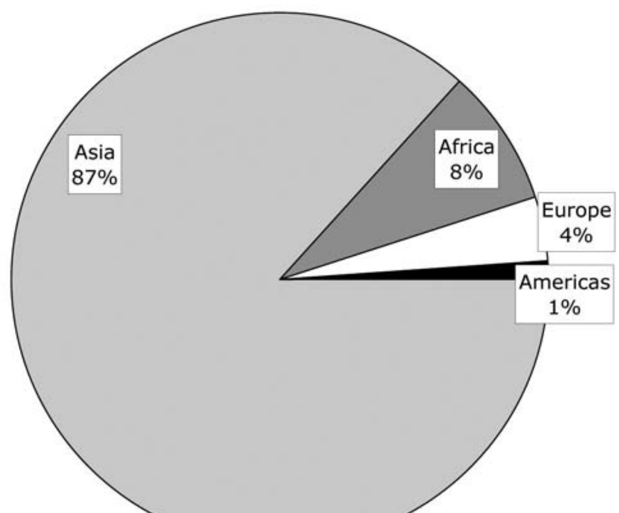


Figure 1-3. *Regional distribution of small-scale farms.* Source: Nagayets, 2005 based on FAO 2001c, 2004c and national statistical agencies.

Note: Small-scale farms are defined as those of less than 2 hectares. The total number of small-scale farms is 404 million.

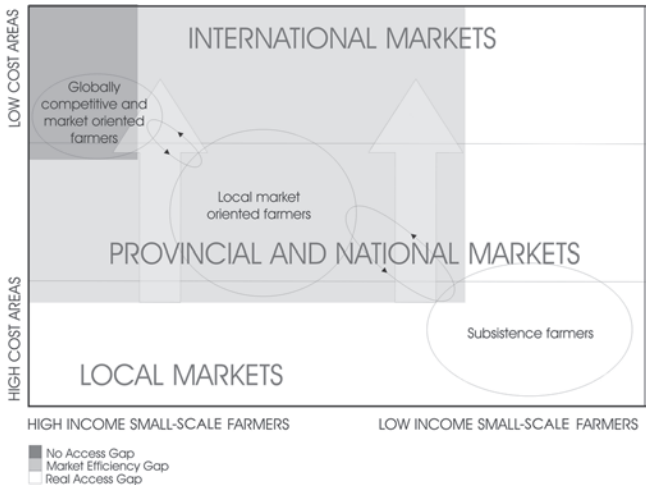


Figure 1-4. *Small-scale farmer heterogeneity; access and market gap.* Source: Huvio et al., 2004

in developing countries (see Mazoyer and Roudard, 1997; see Figure 1-5). In parallel, work incomes increased most in industrialized countries (Mazoyer, 2001) and prices of industrial manufactured goods generally increased relative to agricultural goods, adding to disparities due to differences between productivity levels.

Many small-scale systems have not been able to compete with industrialized production systems for a number of reasons, including subsidies given to farmers in industrialized countries, cheap fossil energy in mechanized systems compared to metabolic energy in small-scale systems, stabilized market prices in industrialized countries as opposed to completely liberalized prices in developing countries, and the inability to access inputs on favorable terms as compared to large-scale systems. Countries and communities based mainly on small-scale economies are the poorest in the world today, as well as the most threatened by ecosystem degradation (UNEP, 2002). Most small farms with a size of less than two hectares are in Asia (87%), followed by Africa (8%), Europe (4%) and America (1%) (Nagayets, 2005). While the trend in industrial countries has been an increase in average farm size (from about ten to more than 100 ha), it has been the opposite in densely populated developing countries (from about 2 to <1 ha). In some contexts small farm size may be a barrier to investment, however, small farms are often among the most productive in terms of output per unit of land and energy. As yet they are often ignored by formal AKST.

Historical trends suggest that small-scale farms will continue to dominate the agricultural landscape in the developing world, especially in Asia and Africa, at least for the coming two to three decades (Nagayets, 2005). The absolute number of small farms is still increasing in a number of countries on these continents, due to further subdivision of landholdings and expansion of agricultural land. This is also reflected in the labor force differences between countries (see Figure 1-6).

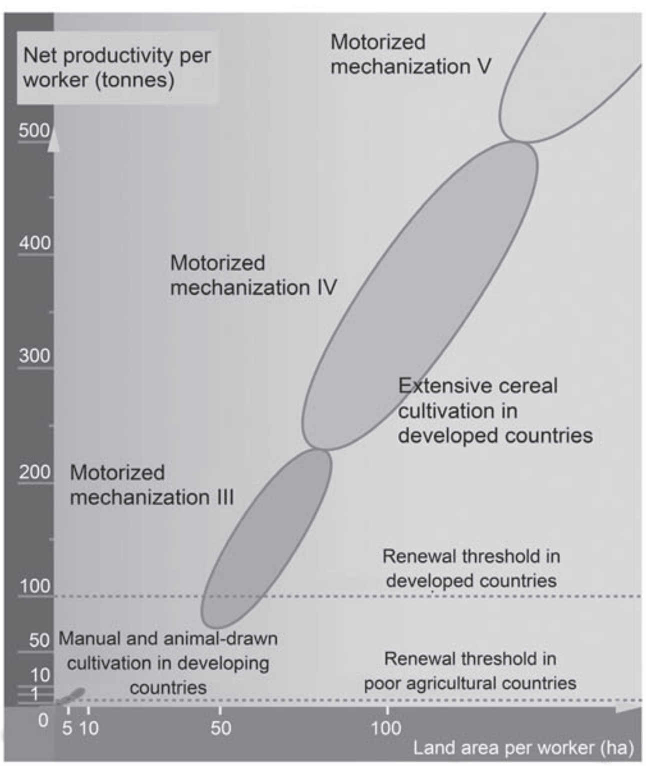


Figure 1-5. *Productivity in developing country cereal systems using motorized mechanization and chemicals and in those using manual or animal-drawn cultivation.* Source: Mazoyer, 2001.

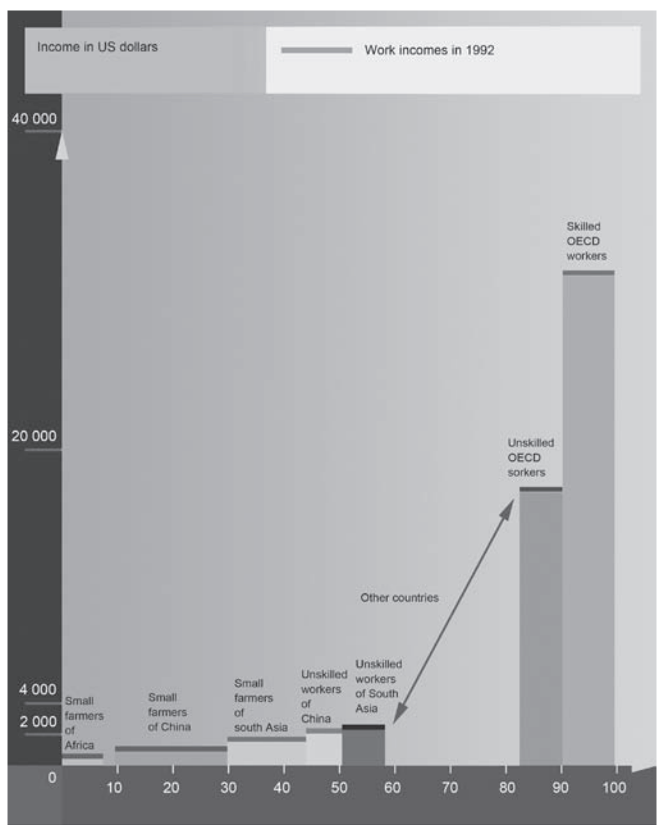


Figure 1-6. *Labor force diversity and income circa 1992.* Source: Mazoyer, 2001.

Ecological changes induced by all types of agriculture

Agricultural activities require change of the natural ecosystem to an agricultural system that is oriented towards human use. This concerns local agricultural practices as well as industrial models and all forms in between. Deforestation was, and still is, the first major step to convert primary tree vegetation into cropland or grazing land, thereby reducing biological diversity in most instances. Other environmental impacts relate to soil, physical, biological and chemical degradation and problems of water quality and quantity.

On the one hand, even in traditional agricultural systems cropping involves tillage operations that may cause accelerated soil erosion. Soil degradation is highest on cropland, but it also affects grazing land and even forest plantations and other agricultural activities (Hurni et al., 1996). Small-scale farming can damage the environment, particularly when practiced under increasing population pressure and with scarce suitable land, involving shortened fallow periods and expansion of cropland areas into unsuitable environmental situations such as steep slopes. This process was particularly accelerated during the past 100 years due to the expansion of farming, despite the emergence of agroecological practices and widespread efforts to introduce sustainable land management technologies on small farms (Liniger and Critchley, 2007).

On the other hand, the advancement of industrial models in agriculture has promoted the simplification of agroecosystems, with reductions in the number of and variability within species. Increased specialization at the field, farm, and landscape levels produces monocultures that potentially increase environmental risks because they reduce biodiversity, ecosystem functions and ecological resilience, and they may be highly vulnerable to climate change. These systems have both benefited and endangered human health and the environment in many industrial countries. While industrial production systems yield large volumes of agricultural commodities with relatively small amounts of labor, they are often costly in terms of human health (Wesseling et al., 1997; Antle et al., 1998; Cole et al., 2002), have additional negative environmental impacts, and are frequently inefficient in terms of energy use. Runoff and seepage of synthetic fertilizers and concentrated sources of livestock waste damage aquifers, rivers, lakes, and even oceans—with costly effects on drinking water quality, fish habitat, safety of aquatic food, and recreational amenities (FAO, 1996a; WWAP, 2003; FAO, 2006b; CA, 2007). This is occurring particularly rapidly in some emerging industrialized countries. However, in countries with increasing industrial production one may also observe more effective food regulation and safety protocols, providing enhanced health protection against foodborne illness. Commercial pesticides often affect non-target organisms and their habitats, and especially when used without strict attention to recommended usage and safety protocols, can negatively affect the health of farm workers (WWAP, 2003). The international transportation of crops, livestock and food products has promoted the global spread of agricultural pests and disease organisms. Many recent significant disease outbreaks have been due to informal, unregulated trade, smuggling, or the industrial restructuring of food systems. The global atmospheric transport of agricultural pollutants, including pesticides, the breakdown products of other agrichemicals, and greenhouse gases, means that environmental costs are also borne by populations far removed from sites of production (Commoner, 1990; UNEP, 2005).

Food security and food sovereignty

Improvement of rural livelihoods, human health and nutrition. Livelihoods are a way of characterizing the resources and strategies individuals and households use to meet their needs and accomplish their goals. Livelihoods are often described in terms of people, their capabilities and their means of living (Chambers and Conway, 1991). Livelihoods encompass income as well as the tangible and intangible resources used by the household to generate income. Livelihoods are basically about choices regarding how, given their natural and institutional environments, households combine resources in different production and exchange activities, generate income, meet various needs and goals, and adjust resource endowments to repeat the process.

Food security exists when all people of a given spatial unit, at all times, have physical and economic access to safe and nutritious food that is sufficient to meet their dietary needs and food preferences for an active and healthy life, and is obtained in a socially acceptable and ecologically sustainable manner (WFS, 1996). *Food sovereignty* is defined as the right of peoples and sovereign states to democratically determine their own agricultural and food policies.

Food sovereignty, the right to food, equitable distribution of food, and the building of sufficient reserves to ensure food security for unexpected events of unpredictable duration and extent (such as hurricanes or droughts), have so far been strategies at the national and international levels with obvious advantages (Sen and Drèze, 1990, 1991). Assumptions that national average food production figures can indicate food security are belied by internal distribution constraints, political limitations on access, inabilities to purchase available food, overconsumption in segments of a population, policies which encourage farmers to shift from family food production to cash crops, crop failure, storage losses, and a range of other factors. Unless all persons feel food secure and are confident in their knowledge of the quality, quantity, and reliability of their food supply, global food security averages cannot be extrapolated to specific cases. The ability to access adequate food covers industrial and cash-cropping farmers, subsistence farmers during crop failures, and non-agriculturists. Access can be limited by local storage failures, low purchasing power, and corrupt or inefficient distribution mechanisms, among other factors. Quality of food, in terms of its nutritional value, is determined by freshness or processing and handling techniques, variety, and chemical composition. A new component in the food security debate is increasing malnutrition in agricultural areas where cash crops, including biofuel crops, replace local food crops.

Food insecurity has been defined in terms of availability, access, stability and utilization. Food insecurity occurs when there is insufficient food over a limited period of time, such as a "hungry season" prior to harvest, or for extended or recurring periods. Food insecurity may affect individuals, households, specific population groups or a wider population. The basic unit for food security within a poor community is the family. Parental sacrifices for children's welfare are demonstrated daily under conditions of scarcity. Families are affected by certain policies, which, perhaps as externalities, create unemployment, inconsistent agricultural prices, and credit-based farming and lifestyles; this is why they are the logical focus for definitions of food security. A family's food supply must be secure "at all times", not simply on average, thereby implying that local storage facilities must be effective, that staples are available out of season, and that distribution systems are uninterrupted by adverse weather, political or budgetary cycles. Food insecurity can be limited to small pockets or affect entire regions. Famine, in contrast, is used to define chronic hunger affecting entire populations over an extended period of time in a famine-affected area, potentially leading to the death of part of the population. Famine may have multiple causes, from political and institutional ones to social, ecological and climatic causes (WFS, 1996).

Temporary food insecurity may be overcome when a harvest comes or when conditions such as weather, wages or employment opportunities improve; it may require action before, during, and even after the period of food insecurity. Household livelihood strategies reflect this. For example, a household that anticipates an upcoming "hungry season" may seek to accumulate savings in advance in the form of cash, grain, or livestock, or it may diversify its economic activities by sending a household member away to seek employment elsewhere. A household experiencing a hungry season may draw on those savings or receive remittances from household members working elsewhere. In more severe cases, a household may borrow money, draw on informal social networks, seek food aid, or even be forced to sell assets (decapitalization)—perhaps achieving temporary food security only at the expense of the ability to generate income in subsequent periods. Other strategies include post-harvest technologies, which may improve storage of products and hence increase both the quantity and quality of available food.

In seeking to meet current needs, some households may be forced to deplete their resources to the point that they remain food insecure for extended periods of time or for recurring periods over many years. In extreme cases, households may have depleted their reserves, exhausted other assets, and be reduced to destitution—with their labor being their only remaining asset. The worst off may, in addition, be burdened with debt and poor health, further limiting their ability to meet current needs, let alone begin rebuilding their capacity to face future challenges.

Whether addressing temporary or chronic food insecurity, it is clear that the challenge goes well beyond ensuring sufficient food in any given period of time. Rather, understanding and meeting the challenge requires a broader perspective on the full range of needs and choices faced by households, the resources and external conditions that influence those choices, and the livelihood strategies that could enable families to meet their food needs over time.

Availability of and access to animal genetic resources can be a problem for pastoralists and poor households. An emerging problem is management of epidemics, as currently illustrated in Asia and increasingly in other parts of the world, where thousands of animals are killed prophylactically because of avian influenza (GTZ, 2006).

1.1.3 Emerging issues

What can agriculture offer globally to meet emerging global demands, such as mitigating the impacts of climate change, dealing with competition over (dwindling) resources? Projections of the global food system indicate a tightening of world food markets, with increasing scarcity of natural and physical resources, adversely affecting poor consumers. Improved AKST in recent years has helped to reduce the inevitable negative environmental impacts of trade-offs between agricultural growth and environmental sustainability at the global scale. Growing pressure on food supply and natural resources require new investment and policies for AKST and rural development in land-based cropping systems.

AKST is well placed to contribute to emerging technologies influencing global change, such as adaptations to climate change, bioenergy, biotechnologies, nanotechnology, precision agriculture, and information and communication technologies (ICT). These technologies present both opportunities and challenges, and AKST can play a central role in accessing the benefits while managing the potential risks involved.

About 30% of *global emissions* leading to climate change are attributed to agricultural activities, including land use changes such as deforestation. Additionally, environmental variations resulting from climate change have also adversely affected agriculture. In extreme cases, severe droughts and floods attributed to climate change make millions of people in resource poor areas particularly vulnerable when they depend on agriculture for their livelihoods and food. AKST can provide feasible options for production systems, manufacturing and associated activities which will reduce the dependence on depleting fossil fuels for energy. Similarly, AKST can provide information about the consequences of agricultural production on the hydrology of watersheds and groundwater resources. AKST can also be harnessed to reduce greenhouse gas (GHG) emissions from agriculture, as well as increase carbon sinks and enhance adaptation of agricultural systems to climate change impacts (Chapter 6).

Continuing structural changes in the *livestock* sector, driven mainly by rapid growth in demand for livestock products, bring about profound changes in livestock production systems. Growing water constraints are a major driver of future AKST. Soil degradation continues to pose a considerable threat to sustainable growth of agricultural production and calls for increased action at multiple levels; this can be strongly supported by AKST. Forestry systems will remain under growing pressure, as land use systems and urbanization continue to spread particularly into these ecologically favorable areas. Biodiversity is in danger as a result of some agricultural practices. Finally, there is significant scope for AKST and supporting policies to contribute to more sustainable fisheries and aquaculture, leading to a reduction of overfishing in many of the world's oceans.

Bioenergy is being promoted in several countries as a lucrative option to reduce GHG emissions from fossil fuels; however, controversy is increasing on the economic, social and ecological cost/benefit ratio of this option. On-farm bioenergy production utilizing farm residues has potential. However, studies have revealed that bioenergy demand is sensitive not only to biomass supply, but also to total energy demand and competitiveness of alternative energy supply options (Berndes et al., 2003). Additionally, the environmental consequences and social sustainability aspects of the processing of crops and feedstocks as biofuels have not yet been thoroughly assessed.

Biotechnology has for millennia contributed to mankind's well-being through the provision of value-added foods and medicines. It has deep roots in local and traditional knowledge and farmer selection and breeding of crops and animals, which continues to the present day. Micropropagation of plants by tissue culture is now a common technique used to produce disease-free plants for both the agricultural and ornamental industries. Recent advances in the area of genomics, including the ability to insert genes across species, have distinguished "modern biotechnology" from traditional methods. Resulting transgenic crops, forestry products, livestock and fish have potentially favorable qualities such as pest and disease resistance, however with possible risks to biodiversity and human health. Other apprehensions relate to the privatization of the plant breeding system and the concentration of market power in input companies. Such issues have underpinned widespread public concern regarding transgenic crops. Less contentious biotechnological applications relate to bioremediation of soils and the preparation of genetically engineered insulin. Commercial transgenic agricultural crops are typically temperate varieties such as corn, soya and canola, which have been engineered to be herbicide resistant or to contain the biological agent Bt (bacillus thuringiensis), traits that are not yet widely available for tropical crops important to developing countries. Transgenic crops have spread globally since 1996, more in industrialized than in developing countries, covering about 4% of the global cropland area in 2004 (CGIAR Science Council, 2005).

Current trends indicate that transgenic crop production is increasing in developing countries at a faster rate than in industrialized nations (Brookes and Barfoot, 2006). This is occurring against a background of escalating concerns in the world's poorest and most vulnerable regions regarding environmental shocks that result from droughts, floods, marginal soils, and depleting nutrient bases, leading to low productivity. Plant breeding is fundamental to developing crops better adapted to these conditions. The effectiveness of biotechnologies will be augmented, however, by integrating local and tacit knowledge and by taking into account the wider infrastructural and social equity context. Taking advantage of provisions under the international protocol on biosafety (Cartagena Protocol on Biosafety) as well as establishing national and regional regulatory regimes are essential elements for using AKST in this domain.

1.2 Conceptual Framework of the IAASTD

1.2.1 Framework for analysis—centrality of knowledge

Conceptual framework of the AKST assessment (Figure 1-7). There is huge diversity and dynamics in agricultural production systems, which depend on agroecosystems and are embedded in diverse political, economic, social and cultural contexts. Knowledge about these systems is complex. The AKST assessment considers that knowledge is coproduced by researchers, agriculturalists (farmers, forest users, fishers, herders and pastoralists), civil society organizations and public administration. The kind of relationship within and between these key actors of the AKST system defines to what degree certain actors benefit from, are affected by or excluded from access to, control over and distribution of knowledge, technologies, and financial and other resources required for agricultural production and livelihoods. This puts policies relating to science, research, higher education, extension and vocational training, innovation, technology, intellectual property rights (IPR), credits and environmental impacts at the forefront of shaping AKST systems.

Knowledge, innovation and learning play a key role in the inner dynamics of AKST. But it is important to note that these inner dynamics depend on how the actors involved respect, reject or re-create the values, rules and norms implied in the networks through which they interrelate. The IAASTD considers that its own dynamics strongly depend on related development goals and expected outputs and services, as well as on indirect and direct drivers mainly at the macro level, e.g., patterns of consumption or policies.

The AKST model emphasizes the centrality of knowledge. It is therefore useful to clarify the differences between "information" and "knowledge". Knowledge—in whatever field—empowers those who create and possess it with the capacity for intellectual or physical action (ICSU, 2003). Knowledge is fundamentally a matter of cognitive capability, skills, training and learning. Information, on the other hand, takes the shape of structures and formatted data that remain passive and inert until used by those with the knowledge needed to interpret and process them (ICSU, 2003). Information only takes on value when it is communicated and there is a deep and shared understanding of what that information means—thus becoming knowledge—both to the sender and the recipient.

Such an approach has direct implications for the understanding of science and technology. The *conventional* distinction between science and technology is that science is concerned with searching for and validating knowledge, while technology concerns the application of such knowledge in economic production (defined broadly to include social welfare goals). In most countries institutional and organizational arrangements are founded on this distinction.

However, this distinction is now widely criticized in contemporary science and development literature, both from a conceptual point of view and in terms of practical impacts. Gibbons and colleagues are a good example of this critical debate: they distinguish between "mode 1" and "mode 2" styles of knowledge development (Gibbons et al., 1994; Nowotny et al., 2003). In very simple terms, the distinction is that "mode 1" approaches (the traditional view) argue for a complete organizational separation between scientific research on the one hand and its practical applications for economic and social welfare on the other. Conversely "mode 2" approaches argue for institutional arrangements that build science policy concerns directly into the conduct

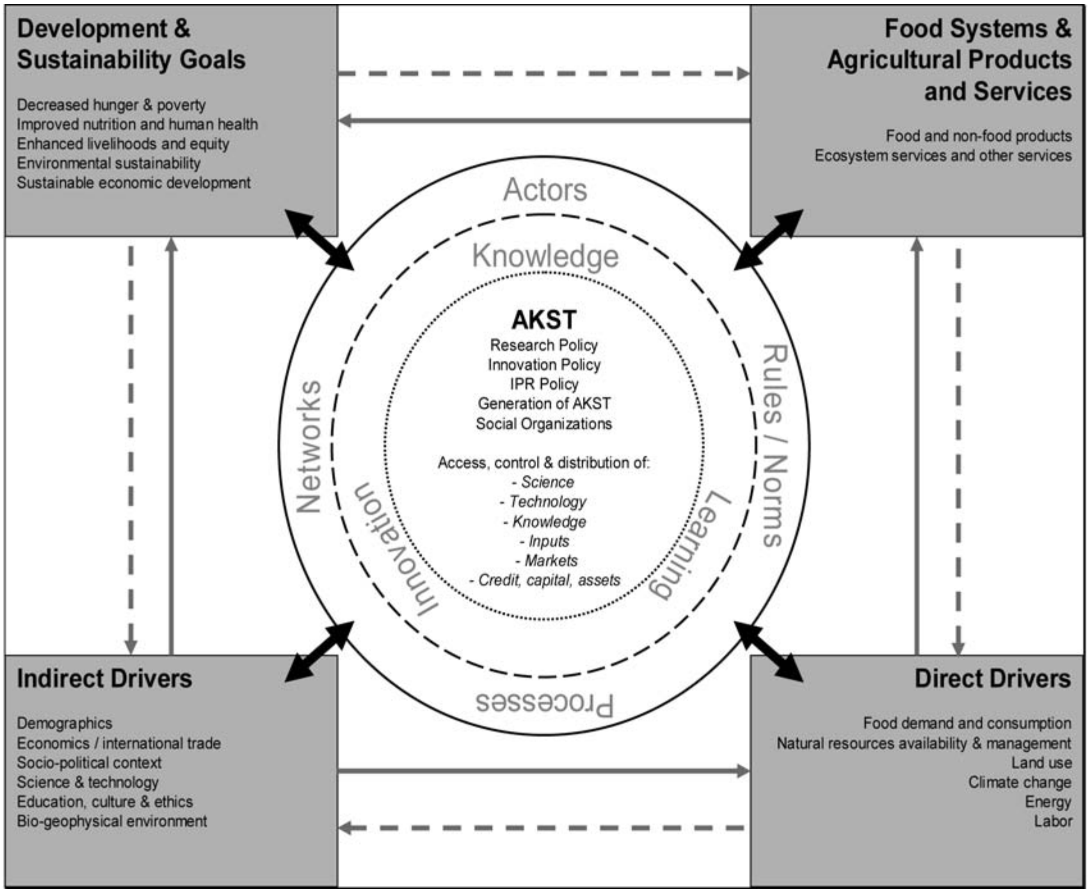


Figure 1-7. *Conceptual framework of the IAASTD.*

of research and development (R&D). As a practical contemporary example, this debate is very much at the heart of current discussions about how agricultural research should be conducted in all countries.

Innovation and innovation systems. Scientific and technological knowledge and information can (1) add value to resources, skills, knowledge, and processes, and (2) create entirely novel strategies, processes, and products (World Bank, 2006a). An innovation system may be defined as the network of agents, usually organized in an interdisciplinary and transdisciplinary manner, with interactions that determine the innovative impact of knowledge interventions, including those associated with scientific research. The concept is now used as a kind of shorthand for the network of interorganizational linkages that apparently successful countries have developed as a support system for economic production. In this sense it has been explicitly recognized that economic creativity actually relies on the quality of "technology linkages" and "knowledge flows" amongst and between economic agents. Where interactions are dynamic and progressive, great innovative strides are often made. Conversely, where systemic components are compartmentalized and isolated from each other, the result is often that relevant research bodies are not innovative. Some approaches suggest that innovation systems cannot be separated from the social, political and cultural context from which they emerge (Engel, 1997), and this context therefore has to be included in the analysis of AKST. This implies a need to focus on those factors that enable the emergence of "innovative potential," rather than on factors related directly to specific innovations.

Collaborative learning processes. The creation of favorable conditions making it possible for different actors to engage in collaborative learning processes—i.e., the increase in space and capacity for innovativeness—has thus gained prime importance. Approaches based on linear understandings of research-to-extension-to-application are being replaced by approaches focusing on processes of communication, mutual deliberation, and iterative collective learning and action (van de Fliert, 2003). More concretely, this implies that sustainable use of natural resources requires a shift from a focus on technological and organizational innovation to a focus on the norms, rules and values under which such innovation takes place (Rist et al., 2006). The enhanced AKST model considers that values, rules and norms that are relevant to the promotion of agricultural development are constantly produced and reproduced by social actors who are embedded in the social networks and organizations to which they belong. Social networks are important spaces where the actors involved in the coproduction of knowledge share, exchange, compare and eventually socialize their individually realized perceptions of what is important, good, and bad, and enable the visions they have for their own families, communities and wider social categories to which they belong.

AKST-related policies. For the IAASTD model of AKST, policy referring to AKST must be understood in a broad sense. Policy can be thought of as a course or principle of action designed to achieve particular goals or targets. The idea of policy is usually associated with government bodies, but other types of organization also formulate policies—for example a local NGO may establish a policy about who is eligible for its programs (DFID, 2001). "Policy analysis" is the process through which the interactions at and between these various levels are explored and articulated. Policy relating to the AKST model is thus understood as the attempt to systematically intervene in the process of shaping and reshaping the interrelationships between the different actors, networks and organizations involved in the processes of coproduction of knowledge for more sustainable and propoor agriculture and food production.

1.2.2 Development and sustainability goals

Reduction of poverty and hunger. Poverty can be defined in different ways, each requiring its own measurement. Poverty can be measured in terms of access to the basic needs of life, such as nutrition, clean water and sanitation, education, housing and health care. An income level of US$1 per day is widely accepted as a rough indicator of poverty although there is general agreement that the multidimensional nature of poverty cannot be captured with this measure. Worldwide, about 1,200 million people live on less than US$1 per day; in percentage terms this is expected to drop from 19% of the world population in 2002 to 10% by 2015 (World Bank, 2006b), although in absolute numbers the difference will be smaller because by then the total population will be larger by about 800 million people. Moreover, many countries, particularly in Africa and South Asia, are not on track regarding achievement of the Millennium Development Goals (Global Monitoring Report, 2006) (Figure 1-8). Furthermore, these numbers should be interpreted with caution. Any change from the nonmonetary provision of goods and services to the cash market, such as a shift from subsistence to commercial crops, will appear as an increase in income whether or not there has been a concomitant improvement in standard of living or reduction in poverty. This indicator focuses our attention exclusively on income derived from market transactions and ignores other components of livelihood.

Approximately 852 million people are unable to obtain enough food to live healthy and productive lives (FAO, 2004a). Hunger is discussed here in the wider sense of encompassing both food and nutritional insecurity (UN Millennium Project, 2005). An estimated 800 million persons, i.e., more than half of the people living in extreme poverty, are occupied in the agricultural sector (CGIAR Science Council, 2005). Their livelihoods are usually derived from small-scale farming. In 1996, around 2.6 billion people, or 44% of the total world population were living in agriculture-dependent households, mostly in Asia and Africa (Wood et al., 2000). Poverty is thus disproportionately rural (poor farmers and landless people) despite ongoing migration from rural to urban areas. Among other factors such as civil wars and diseases, migration has led to an increase in female-headed households and intensified the already heavy workload of rural women (García, 2005).

Decapitalization (e.g., through sale of livestock and equipment), deterioration of infrastructure and natural capital (e.g., soils), and the general impoverishment of peasant communities in large areas in developing countries (for Africa, see Haggblade et al., 2004) remains a serious threat to livelihoods and food security. The loss or degradation of production assets is linked to the overexploitation of scarce resources (land, water, labor), markets that are inequitable (IFAD, 2003) and difficult to access, competition from neighboring farms, and in some instances the combined effects of competition from the industrialized sector (leading to low prices), and the direct and indirect taxation of agriculture. It may also be a consequence of the barriers to capital accumulation and investment associated with the realities faced by some small-scale farmers (Mazoyer and Roudard, 1997). On the other hand, agricultural growth can, despite this difficult context, lead to important benefits for poverty alleviation (Byerlee et al., 2005). In some cases the beneficiaries are people remaining in small-scale agriculture but there may also be important opportunities for those who work, for example, in agriculture-related product processing activities.

Improvement of livelihoods, human health and nutrition. Even though a large number of people depend entirely on agriculture, off-farm income is important for many households that depend on agriculture for their livelihoods. The resulting variety of livelihood strategies can be thought of in terms of adjustments in the quantity and composition of an individual's or household's resource endowment. Different resource endowments and different goals imply different incentives, choices, and livelihood strategies.

Health is fundamental to live a productive life, meet basic needs and contribute to community life. Good health offers individuals wider choices regarding how to live their lives. It is an enabling condition for the development of human potential. The components of health are multiple and their interactions complex. The health of an individual is strongly influenced by genetic makeup, nutritional status, access to health care, socioeconomic status, relationships with family members, participation in community life, personal habits and lifestyle choices. The environment—natural, climatic, physical, social or workplace—can also play a major role in determining the health of individuals. For example, in most societies, biomass fuel collection is a woman's task. Women often spend hours collecting and carrying fuelwood back home over long distances. Poor women are among the more than two billion people who are unable to obtain clean, safe fuels and have to rely on burning biomass fuels such as wood, dung or crop residues. The time and labor spent in this way limits their ability to engage in other productive activities; and their health suffers from hauling heavy loads and from cooking over smoky fires (Lambrou and Piana, 2006). On the other hand about 50% of the health burden of malnutrition is attributable to poor water, sanitation and hygiene (Prüss-Üstün and Corvalán, 2006). For example, some long-standing problems such as mycotoxins continue

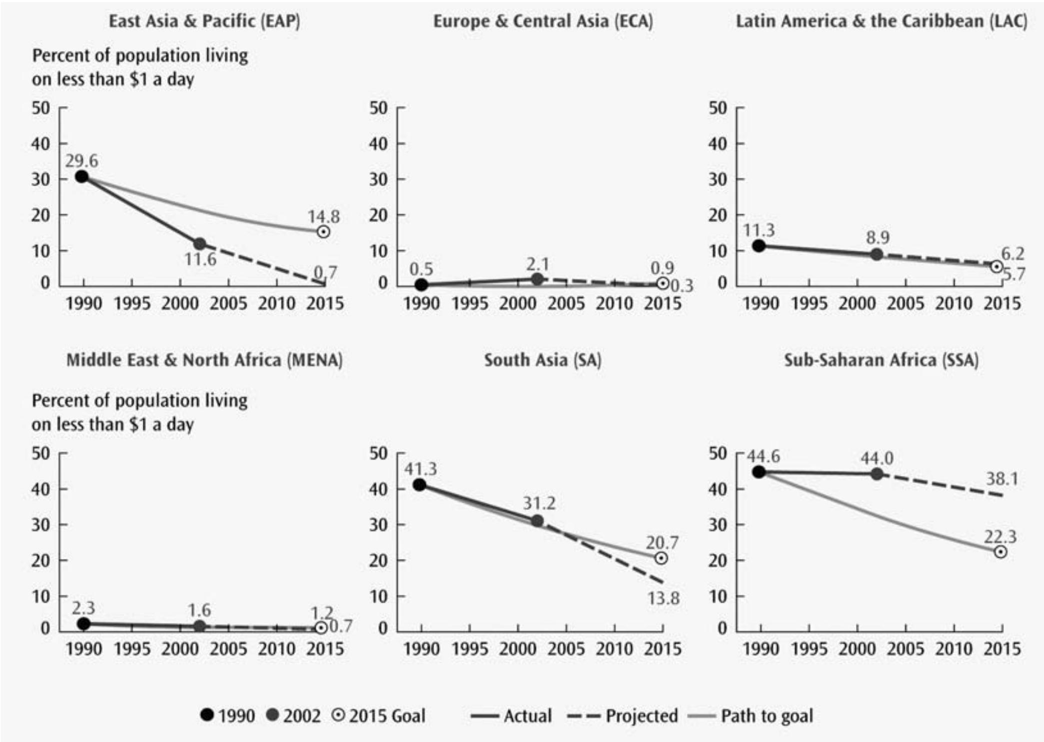


Figure 1-8. *Poverty by region, 1990-2002, and forecasts to 2015.* Source: Global Monitoring Report, 2006.

to significantly add to the health burden, especially of infants (Gong et al., 2004), and cause widespread problems with basic foodstuffs (Strosnider et al., 2006). This has become an issue for formal AKST, as is water quality, which is linked to improving rural livelihoods, human health and nutrition and to the covering of protein requirements, particularly in the case of children. Human health is also linked with animal health: numerous examples of zoonoses are reported, including avian influenza, hoof and mouth disease, and brucellosis.

In 50% of cases undernutrition is due to poor sanitation and diseases (Prüss-Üstün and Corvalán, 2006). This fundamental issue is reflected throughout the AKST context and emphasizes traditional food safety, including hygiene issues related to animal husbandry and phytosanitary protection, food storage in homes and food handling in developing countries. Furthermore, in developing countries such phytosanitary issues as Claviceps purpurea or ergotism, (which are no longer problems in the North because of highly protected industrial food production), are significantly adding to the health burden, especially of infants (Gong et al., 2004) and cause hygienic problems amongst billions with basic foodstuffs (Strosnider et al., 2006). Poverty and undernourishment are intimately linked. The MDG targets for 2015 are expected to be met by most regions except for sub-Saharan Africa in particular and South Asia (see Figure 1-9).

A direct consequence of poverty is undernourishment, which is an issue not only for the urban poor and for landless persons, but particularly for the underprivileged such as women and children. Undernourishment also affects rural people producing agricultural goods and services on farms that are too small, not productive enough, or too degraded to produce sufficient outputs for a decent living. Good nutrition has thus much to contribute to poverty reduction. It is intrinsic to the accumulation of human capital, since sound nutrition provides the basis of good physical and mental health, and thus of intellectual and social development and a productive life. If global poverty is to be reduced, agricultural development will have to pay particular attention to the problems faced by deprived small-scale producers and their families. Science and technology are expected to contribute to the achievement of this goal.

Promotion of socially equitable and environmentally and economically sustainable development. Sustainable development is about meeting current needs without compromising the ability of future generations to meet their own needs. Within this context, sustainability is envisaged within three key dimensions: social, environmental and economic, all three of which have direct and indirect linkages to agriculture. In the context of the IAASTD, the term "agriculture" encompasses crop cultivation, livestock production, forestry and fishery. This broader definition provides future opportunities for maximizing synergies in achieving development and sustainability goals. It serves the primary goal of providing sufficient and nutritious food for humankind, in the present and in the future. It is indisputable that agriculture as a sector cannot meet this goal on its own. Agriculture, however, fulfills a series of additional goals besides food production. Last but by no means least, agriculture ensures the delivery of a range of ecosystem services. In view of a globally sustainable form of development, the importance

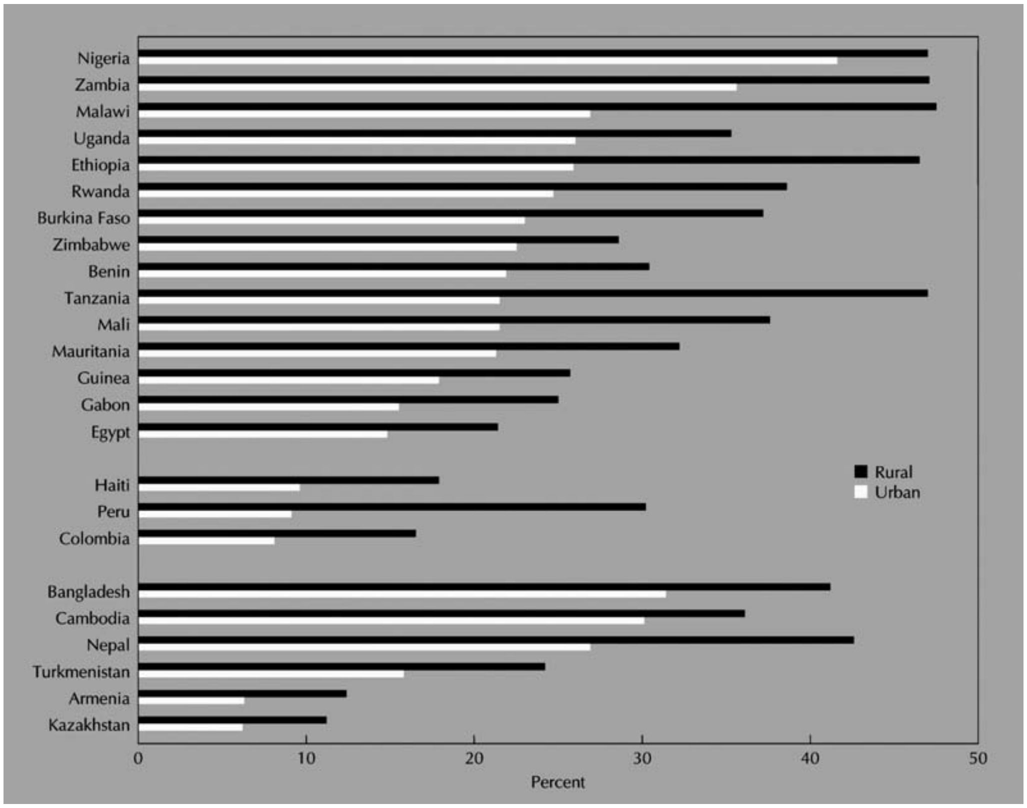


Figure 1-9. *Child malnutrition (low height for age) among preschool children in surveys since 1999.*
Source: Rosegrant et al., 2006

of this role may increase and become central for human survival on this planet.

1.2.3 Agricultural Knowledge, Science and Technology (AKST)

A challenge for formal AKST is the great imbalance in numbers of researchers per million inhabitants: this number is 65 times smaller in Africa than in industrialized countries (Hurni et al., 2001). Nearly half of public agricultural research expenditures, amounting to US$23.0 billion in 2000, are spent in developed countries, i.e., benefiting only a few million, though highly productive, farmers (Pardey et al., 2006). While private agricultural research spending is somewhat higher than public spending in developed countries, private spending in developing countries is very low, accounting for only 8% of total public and private investments in AKST (see chapter 8 for details of AKST investment levels).

Public agricultural research in industrial countries also benefits farmers in other countries, since much public agricultural research is basic research that may later be applied to a variety of agricultural settings through technology transfer, and public research often leads to publicly available crop varieties that are widely distributed. Traditional experimental systems and many emerging farmers' programs—some initiated by international institutions such as FAO but most from farmers' organizations and social movements—are also considered as a component of agricultural research.

Regional shares in public agricultural research expenditures have been changing in the past 40 years (Pardey et al., 2006). While overall investments nearly doubled, industrialized countries, which had 55% of all investments in 1981, received a smaller share—44% in 2000, while in China and other Asian states investments increased manyfold. In general, research and development (R&D) investments have so far generated high returns (Byerlee and Alex, 2003; Chapter 8.2), however at a high ecological cost. For example, trends in cereal production since 1960 show that area productivity increased by a factor of 2.5 in industrialized countries, from 2.1 to 4.9 tonnes ha^{-1} on average on a total of 140 million hectares. In developing countries, the factor was even higher, i.e., 2.8, and the increase was from 1 to 2.8 tonnes ha^{-1} on a total cropped area of 440 million ha (Cassman, 2003). It must be noted, however, that stagnation in land productivity increase has been observed in many areas since about 1985 (Cassman, 2003).

Some recent changes in thinking have raised a number of cognate issues in formal AKST systems. The policy agenda has evolved from a formal "science push" approach to one that places more emphasis on participatory, multi-stakeholder, inter- and transdisciplinary, and client-driven research agendas. Donors, supranational structures, regional organizations, and governments are looking for stronger interinstitutional support for development projects in order to attract private sector investments. Largely, this has been driven by changing contexts and circumstances since the days of the Green Revolution. Perhaps the biggest challenge is to fill the gap in research and technology that is relevant to the poorest. In particular much private and public R&D is spent on corn, wheat, maize, and rice, while very little is devoted to cassava, millet, sorghum and potatoes. However, it has not proved easy for research and extension organizations to adapt their established practices (Graham et al., 2001) to the new way of understanding rural development as part of an AKST system based on the idea that knowledge is coproduced by all actors involved. The most important of these issues are summarized in the present subchapter. Thinking on rural development has shifted from the 1960s to the 1990s and has reached a balanced state between the productive and social sectors, and between state and market interventions.

Effectiveness of formal AKST organizations. It is well known that many public research and development (R&D) bodies of national agricultural research systems (NARS) are finding it difficult to deal with poor farmer- and peasant economy-based issues in many countries. The problems range from resource constraints on the one hand to rigid, disciplinary-bound research planning on the other (IAC, 2004). Often there is a lack of engagement with client sectors and unwillingness to exchange and co-generate knowledge with other research bodies in the sector. This is also related to the process of identifying research problems, which is often based solely on perceptions of disciplinary-based researchers with incentive systems usually grounded mainly on the number of publications. The inevitable result is that all too often resource allocation to the NARS does not pay off in terms of economic, social and environmental development possibilities for poor farmers. While a number of countries have initiated some remedial policies for these issues, the relevant literature shows that there is still some way to go. The difficulties of more equality-based engagement with farmers, peasants, or "clients" has also to do with an understanding of the reasons guiding rural actors' decisions, actions and livelihoods that is too narrow (see Yapa, 1993 for Asia; Wiesmann, 1998 for Africa; Trawick, 2003 for Latin America).

Promotion of other stakeholders' AKST. Traditionally, the passing on of results of agricultural research to users was handled by state-funded extension services. Not only have these suffered through structural adjustment measures, but an increasing number of questions have also been raised by the extension systems themselves as operational organizational mechanisms (Farrington et al., 2002; IAC, 2004). There is also evidence of an increased need to engage in partnerships in order to reconceptualize (in theory and practice) the delivery of technology in the context of an AKST system that is based on the paradigms of knowledge coproduced by scientists, policy makers and client groups. These partners include private sector organizations, but they also involve NGOs, community-based organizations (CBOs) and social movements that are able to bring skills and knowledge to bear simply due to the close relationships they have established with specific communities. Today's challenges in community development in developing countries make it more compelling for higher education to reach effective changes of vision and prepare professionals to lead innovative rural development processes. Training, capability building, and reinforcement of small-scale farmers' skills to enable them to participate in the agriculture supply chain are urgent tasks.

Coproduction of agricultural knowledge

The combination of various forms of exogenous scientific knowledge, e.g., from the natural, agronomic, economic or social sciences, with the many and highly diverse forms of so-called "local", traditional or endogenous knowledge is a basic challenge. These different forms of knowledge are represented by different local (farmers, traders, craftsmen, etc.) and external actor groups (civil servants, extensionists, researchers, service providers, etc.). One can therefore call them "knowledge systems". Combining endogenous and exogenous knowledge is achieved by increased participation of "end users"—including marginalized and poor actors—in the different forms of research and development. While the initial focus of combining knowledge was on increasing participation at local levels, today emphasis is shifting towards upscaling participatory processes into the meso- and macro-levels of social organization (Gaventa, 1998) resulting in multilevel and multistakeholder approaches.

When taking into account the centrality and value of endogenous, traditional or local forms of knowledge related to agricultural development—e.g., through ethnological approaches in sciences studying agricultural soils, plants and animals (Nazarea, 1999; Winklerprins, 1999)—it is necessary to reflect on the ethical and epistemological implications related to the integration of different knowledge systems (Dove and Kammen, 1997; Olesen et al., 2000; Rist and Dahdouh-Guebas, 2006). Integration of, and cooperation between, different knowledge systems is often hampered by interaction that does not take into account the need for the process of communication to move beyond the practical and generally tangible technological economic, ecological and social effects of innovations. In the long run, innovation can only be successful if it "makes sense" to all those involved, i.e., it needs to be integrated into (and by) the different knowledge systems involved. This is also particularly important for innovations in rural development (Dove and Kammen, 1997; Olesen et al., 2000).

There is also growing consensus among researchers concerned with sustainable agriculture that no single group of actors should appropriate the right to define what type of combination should exist between scientific and "local" forms of knowledge (Röling and Wagemakers, 2000; Rist and Dahdouh-Guebas, 2006). As a consequence, participatory forms of coproduction of knowledge, based on social learning among actors involved, have become a key feature of sustainable agriculture and resource management (Wollenberg et al., 2001; Rist et al., 2003; Pahl-Wostl and Hare, 2004). This means that the role of science within a process of participatory knowledge production must be redefined. Instead of striving to find and voice the ultimate instance of "truth", the scientific community must complement conventional and generally discipline-based knowledge production with inter- and transdisciplinary approaches. The particularity of a transdisciplinary approach is that it implies examining "real-world problems" from a perspective that (1) goes beyond specific disciplines by combining natural, technical, economic and social sciences, and (2) is based on broad participation, characterized by systematic cooperation with those concerned (Hurni and Wiesmann, 2004). A major task of sciences relating to society in a transdisciplinary perspective is to assure that the diversity of actors, interests, complexity and dynamics of the processes involved are given adequate consideration. More concretely this means bringing three basic and interrelated questions into societal debates on sustainable agriculture: (1) How do processes constitute a problem field, and where is the need for change? (2) What are more sustainable practices? (3) How can existing practices be transformed (Hirsch Hadorn et al., 2006).

Engagement with agribusiness opportunities. Agricultural research partly faces the agenda of an agricultural research system which is frequently inappropriate for the emerging realities of the often poverty-affected agricultural sector in developing countries. While production, sale and consumption of major food crops remains important, a number of niche sectors with impressive growth rates are emerging, and this is coupled with fundamental changes in the nature of the sector as a whole. New and rapidly growing markets are emerging, e.g., for livestock, horticulture and cut flowers, pharmaceutical and nutriceutical crops, natural beauty products, and industrial use products such as biofuels and starch. The role of the private sector is increasing, and with it new issues arise, such as corporatization of craft-based industries, the exposure of producers and firms to competition, changing international trade rules and regulations such as sanitary and phytosanitary standards, intellectual property rights (IPR, see below), the knowledge-intensive nature of these niche sectors, and the importance of innovation as a source of competitive advantage under rapidly evolving market and technology conditions.

Transfer and use of imported AKST. The recent report of Task Force 10 on Science, Technology and Innovation (UN Millennium Project, 2005) emphasizes the general importance for all actors involved in agricultural production and marketing of acquiring knowledge in a globalized world. A key change is the emergence of private sector research. This is partly a result of strengthened intellectual property protection regimes and technical advances in biotechnology. Also significant are the opportunities that economic and trade liberalization and globalization are now offering for private investments in agroindustries such as seed production. The net result is that on the one hand, public agricultural research systems have to consider more complex agendas including for example how to appropriately acquire genetic resources and how to establish equitable benefit-sharing regimes for those societies and communities from whose livelihood sphere the primary ingredients for corporate patents often originate. On the other hand, this also implies that research and development centers have to learn how to better respond to sociopolitical debates that can shape and define the societal preconditions that influence the amounts, use and allocation of financial and human resources available for research and development in rural areas. Technocratic, hierarchical and disciplinary-based definitions of research and development policies are no longer adequate in the context of civil society organizations' growing participation in defining policies related to research and technology development. Against this background, an especially important issue is related to local knowledge, which was perceived as an "obstacle" for development, and is now considered an important resource that contributes to better targeted development efforts (Scoones and Thompson, 1994; Blaikie et al., 1997).

International agreements and implications for AKST. A related issue is that of the growing number of relevant international agreements that many developing countries have signed and ratified. One good example is the Convention on Biological Diversity (CBD), with a number of articles on opportunities for sustainable agricultural development. For example, Article 15 on access to genetic resources enjoins members to rationalize the use of biological resources in ways that promote exploitation of such resources for socioeconomic purposes. Many countries are aware that there are significant opportunities here for the acquisition of significant off-farm income generation that could go some way towards alleviating poverty, but there is often a severe shortage of technological capacity to realize these opportunities (Glowka et al., 1994). The key point is that such agreements imply a need for developing countries to increase AKST capacity relevant to the new contexts.

Management of relevant "intellectual property rights" (IPR). Management (and protection) of intellectual property (IP) in agriculture is now recognized as a fundamental task of knowledge-based development. But while large international companies have moved forward in this respect, many developing countries still have great difficulties ensuring that their creativity can achieve similar protection. Part of the problem is clearly institutional. Scientists find it difficult to understand that their research will often give rise to significant IP and that they have additional responsibilities in this respect, if only to protect the novel public goods that they have helped to create. Similarly the organizations in which they work are often trapped in a "mode 1" world (Gibbons et al., 1994) and see their responsibilities as ending with the publication of scientific papers in refereed journals. Moreover, patents on life forms create broad controversies, especially those connected with a ban on using harvested grain as seed. Patent claims for animals currently regard whole breeds.

Therefore, questions that arise in this context have to do with the creation of capacity and related initiatives which ensure that knowledge coproduction and technology development in developing countries are as fully informed as possible in these respects. However, it remains open whether the global tendency to protect IP rights is realistic, considering the fact that numerous instances of intellectual property are based on societies' centuries-old intellectual and empirical inputs. In such situations, the quest for equitable benefit sharing may seem impossible, thus calling into question the entire discussion about IPR. The patenting case of Neem extracts (Azadirachta indica) may be quoted as an example. By challenging the patent on a Neem product, the Indian Government was able to prove that the same Neem product was industrialized and has been used in India for several millennia (Sheridan, 2005).

Access to and reform of AKST education

A broader set of issues concerns the formal training of scientists and related workforce. As the MDG Task Force 10 has emphasized, higher education is increasingly being recognized as a critical aspect of the development process; at the same time, however, most universities are ill-equipped to meet the challenge. Outdated curricula, under-motivated faculties, poor management and a continuous struggle for funds have undermined the capacity of universities to play their roles as engines of community or regional development (UN Millennium Project, 2005).

A report by the InterAcademy Council (IAC, 2004) recently underlined the relative decline of the agricultural research and education system in Africa in the past decades. Among the reasons discussed in the report are the relative weakness of science education in African schools, low investment in research in general, and the growth of student numbers (by 8% per year), with funding falling short of this increase and funding decline accentuated by structural adjustment. The report also notes an unexpected renewal phase initiated by a half dozen African universities in the recent past.

Some MSc and PhD programs in industrialized countries do not always suit the needs of less industrialized countries. The implications both for curriculum revision and access are therefore considerable from an AKST standpoint and will be covered at various points in this report. A positive example is the higher education system in Costa Rica, which is making significant efforts to focus agricultural development on knowledge and technological innovation. It is also important to take into account the gender disparity in training as well as the lack of focus on gender analysis in the curricula of agricultural universities in developing and—most often also in industrialized—countries.

Besides overcoming shortcomings with regard to quantitative aspects of human and financial resources, it will also be of paramount importance to combine an increase in resource allocation and further capacity development of actors involved in research and extension aimed at a qualitative shift towards more societal modes of knowledge production emphasizing inter- and transdisciplinary approaches (Hurni and Wiesmann, 2004).

Capacity development is broadly defined here and includes developing (1) common understandings of problems, solutions and ways to approach them, using a variety of interpersonal and intra-social processes; (2) social and cultural resources, not just human resources; (3) multiple, strategic skills across a range of areas to intervene and advocate, not just passive receipt of programs and policies, and (4) institutional and organizational bases of power. If policies for organizational reforms are introduced, medium- to high-level scientific resources are made available for formal higher and tertiary education systems, and organizational change is initiated in the structure of relevant governance procedures, such as those concerned with the management of extension services, funding of R&D, mobilizing of informal inputs from NGO and related bodies, optimizing the use of foreign technology, and providing procedures for a balanced use of the private sector, deployment of AKST will become far more effective. Indeed, such changes will enable more adequate analysis of agroecosystem services, which is usually not included in production-oriented AKST, and the finding of strategies to mitigate negative impacts ("damages") caused by agricultural practices to such services. Further improvements can be achieved by promoting knowledge of interventions that are environmentally and socially sustainable, including measures to empower women to a much greater degree than has been the case in the past.

Measurement of "knowledge" categories

There is a large gap in research intensity (measured as public R&D investment as a ratio of agricultural GDP) between developing and industrialized countries. In 2000, the intensity ratio for the developing countries as a total averaged 0.53%, compared to 2.36% for the developed countries as a group (Pardey et al., 2006). This intensity gap has increased over the past decades as a result of a much higher growth in agricultural output in developing countries as group than in the developed countries.

One of the problems in dealing with AKST policy (indeed, KST of all types) is that of measurement—both for "inputs", i.e., investment in AKST, and "outputs", i.e., indicators of resultant knowledge impacts. In the case of the former, a range of proxies are used, the most common being agricultural R&D expenditures in the public sector. Another is the number of persons with PhDs currently working in agricultural R&D organizations. Both are unsatisfactory for the obvious reason that they probably give a distorted picture of knowledge investment. For example, they do not account for external inputs from overseas, which may be higher than the internal inputs. A similar problem exists on the output side since outputs can also take a variety of forms, for instance number of patents, number of new plant varieties registered or number of relevant scientific papers published in refereed journals. Again, all kinds of problems involved in the interpretation of these data are due to paucity of information, lack of disaggregation, variations in national practices, and of course the fact that they often do not pick up on several types of tacit knowledge. It is therefore worth noting that attempts to be quantitative in this area need to be treated with great care.

Giving local knowledge due recognition means to specifically monitor its integration into the processes of knowledge production at the interface of research and practice. The above indicators must be differentiated more accurately, taking into account the share of research and development expenditures per sector, number of PhDs, and scientific publications, explicitly in relation to the search for new modes of knowledge production that focus on the integration of local forms of knowledge. Indicators must not only allow quantification of resources allocated to local and traditional components of AKST systems. They must also make visible to what degree the resources allocated to these components of an AKST system reflect the overall relationship that local or traditional knowledge and external knowledge actually have in ensuring the livelihood systems of rural people in general and of poor and marginalized people in particular.

Multifunctionality and sustainability would require indicators of both local and scientific knowledge.

1.2.4 Agrifood systems, agricultural products and services

Agricultural systems, outputs and services. The major outputs generated by the multiple agricultural systems worldwide may be referred to as "provisioning services" (MA, 2003):

- Food consisting of a vast range of food products derived from plants, animals, and microbes for human consumption;
- Feed products for animals such as livestock or fish, consisting of grass, herbs, cereals or coarse grains and other crops;
- Fiber such as wood, jute, hemp, silk, and other products;
- Fuel such as wood, dung, biofuel plants and other biological materials as sources of energy;
- Genetic resources including genes and genetic information used for animal and plant breeding, and for biotechnology;
- Biochemicals, natural medicines, and pharmaceuticals including medicines, biocides, food additives, and biological materials;
- Ornamental resources including animal products such as skins and shells, and ornamental plants and lawn grass; and
- Freshwater from springs and other sources, as an example of the linkage between provisioning and regulating services.

Agricultural systems are highly complex, embracing economic, biophysical, sociocultural and other parameters. They are based on fragile and interdependent natural systems and social constructions. Agriculture has a potential to play positive roles at different scales and in different spheres (Table 1-3).

Diversity of agricultural systems

Globally, agricultural systems have been changing over time in terms of intensity and diversity, as agriculture undergoes transition driven by complex and interacting factors related to production, consumption, trade and political concerns. There are a multitude of agricultural systems worldwide. They range from small subsistence farms to small-scale and large commercial operations across a variety of ecosystems and encompassing very diverse production patterns. These can include polycultures or monocultures, mixed crop and livestock systems, extensive or intensive livestock systems, aquaculture systems, agroforestry systems, and others in various combinations. In Africa alone, there are at least 20 major farming systems combining a variety of agricultural approaches, be they small- or large-scale, irrigated or non-irrigated, crop- or tuber-based, hoe- or plough-based, in highland or lowland situations (Spencer et al., 2003).

Agricultural systems are embedded in a multiplicity of different economic, political and social contexts worldwide. The importance of the agricultural sector in these economies, or the type of agricultural policy enforced will therefore depend on the national economies. It is thus crucial to gain a clear knowledge of the state of agriculture in the different ecological and socioeconomic contexts to be able to assess the potential for further development of this sector in relation to development and sustainability goals. The different contexts have led to economic disparities within and among regions, countries and especially between industrial and small-scale farmers (FAO, 2000). Apart from differences in labor productivity, examples of disparities are average farm sizes (121 ha in North America vs. 1.6 ha in Asia and Africa, see von Braun, 2005; 100,000 ha in Russia, Ukraine and Kazakhstan, see Serova, 2007) and the crop yield gap between high- and low-income countries.

The last 50 years have seen a tremendous increase in agricultural food production, at a rate more rapid than human population growth. This was mainly due to the increase in area productivity, which differed between the regions of the world, while cereal-harvested area stagnated almost everywhere (Cassman, 2003).

In all regions of the world, however, a decrease in the economic importance of the agricultural sector at different stages of economic development can be observed. But there is insufficient recognition of the fact that, in a monetized economy, the central functions of agriculture support the performance of other sectors. The regulating and supporting functions of global ecosystems are insufficiently understood. The findings of the Millennium Ecosystem Assessment (MA, 2005b) show the key role of agriculture not only in productive and social aspects but also in preserving or endangering ecosystem functions.

The crops component of agriculture

World crop and livestock output growth fell in 2005 to the lowest annual rate since the early 1970s, and well below the rates reached in 2003 and 2004, with a strong decline in industrialized countries as a group and negative 1.6% growth in 2004 (FAO, 2006a). This was mainly due to a decrease in output growth in the crops sector from 12% in 2004 to negative 4% in 2005 in industrialized countries. But with growing resource scarcity, future food production depends more than ever on increasing crop yields and livestock productivity (FAO, 2006a). The positive and negative effects of technological progress have raised uncertainties. Two groups of crops are cited here as examples.

Cereal crops. World cereal production, after several years of stagnation, increased sharply in 2004/2005, reaching 2,065 million tonnes, a 9% increase from the previous year, and global utilization continued an upward trend (FAO, 2006a). However, cereal yields in East Asia rose by an impressive 2.8% a year in 1961–2004, much higher than the 1.8% growth in industrialized countries, mainly due to widespread use of irrigation, improved varieties, and fertilizer (Evenson and Gollin, 2003).

The green revolution doubled cereal production in Asia between 1970 and 1995, yet the total land area cultivated with cereals increased by only 4% (Rosegrant and Hazell, 2001) while in sub-Saharan Africa it changed little in the same period.

Slowing down expansion of cultivated areas through intensification benefited the environment by preserving the forests, wetlands and biodiversity. But there are negative

Table 1-3. **Positive functions of agriculture.**

	Environmental	Social	Food Security	Economic	Cultural
Global	Ecosystem resilience Mitigation of climatic change (carbon sequestration, land cover) Biodiversity	Social stability Poverty alleviation	Food security/ food for all	Growth, international trade	Cultural diversity
Regional/National	Ecosystem resilience Soil conservation (erosion, siltation, salinization) Water retention/availability (flood and landslide prevention) Biodiversity (agricultural and wildlife) Pollution abatement	Balanced migration Social stability (and sheltering effects during crisis) Unemployment prevention Poverty alleviation	Access to food National security Food safety	Economic stability Employment Foreign exchange Tourism	Landscapes Cultural heritage Cultural identity Social capital
Local	Ecosystem resilience Soil conservation Water retention Biodiversity Pollution abatement	Social stability (employment, family) Livelihoods Balanced gender relations	Local and household food security	Employment effects on secondary and tertiary sectors	Landscapes Indigenous, local knowledge Traditional technologies Cultural identity

environmental impacts such as excessive use of agrochemicals (fertilizers and pesticides) resulting in water pollution, which affects human and animal health and indirectly damages ecosystems. An example is the intensive and continuous monoculture of rice-wheat systems in the Indo-Gangetic Plain of India and Pakistan, which led to soil and water degradation that has canceled the gains from the green revolution (Ali and Byerlee, 2002). In all regions, especially in the heterogeneous and risky rainfed systems of sub-Saharan Africa, there is a need for sustainable technologies that increase the productivity, stability and resilience of production systems (Conway, 1999). It is important to note that most rice-producing areas such as China, India, Japan and Indonesia have experienced stagnation in rates of productivity increase as of 1985-2000 (Cassman, 2003).

The fishery component of agriculture

Fisheries play a very important role in agriculture and the world economy. Rapid population growth in developing countries, changing consumer preferences and increased disposable income have increased global demand for fishery products. About 200 million people worldwide, most of them in developing countries, live on fishing and aquaculture, and fish provides an important source of food, cash income for many poor households, and is a widely traded food commodity (Kurien, 2006; WorldFish Center, 2006). Over a billion people worldwide rely on fish as their main source of protein or their most inexpensive source of animal protein. In 2004, aquaculture production accounted for 43% of fish consumption (FAO, 2006b). Fish contributes to national food sufficiency through direct consumption and through trade and exports.

Total fishery production in 2004 was 150.5 million tonnes, of which 45.5 million tonnes were from aquaculture, of which 40% that entered international trade reached a value of US$71.5 billion (FAO, 2006c). While capture increased moderately from 1970 to 1998, aquaculture multiplied by a factor of 15 in the same period, from about 2 million tonnes in 1970 to about 30 tonnes in 1998 (Delgado et al., 2003; Figure 1-10). Fishery exports have become a significant foreign currency earner for many developing countries, contributing slightly less than 50% of such exports. The export value of world trade in fish, US$58 billion in 2002, is more than the combined value of net exports of rice, coffee, sugar and tea (World Bank, 2004a). Demand for fish products is increasing rapidly as income levels rise in Asia and the population grows in Africa. Led by Asia, developing nations produce nearly three times as much fish as industrialized countries (Delgado et al., 2003).

World capture fishery production was from 90 to 100 million tonnes in 2005, an increase of about 5% from 2003 (FAO, 2006c). Aquaculture may substitute for wild catch but can create environmental problems, especially when practiced intensively, such as in large-scale, intensive operations, most of which (with the exception of shrimp farming) are found in temperate countries.

The forestry component of agriculture

Forests are intensively linked to agriculture, providing products (i.e., wood, fuelwood, food, medicines), inputs for crop and livestock production (fodder, soil nutrients, pollination, etc.), and services (i.e., watershed protection, climate regulation, carbon storage, biodiversity conservation). World roundwood production in 2004 reached an estimated 3,418

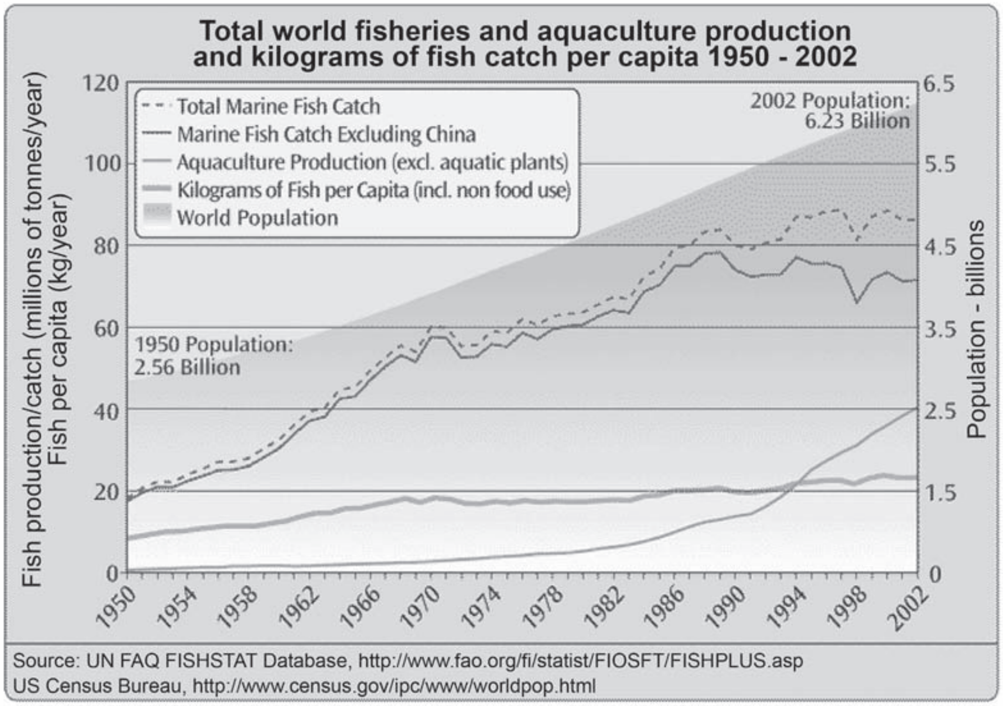


Figure 1-10. *Global capture fisheries and aquaculture production, 1950-2002.* Source: FAO, 2007b; US Census Bureau, 2007.

million cubic meters, of which 60% was produced in developing countries where wood is the most important source of energy (FAO, 2006d).

Forests cover 31% of global land surface (FAO, 2007a) and have potential to provide products and services, hence, could contribute to meeting development and sustainability goals. All types of forests contribute to agriculture in two main ways: (1) the world's forests act as a buffer against climate change, storing 50% carbon in their biomass, deadwood, litter and soil, i.e., more than the amount of carbon dioxide in the atmosphere alone; and (2) they are a principal source of biodiversity. Forests also play a key role in agriculture as the source of much of the land and soils for agriculture. "Slash and burn" agriculture is dependent on forest ecosystems for regeneration of soils, and forests are the source of many types of fruit, meat, timber, fuelwood, medicine, etc. for rural people.

Almost a quarter of a billion people live in or near tropical forests, and their well-being depends on them (CIFOR, 2006). Two billion people, a third of the world's population, use fuelwood and charcoal, most of which is harvested in the forest; and two billion people rely on traditional medicines, much of which depends on forest products (CIFOR, 2006). The rapid development of agriculture has proceeded through conversion of natural forests, mainly due to rapid population growth, and the higher food production and cash income that can be obtained from farming rather than from forestry. Deforestation, mainly due to conversion of forests to agricultural land, continues at the rate of 13 million ha per year (FAO, 2005b). The net global change in forest area in 2000-2005 is estimated at -7.3 million ha per year, down from -8.9 million ha per year in 1990-2000 (FAO, 2005b). The deforestation trend is increasingly being reversed as forest goods and services are becoming scarce. Changes in cropland show that most of this deforestation has not been for conversion of cropland. Eighty percent of incremental crop production in developing countries by 2030 will come from intensification and only 20% from area expansion (FAO, 2003).

The livestock component of agriculture

Global livestock production continues to grow more rapidly than crop agriculture, with growth rates of 5% in the 1990s, but has slowed down since 2004 (FAO, 2006a).The volume of livestock production in developing countries has steadily increased since the early 1980s, both for internal consumption and for export (COAG, 2005), driven by rising demand for poultry, pork and eggs as income rises. Livestock production accounts for 40% of the agricultural GDP (FAO, 2006a), produces about one-third of humanity's protein intake, employs 1.3 billion people and creates livelihoods for one billion of the world's poor (Steinfeld et al., 2006). The social and energy benefits of livestock production have long been recognized, as well as its economic contribution outside the formal market system. Women play a key role in small-scale livestock production, and in processing and marketing animal products.

Outbreaks of animal diseases, in particular avian influenza, and subsequent consumer fears, trade bans and declines in poultry prices have caused slow growth rates. Livestock production systems also cause environmental problems, with negative impacts on land, climate, water quality and quantity, and biodiversity (FAO, 2006a). As poverty declines, there is predicted to be increased demand for animal protein in diets, exacerbating already fragile environmental conditions in developing countries and causing further loss of biodiversity.

Much of livestock production is on small farms, where it is an integrated component of the farming system, often with multipurpose uses (Dolberg, 2001; LivestockNet, 2006). However, there are also nomadic systems, particularly in Africa, in extreme northern Asia, Europe and America (in the tundra) where livestock continues to be the primary source of livelihoods.

Some emerging agricultural systems

Organic agriculture. In the past few years, organic agriculture has developed rapidly with more than 31 million ha in at least 623,174 farms worldwide in 120 countries (Willer and Yussefi, 2006).

Global sales of organic food and drink increased by about 9% to US$27.8 billion in 2004, with the highest growth in North America, where organic product sales are expanding by over US$1.5 billion per year, with the United States accounting for US$14.5 billion sales in 2005 (Willer and Yussefi, 2006).

Organic agriculture is a holistic production management system that promotes and enhances agroecosystems health including biodiversity, biological cycles, and soil biological activity (Codex Alementarius Commission, 2001). It emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This can be accomplished by using, wherever possible, cultural, biological, and mechanical methods instead of using synthetic materials, to fulfill any specific function within the system. Organic agriculture can contribute to socially, economically and ecologically sustainable development, firstly, because organic practices use local resources (local seed varieties, dung, etc.) and secondly, because the market for organic products has high potential and offers opportunities for increasing farmers' income and improving their livelihood. It also contributes to *in situ* conservation and sustainable use of genetic resources. But organic agriculture also has negative environmental impacts such as overuse of animal manure, which can lead to nitrite pollution of water supplies; on the other hand, insufficient application of organic manure can lead to soil mining and long-term productivity declines (World Bank, 2004a).

The sustainability of organic agriculture is often debated, with divergent views regarding its feasibility and productivity potential in resource-poor areas. Most information is from temperate countries and the technological needs in low-potential areas are not addressed. Organic production requires a high level of managerial knowledge, the ability to protect crops from pests and diseases, and compliance with production process requirements. Certification is one of the most important cost items. Reliable and independent accreditation and control systems are essential to enforce organic standards and regulations and to meet phytosanitary standards and general quality requirements.

Urban and peri-urban agriculture refers to growing plants and raising animals for food and other uses within and around cities and towns, and related activities such as the production and delivery of inputs and the processing and marketing of products (van Veenhuizen, 2006). It has received increasing attention from development organizations and national and local authorities, and is likely to do so in future as well, as migration of poor people from rural to urban areas will continue to be a major trend in developing countries. This results in shifting poverty from rural areas to urban slums and increasing the importance of urban and peri-urban agriculture, as it contributes to reliable food supply and provides employment for a large number of urban poor, especially women (World Bank, 2004a). It is an integral part of the urban economic, social and ecological system (Mougeot, 2000).

Urban and peri-urban agriculture includes a range of production systems from subsistence production and processing at household level to fully commercialized agriculture. It may include different types of crops (grains, root crops, vegetables, mushrooms, fruit) or animals (poultry, rabbits, goats, sheep, cattle, pigs, guinea pigs, fish) or combinations of these (ETC-Netherlands, 2003). Non-food products include aromatic and medicinal herbs, ornamental plants, tree products (seed, wood, fuel), and tree seedlings. For example in Hanoi, Vietnam, urban and peri-urban agriculture supplies about one-half of the food demand and engages more than 10% of the urban labor force in processing, marketing, retailing, input supply, and seed and seedling production (Anh et al., 2004)

Urban and peri-urban agriculture is characterized by closeness to markets, high competition for land, limited space, use of urban resources such as organic solid wastes and wastewater, a low degree of farmer organization, mainly perishable products, and a high degree of specialization (van Veenhuizen, 2006). Some critical issues include the use of pesticides; use of urban waste in agricultural production; environmental pollution caused by agricultural activities in densely populated areas; conflicts over land and water between agricultural, industrial, and housing uses; unhygienic food marketing; and inability of producers, wholesalers, retailers and other agents engaged in food processing and marketing to adapt to coordinated food chains (World Bank, 2004a). Urban planning will need to take into account the potential environmental impacts of urban and peri-urban agriculture.

Conservation agriculture. Conservation or zero-tillage agriculture is one of the most important technological innovations in developing countries, as part of Sustainable Land Management approaches. It is a holistic agricultural system that incorporates crop rotations, use of cover crops, and maintenance of plant cover throughout the year, with positive economic, environmental and social impacts (Pieri, et al., 2002). It consists of four broad intertwined management practices: (1) minimal soil disturbance (no plowing and harrowing); (2) maintenance of permanent vegetative soil cover; (3) direct sowing; and (4) sound crop rotation.

The United States has the longest experience in conservation agriculture approaches, which were first implemented in large and medium-sized farms. Conservation agriculture then began to be widely used in diverse farming systems in Brazil and adapted to small farms in the southern part of the country. It is rapidly being adapted to irrigated rice-wheat systems in the Indo-Gangetic Plains, especially in India, where 0.8 million hectares were planted in 2004 using this system (Malik, Yadav and Singh, 2005).

Broader adoption of conservation agriculture practices would result in numerous environmental benefits such as decreased soil erosion and water loss due to runoff, decreased carbon dioxide emissions and higher carbon sequestration, reduced fuel consumption, increased water productivity, less flooding, and recharging of underground aquifers (World Bank, 2004a).

Agriculture, agrifood systems and value chains

Agrifood systems are described as including a range of activities involved at every step of the food supply chain from producing food to consuming it, the actors that both participate in and benefit from these activities, and the set of food security, environmental and social welfare outcomes to which food system activities contribute (Ericksen, 2006). They include the primary agriculture sector and related service industries (i.e., veterinary and crop dusting services); the food and beverage, tobacco and non-food processing sectors; the distribution sector (wholesale and retail); and the food service sector. Value chains are multinational enterprises or systems of governance that link firms together in a variety of sourcing and contracting arrangements for global trade. Lead firms, predominantly located in industrialized countries and comprising multinational manufacturers, large retailers and brand-name firms, construct these chains and specify all stages of product production and supply (Gereffi et al., 2001). The value chain perspective shifts the focus of agriculture from production alone to a whole range of activities from designing to marketing and consumption.

Agrifood systems range from traditional systems that are localized where food, fuel and fiber are consumed close to the production areas using local resources, to large agrifood industries that are globalized and linked to integrated value chains. Traditional systems may include hunter-gathering and peasant agriculture that meet the needs of the community from local resources. The major traditional agrifood systems comprise small family farms that supply products to the local markets but are continuously being transformed in response to market signals. At the other end, there are large agrifood industries consisting of international or transnational companies that are globalized and integrated into complete value chains. These systems are continuously being transformed by market and consumer demands, with new agrifood systems emerging that consider social and environmental aspects and use technological innovations. Organic agriculture is an example, which showed rapid growth in the 1990s in Europe, where 4% of EU agricultural land area is now organic, compared with only 0.3% in North America (Willer and Yussefi, 2006).

Agrifood systems have a strong influence on culture, politics, societies, economics and the environment, and their interactions affect food system activities. Agrifood system activities can be grouped accordingly: producing, processing and packaging, distributing and retailing, and consuming (Zurek, 2006). As the agrifood systems become more sophisticated and globalized, they have to adhere to regulations and standards to meet product safety and quality, and consumers' specific needs in order to survive. New and more innovative technology in food production, post-harvest treatment, processing, packaging and sanitary treatment are now playing a more important role.

Agriculture and the environment

Land cover and biodiversity changes. Beyond its primary function of supplying food, fiber, feed and fuel, agricultural activity can have negative effects such as leading to pollution of water, degradation of soils, acceleration of climate change, and loss of biodiversity. Conversion of land for production of food, timber, fiber, feed and fuel is a main driver of biodiversity loss (MA, 2005b). Many agricultural production systems worldwide have not sufficiently adapted to the local/regional ecosystems, which has led to disturbances of ecosystem services that are vital for agricultural production. Requirements for cropland are expected to increase until 2050 by nearly 50% in a maximum scenario, but much less in other, more optimistic scenarios (CA, 2007; see Figure 1-11).

Soil degradation has direct impacts on soil biodiversity, on the physical basis of plant growth and on soil and water quality. Processes of water and wind erosion, and of physical, chemical and biological degradation are difficult to reverse and costly to control once they have progressed. The Global Assessment of Human-induced Soil Degradation (GLASOD) showed that soil degradation in one form or another occurs in virtually all countries of the world. About 2,000 million hectares are affected by soil degradation. Water and wind erosion accounted for 84% of these damages, most of which were the result of inappropriate land management in various agricultural systems, both subsistence and mechanized (Oldeman et al., 1990).

Water quality and quantity changes. Access to enough, safe and reliable water is crucial for food production and poverty reduction. Most people without access to an improved water source are in Asia, but their number has been rapidly decreasing since 1995, which is less the case in sub-Saharan Africa, Latin America, West Asia and Northern Africa (see Figure 1-12).

However, putting more water into agricultural services threatens environmental sustainability. Water management in agriculture thus has to overcome this dilemma (CA, 2007). Intensive livestock production is probably the largest sectoral source of water pollution and is a key player in increasing water use, accounting for over 8% of global human water use (Steinfeld et al., 2006). Excessive use of agrochemicals (pesticides and fertilizers) contaminates waterways. Better management of human and animal wastes will improve water quality. Agriculture uses 85% of freshwater withdrawals in developing countries, mainly for use in irrigation, and water scarcity is becoming an acute problem, limiting the future expansion of irrigation (CA, 2007). Water conservation and harvesting also have an important potential for rainfed farming (Liniger and Critchley, 2007) as water scarcity is widespread.

Climate change: Climate change influences and is influenced by agricultural systems. The impact of climate change on agriculture is due to changes in mean temperature and to seasonal variability and extreme events. Global mean temperature is very likely to rise by 2-3°C over the next

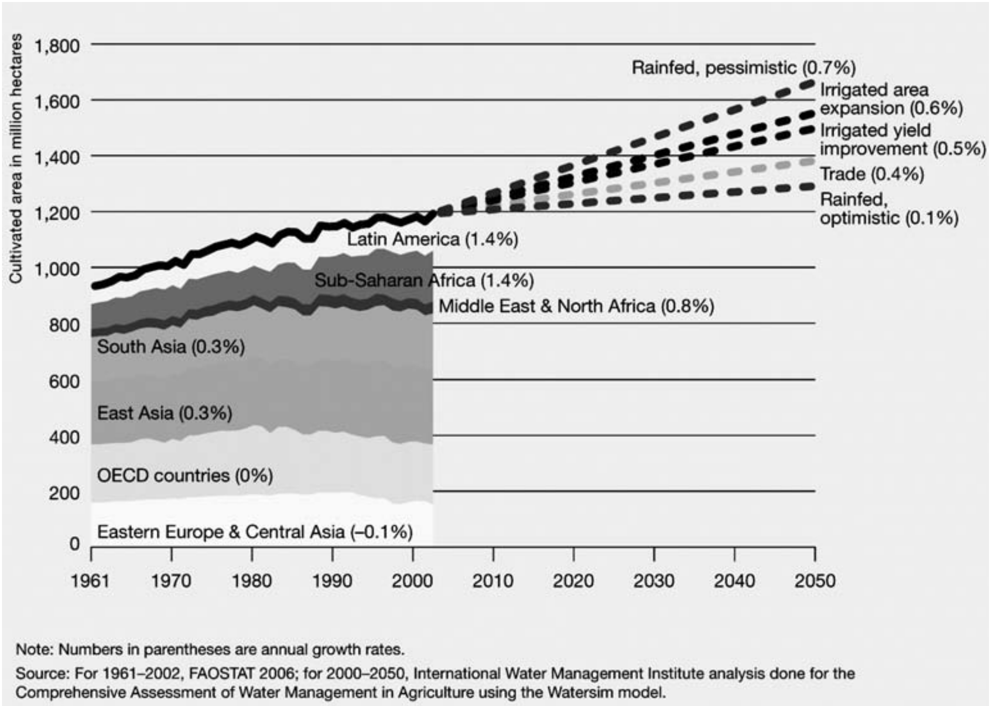


Figure 1-11. *Scenarios of land requirements by regions from 2000 to 2050.*

50 years, with implications for rainfall and the frequency and intensity of extreme weather events (Stern, 2006). The outcomes of this change will vary heavily by region. Crop-climate models predict an increase in crop production in slight to medium warming scenarios of less than 3°C (Parry et al., 2007). Livestock production is one of the major contributors to climate change within agriculture (Steinfeld et al., 2006).

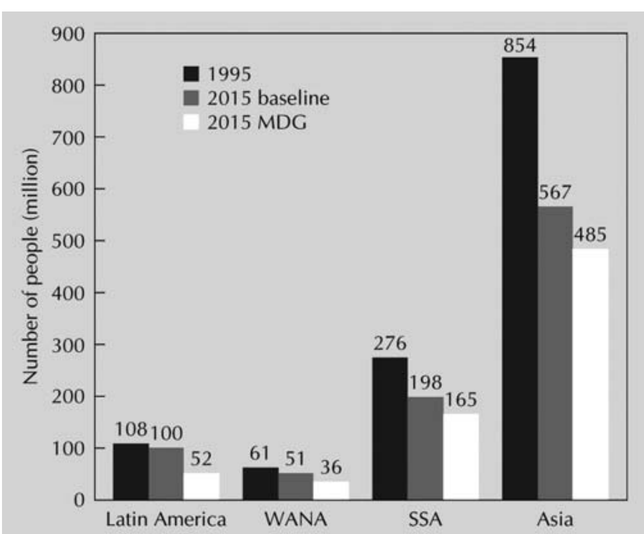


Figure 1-12. *Number of people in 1995 without access to an improved water source, MDG goal and projection to 2015.*
Source: Rosegrant et al., 2006.

1.2.5 Direct and indirect drivers

Direct drivers of change

Changes in human well-being, as characterized by the development and sustainability goals of the IAASTD, come about as the result of a multitude of factors at a variety of scales. For example, change for a particular household may occur as the direct effect of a better harvest due to use of an improved technology. The improved technology itself may have been developed as a result of investment in agricultural research, science and technology and its adoption may have been facilitated by changes in prices or improvements in education and market infrastructure. Effective policy measures depend on a careful distinction between direct and indirect drivers of change.

Following the framework, direct drivers of change include food demand and consumption patterns, land use change, the availability and management of natural resources, climate and climate change, energy and labor, as well as the development and use of AKST.

Relevant natural resources include land resources—i.e., soil, water, flora and fauna—and climate. Growing demand for food, feed, fiber and fuel drives the pace of changes in land use. These changes may include clearing or planting of forests, drainage of wetlands, shifts between pasture and cropland, and conversion to urban uses. Climate change has the potential to change patterns of temperature and precipitation as well as the distribution of pests and diseases. Other natural, physical, and biological drivers include evolution, earthquakes, and epidemics, the use of labor, energy, inputs such as chemical fertilizers, pesticides, and irrigation, and the use of new plant and animal species or varieties. Finally, direct drivers include AKST development and use, including new tools and new techniques such as soil and water conservation or biotechnology. This may also comprise aspects of access to, control over and distribution of AKST, such as extension and dissemination efforts, credit markets and capital assets, and markets for information and knowledge. Species introduction or removal may be intentional or unintentional. Epidemics are increasing the vulnerability of plant and animal production in a globalized economy and are therefore also considered to be direct drivers.

These changes may enhance the well-being of some people and diminish that of others; they may have beneficial effects in the short term but adverse effects over time (or the reverse), and they may have beneficial effects locally but adverse effects at larger scales (or vice versa).

Indirect drivers of change

Many indirect drivers result in turn from a variety of other indirect drivers. Demographic factors include total population and its composition and spatial distribution in terms of age, gender, urbanization, and labor, as well as pressure on land resources within a farm or between farms. Economic factors include prices and other market characteristics, globalization, trade, land tenure and access regulations, agribusiness, credits, markets, and technology. Sociopolitical factors include governance, formal and informal institutions, legal frameworks such as international dispute mechanisms, kinship networks, social and ethnic identity, and political stability. Indirect drivers also include infrastructure such as transportation, communication, utilities, and irrigation. Indirect drivers of science and technology include institutions and policy, funding for R&D, knowledge and innovations systems, advances and discoveries in biotechnology, intellectual property rights, communication systems and information technology, harnessing and adapting local knowledge, and local and institutional generation of AKST. Education, culture and ethics (e.g., in cultural and religious developments or choices individuals make about what and how much to produce and consume and what they value) may also influence decisions regarding direct drivers. Whether direct or indirect, some drivers may have cumulative effects that are felt only when a critical threshold level is reached, as for example when rising pollutant levels exceed a watershed's natural filtration capacity.

Finally, improvements in AKST are driven both by factors that help generate new AKST as well as factors that encourage its adoption and use. Factors that help generate AKST include research policy and funding, intellectual property rights, and farmers' innovation capacity. Factors that affect adoption and use of AKST include extension services, education, and access to natural, physical, and financial resources. These will be explored fully in the chapters to follow.

Conditions determined by political, economic, social and cultural contexts

Agriculture and AKST are strongly bound to the human context in which they are embedded. For example, in the context of Switzerland, where the agricultural sector constitutes merely 3% of the tax-paying workforce, small-scale farmers with an average farm size of 16 ha which they may use for livestock breeding, will not generate sufficient income for the family for a decent livelihood. Because of the importance of agriculture for nonproductive services such as cultural landscape preservation, recreation forests, and water management, Swiss farmers are paid by society for their environmental and social services, up to a total of over 50% of their income, thus reaching the minimum national income standard of about US$35,000 in 2005 (BFS, 2006).

A farming household in Ethiopia, by contrast, typically survives on one hectare of cultivated land and some communal pastureland for livestock rearing. This family produces about one tonne of cereals and pulses per year, of which about 10-20% is marketed and the rest is used for home consumption. Such a household has to pay head taxes but only very marginally profits from investment programs by government or foreign aid. There are millions of farming households all over the world in the same situation, which have an average annual per capita GNP of less than US$200.

Any assessment of the potential of AKST to contribute to more equitable development will thus have to take into account the political, economic, social and cultural contexts in which agricultural land users operate. Additionally, AKST assessments are inherently inter- or multidisciplinary and generate knowledge through transdisciplinary approaches.

Conditions determined by ecosystems, agricultural systems and production systems

The concept of ecosystems provides a valuable framework for analyzing and acting on the linkages between people and the environment (MA, 2005a). An ecosystem is defined as a dynamic complex of plant, animal and microorganism communities and their nonliving environment, interacting as a functional unit (UN, 1992). The AKST conceptual framework uses ecosystems as the broadest context within which agricultural production/farming systems are analyzed.

The predominance of the "cultivated" ecosystem category for agriculture is immediately apparent in the table, followed by mountain ecosystems, which constitute 26% of the Earth's land surface, followed by forestland, covering about 30% of the land surface, as well as drylands, which constitute about one third of all land area worldwide. Together these land cover areas provide about 93% of agricultural products. It should be noted, however, that other services provided by agroecosystems will have a considerably different balance. An example is forests, which provide clean water, reduce flooding, offer biodiversity protection and recreational and spiritual value, which adds to the importance of the forests' production value.

1.3 Development and Sustainability Issues

1.3.1 Poverty and livelihoods

Eradication of extreme poverty and hunger is a key goal of the assessment. Progress has been particularly striking in Asia, but the proportion of people in sub-Saharan Africa who live in extreme poverty has changed little since 1990. Hunger is inextricably linked to poverty, and here again progress is evident but uneven, with reductions in Asia and Latin America partly offset by increases in Africa and the Middle East. Poverty and hunger arise out of the interaction between economic, environmental, and social conditions and the choices people make. Livelihoods depend not only on current incomes but on how individuals, households, and nations use resources over the long term. Physical and financial capital is critical and relatively easily measured. Equally important but less easily measured are sustainable use of natural capital and investment in human and social capital.

Poverty and hunger

Extreme poverty (crudely measured by the percentage of people living on less than US$1 per day) in developing countries decreased from 28% in 1990 to 19% in 2002, and is projected to fall further to 10% by 2015 (World Bank, 2006c). Progress has been particularly striking in East Asia and the Pacific, where the target of the MDGs has already been achieved, and in South Asia, where progress is on track. But the proportion of people in sub-Saharan Africa who live in extreme poverty has changed little since 1990, and remains at about 44% (World Bank, 2006c). The prevalence of undernourishment has fallen from 20% of the population of developing countries to 16% over the past decade, with reductions in Asia and Latin America partly offset by increases in Africa and the Middle East (World Bank, 2006c). Poverty is most pronounced in Africa and South Asia.

In the simplest terms, hunger can be thought of as the situation that occurs when consumption falls short of some level necessary to satisfy nutritional requirements. Similarly, poverty can be thought of as the situation that occurs when income falls short of some level defined by society, usually in terms of the ability to afford sufficient food and other basic needs. These definitions provide a starting point, but simple definitions mask more complex relationships. In fact, income and consumption fluctuate in response both to changing conditions and to choices made by farmers and others. This challenges us to consider more carefully how hunger and poverty arise out of the interaction between economic, environmental, and social conditions and the choices people make.

Hunger is still the result of insufficient consumption, but insufficient consumption may itself arise for several reasons. For example, household income may be insufficient to acquire sufficient food to meet the nutritional requirements of its members, or food may be inequitably distributed within the household. Alternatively, income may allow a household to acquire sufficient food, but doing so may leave insufficient income to meet other needs, such as paying costs associated with schooling—forcing the household to choose between competing priorities. Similarly, poverty is still the result of insufficient income, but insufficient income may itself arise for a variety of reasons. For example, drought or illness might reduce the amount of crops or labor a household has to sell, while low wages or prices may reduce its value (Sen, 1981). Alternatively, income may be low (or high) in part because of choices a household made earlier in the season, such as which crops to plant, or how much fertilizer to apply, or whether to migrate in search of employment. These choices in turn depend on the resources available to the household. Resources may include natural resources such as land and water as well as the household's labor power, tools and financial resources. Resources also include the household's social and institutional settings, which shape property rights and access to infrastructure and social support services.

To complete the cycle, the quality and quantity of the household's resources in turn depend, at least in part, on the consumption and investment choices the household made previously. Given its income last week (or last year), for example, a household will make decisions about how much to spend on food, health care or education (each of which affects the quality of its labor resources), how much to spend on seeds, fertilizer and other agricultural inputs, and how much to save or invest in other ways. Once we recognize the dynamic interaction between household resources, choices, and outcomes, it becomes clear that a more complete understanding of hunger and poverty requires not only a broader understanding of the factors that affect them, but also a longer-term perspective on how they interact over time.

Livelihoods

Livelihoods are a way of characterizing the resources and strategies individuals and households use to meet their needs and accomplish their goals or in other words: "people, their capabilities and their means of living" (Chambers and Conway, 1991). Livelihoods encompass income as well as the tangible and intangible resources used by people to generate income and their entitlements to them. In 2003 about 2.6 billion people, or 41% of the world's population, depended on agriculture, forestry, fishing or hunting for their livelihoods (FAOSTAT, 2006), even while agriculture (including forestry and fishing) represented only 12% of GDP in developing countries in 2004, and 4% for the world as a whole (World Bank, 2006c).

Diversification of livelihoods, both within agriculture and beyond, i.e., focusing on other sectors of the economy, is particularly important for countries where the proportion of people engaged in the primary sector is above 40% of all employment (ILO, 2004). This concerns about half of all countries worldwide. The share of households with wage-specialized earnings appears to considerably contribute to an increase of household GDP per capita (Hertel, 2004).

Migration is another livelihood strategy pursued by nearly 200 million people. Reasons for migration are manifold; they range from labor seeking, economic interest and family reunification to displacement due to natural or cultural disasters. Temporary migration and commuting to national and international, rural and urban destinations are now a routine part of the livelihood strategies of many households, including farm households, both in industrialized and developing countries. The effects of migration on agriculture are highly diverse—migration can be a negative phenomenon that creates labor shortage in rural areas, leaving the land abandoned; or it can mitigate population pressure and resource use, and the remittances from family members can boost agricultural development (IOM, 2007).

Income

Economic well-being is most commonly thought of in terms of income (measured as a flow over a particular period of time). For a farm household, for example, this may be in kind (such as food crops produced on the farm) as well as in cash, and may come from both on-farm and off-farm sources. Gross national income per capita averaged US$1,502 in developing countries in 2004, or about US$4 per day (World Bank, 2006c); half the people in developing countries live on less that US$2 per day, and 19% live on less than US$1 per day (World Bank, 2006c). By contrast, income per capita in high-income countries averaged US$32,112 in 2004, or about US$88 per day. Generally, there is a strong correlation between the average income per capita and the share agriculture takes in GDP. The lower this share is, the higher the income (see Figure 1-13).

A simple measure of economic well-being can be derived by comparing an individual's or household's income over a given period of time with their needs or wants over that same period of time. The disadvantage of such a simple measure is that it could indicate that a household was well-off at present even if it was increasing its income in the short term by depleting its resources in a way that is unsustainable over the long term. Thus a more complete measure of economic well-being requires knowledge about the resources from which an individual or household derives its income.

Resources. Control of resources shapes income-generating opportunities, and determines how resilient households are when incomes fluctuate in response to changing economic conditions or natural disasters. Resources can be grouped in various ways, e.g., natural, human and social capital and wealth (or man-made capital) (Serageldin, 1996). Wealth can be further divided into physical and financial forms (Chambers and Conway, 1991). Access to different forms of capital varies widely across and within regions, affecting the choices that households make in combining resources in their diverse livelihood strategies, and also affecting the types of AKST investments that are most relevant in any particular context.

An important aspect of resources is the discussion of labor productivity versus land productivity. These are often compared to show the differences between the achievements of formal AKST versus local knowledge. The value of production in industrialized countries is much higher than in developing countries (Wood et al., 2000), simply because the energy balance is hardly taken into account when comparing mechanized with manual agricultural systems. It is noteworthy, however, that there are groups of countries where labor productivity made particular progress (probably through mechanization), while others made most progress in land productivity, and sub-Saharan countries had only little advances over the past 30 years, although with probably the best energy balance (Byerlee et al., 2005). Latin America has the highest levels of labor productivity in the developing world, followed by the Middle East and North Africa, and transition economies. South-East Asia and sub-Saharan Africa have considerably lower labor productivity levels although, in terms of growth, China is leading (ILO, 2004; see Figure 1-14).

Education. Reported gross primary school enrolment rates are near universal in developing countries already, but completion rates are lower, and more than 100 million children of primary school age remain out of school. Gross enrolment rates drop to 61% for secondary education and 17% for tertiary education (World Bank, 2006c). Primary and secondary education are near-universal in high-income countries, and drop to 67% for tertiary education. Adult literacy rates in developing countries are 86 and 74% for men and women, respectively (World Bank, 2006c).

Research. Expenditures for public agricultural research and development (R&D) averaged 0.5% of agricultural GDP in high-income countries (Pardey et al., 2006), which in view of the high disparity between the GDPs themselves must be seen as a potentially greatly underrated difference. Moreover, about five times as many scientific and technical journal articles were published by authors from high-income

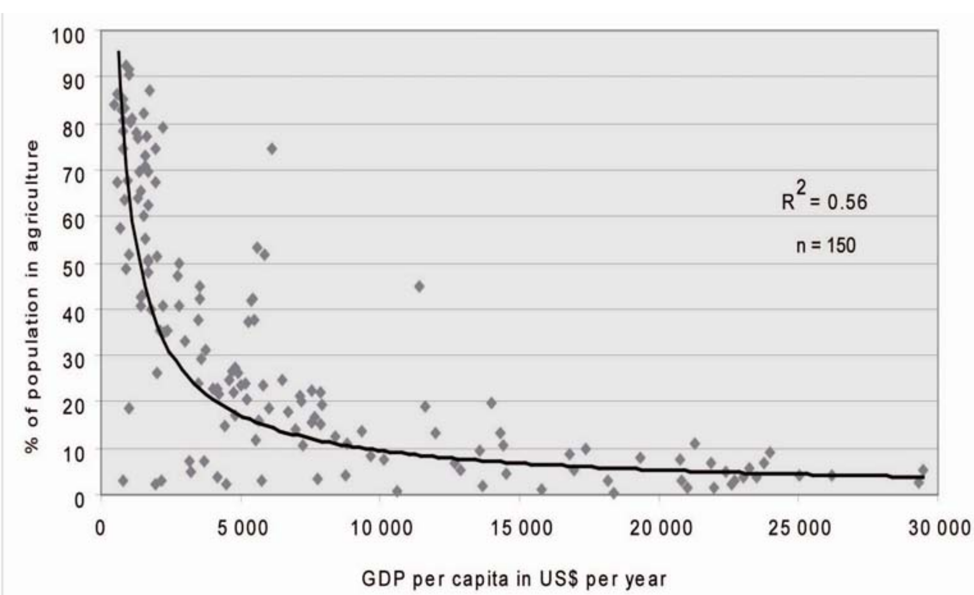
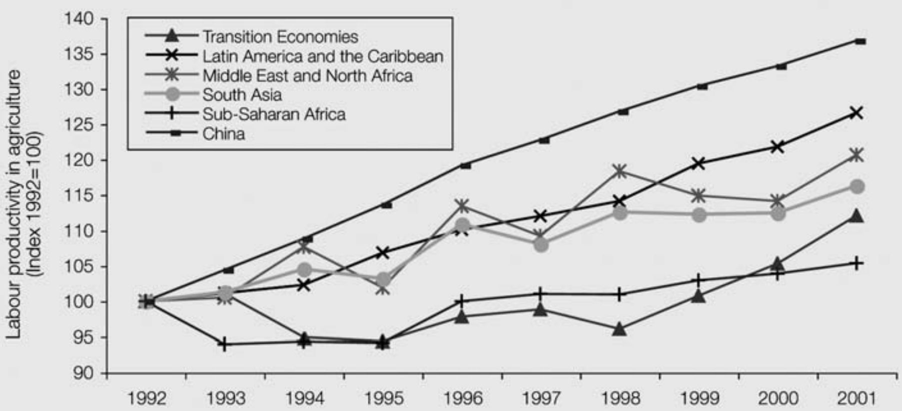


Figure 1-13. *World distribution of GDP per capita and percentage of population working in agriculture (Average of years 1990-2002).* Source: Based on Hurni et al., 1996, with data from World Bank, 2006c; ILO, 2007.



Labour productivity in agriculture in 1992 and 2001, (US$ 1995)

	1992	2001
Transition Economies	2165	2427
Latin America and the Caribbean	2874	3640
Middle East and North Africa	1993	2405
South Asia	360	418
Sub-Saharan Africa	344	362
China	250	342

Figure 1-14. *Labor productivity in agriculture by region (1992-2001) and labor productivity levels in 1992 and 2001.* Source: ILO, 2004

countries as were published by authors from developing countries in 2001 (World Bank, 2006c).

Measurement of the different forms of capital poses many challenges, particularly for those forms that are non-marketed. In an effort to better understand the importance of different types of capital, the World Bank (1997) undertook to estimate the value of human resources, produced assets, and natural capital. They noted that human resources include both raw labor power and the embodied knowledge that comes from education, training and experience. Monetary values are admittedly imprecise, but what was striking about their results was the uniform dominance of human resources, which accounted for 60-80% of total wealth in all regions except for the Middle East, where natural capital, in the form of energy reserves, accounted for an unusually high proportion.

Livelihoods, resilience, and coping strategies. Even though a large number of people depend entirely on agriculture, off-farm income is important for the livelihoods of many farming households. Agriculture's share of GDP was declining in both developing and high-income countries, while the share accounted for by the service sector was increasing—to 52% in developing countries and 72% in high-income countries (World Bank, 2006c). Data are scarce, but in many developing countries the informal sector accounts for a large (and in some cases rising) share of urban employment (World Bank, 2006c). Remittances from workers abroad form an increasing share of income in most developing regions, totaling US$161 billion in 2004 and accounting for more than 3% of GDP in South Asia (World Bank, 2006c). A household may be able to avoid hunger and maintain its human capital during a drought by depleting its financial, physical or natural capital (for example, by drawing on its savings or selling its livestock or failing to maintain the fertility of its soils). But this may threaten its ability to survive over the longer term. Alternatively, a household may accept severe cuts in consumption in the short term, with consequences for health and strength, precisely in order to protect its endowment of other resources and its ability to recover in future.

Different resource endowments and different goals imply different incentives, choices, and livelihood strategies. For example, two households that have the same endowments of land, labor, and materials may choose different cropping strategies if one household does not have access to savings, credit or insurance and the other one does. In this case the first household may choose to plant a safe but low-yielding crop variety while the second household will plant a riskier variety—expecting higher yields while at the same time knowing that additional financial capital could help sustain income (and consumption levels) even if it were to suffer a poor harvest.

Likewise different livelihood strategies and different weather and market conditions imply different outcomes, which in turn imply different endowments. In the example just mentioned, the first household may suffer smaller losses in a drought year, but also smaller gains in average and good years. Even when both households suffer losses, their coping strategies might differ. The first, in order to meet consumption needs, might be forced to sell assets. If many other households are in a similar position, asset prices might fall, making it even more difficult to exchange them for sufficient food. Households with sufficient food or financial reserves, by contrast, may be in a position to buy assets at discounted prices, increasing not only their own ability to survive future droughts but also the degree of inequality in the region (Basu, 1986).

These sometimes desperate tradeoffs between different components of the resource endowment illustrate why simple or short-term definitions of poverty, hunger and food security provide an incomplete understanding of household's livelihood strategies. They have important implications for economic sustainability, which we will explore in the next subchapter. They also have important implications for environmental sustainability and social equity.

Economic dimensions of sustainability

Sustainability, like food security, has been defined in many ways. The Brundtland Commission (WCED, 1987) defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." But even such an intuitively appealing definition raises difficult operational questions regarding both needs and ability (Serageldin, 1996). Abilities depend on the resources that individuals and households have at their disposal, and the ways in which they can be combined and exchanged to produce goods and services that they desire.

Sustainability can, in turn, be understood in terms of maintaining or increasing a household's ability to produce desired goods and services—which may or may not involve maintaining or increasing the level of each particular component of the household's resource endowment. A very narrow interpretation of sustainability involves maintaining each component of the resource endowment at its current level or higher. In its strictest sense this would mean that non-renewable resources could not be used at all, and that renewable resources could be used only at rates less than or equal to their growth rates. Such a requirement would preclude extraction of oil to improve human capital, for example by investing in education for girls (Serageldin, 1996). A broader interpretation of sustainability by contrast, involves maintaining the total stock of capital at its present level or higher, regardless of the mix of different types of capital. This would require the unrealistic assumption that different types of capital can be substituted completely for one another, and that complete depletion of one type is acceptable as long as it is offset by a sufficient increase in another. An intermediate alternative involves maintaining the total stock of capital, but recognizing that there may be critical levels of different types of capital, below which society's (or an individual's, or a household's) ability to produce desired goods and services is threatened.

Measuring the different forms of capital poses considerable challenges, and these in turn complicate assessments of sustainability. In an effort to improve such assessments, the World Bank (1997) sought to adjust national accounts and savings rates for investment in and depletion of natural and other forms of capital not traditionally included in those accounts. Accounting for changes in natural capital and human resources, they found that high-income OECD countries have had "genuine savings rates" of around 10% per year over the past several decades—less than traditional measures of investment, but still positive (and thus sustainable, at least in the broad sense). Asia and Latin America have also had positive genuine savings rates, most notably in East Asia (with rates approaching 20% per year). Sub-Saharan Africa and the Middle East/North Africa, on the other hand, have consistently had negative genuine savings rates of -5 to -10% per year (World Bank, 1997). Such patterns and concerns continue today.

The World Bank's measure of adjusted net savings currently begins with gross savings, adds expenditures on education, and subtracts measures of consumption or depletion of fixed (i.e., produced) capital, energy, minerals, forest products and damages from carbon dioxide and particulate emissions. In contrast to gross savings of 27.5% of GNI in developing countries and 19.4% in high-income countries in 2004, adjusted net savings after accounting for selected changes in human, physical, and natural capital were 9.4 and 8.7% in the two regions, respectively. Adjusted net savings were highest in East Asia and the Pacific (23.9% of GNI) and lowest in sub-Saharan Africa (-2.0%) and the Middle East and North Africa (-6.2%) (World Bank, 2006c). These findings reinforce concerns about sustainability by any of the measures described above. Similarly, the recent growth in crops, livestock, and aquaculture production has come at the expense of declines in the status of most other provisioning, regulating and cultural services of ecosystems (MA, 2005a).

1.3.2 Hunger, nutrition and human health

Some key characteristics of hunger, nutrition and human health are related to working conditions in agriculture and the effects of HIV/AIDS on rural livelihoods. Health is fundamental to live a productive life, to meet basic needs and to contribute to community life. Good health offers individuals wider choices in how to live their lives. It is an enabling condition for the development of human potential. Societies at different stages of development exhibit distinct epidemiological profiles. Poverty, malnutrition and infectious disease take a terrible toll among the most vulnerable members of society. Good nutrition, as a major component of health, has much to contribute to poverty reduction and improved livelihoods.

Health

Health has been defined as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO, 1946). It is an enabling condition for the development of human potential. The components of health are multiple and their interactions complex. The health of an individual is strongly influenced by genetic makeup, nutritional status, access to health care, socioeconomic status, relationships with family members, participation in community life, personal habits and lifestyle choices. The environment—whether natural, climatic, physical, social or at the workplace—can also play a major role in determining the health of individuals.

The health profile of a society can be framed in terms of both measurable aspects—for example, access to clean water, safe and nutritious food, improved sanitation, basic health care, and education; mortality and morbidity rates for various segments of the population; the incidence of disease and disability; the distribution of wealth across the population—as well as factors that are less easily quantifiable. Among these are issues of equity or discrimination as evidenced in a society's treatment of minority groups, such as indigenous peoples, immigrants and migrant workers, and of vulnerable groups, such as women, children, the elderly and the infirm. These factors influence not only the general sense of social well-being but also the health of individuals and groups. Multiple measurement approaches can maximize data accuracy; however, the cost of such measurements must be taken into account.

Societies at different stages of development exhibit distinct epidemiological profiles. The prevalence of various causes of death, average life expectancy, disability-adjusted life years, infant and under-five mortality rates and maternal mortality rates all fluctuate in discernible patterns as the economic underpinnings of society change. For example, societies that depend on hunting and gathering typically have short average life expectancies and deaths due to accident or injury are more prevalent. Agrarian societies show a greater prevalence of death from infectious disease as the major cause of death, particularly among children. In industrial societies, death from cardiovascular disease is predominant, whereas in a service-based post industrial society, the major cause of death is cancer. In the societal form now emerging, it is expected that the predominant cause of death will be senescence—age-related disorders (Horiuchi, 1999).

Such a typology is useful as a rough guide when examining the health statistics or "health profiles" of countries at different stages of development. They demonstrate the linkages between socioeconomic development and human health: the heavy burden of infectious disease in poor, predominantly agrarian countries; the double burden of both infectious and noncommunicable diseases in middle-income developing countries where basic sanitation, clean water and health care systems have already considerably reduced under-five and maternal mortality rates and thereby lengthened average life spans. However, great differences still exist in the health status of rural and urban population groups; and advanced industrialized economies, with aging populations and a predominance of "lifestyle" diseases often related to excessive consumption, inadequate physical activity and the use of tobacco.

Health gains in recent decades are nowhere more evident than in the extension of life expectancy at birth from a global average of 46 years in 1950-55 to 65.4 years a half century later. This progression is expected to continue, reaching an estimated global average life expectancy of 75.1 years in the period 2045-2050 (UN, 2005a). These positive gains are also witnessed in the speed with which developing countries have narrowed the gap in life expectancy between more industrialized and less developed regions of the world, from a difference of 25 years in the period 1950-1955 to slightly over 12 years in 2000-2005 (UN, 2005b). This rapid improvement is due principally to greater access to clean water, sanitation, immunization, basic health services and education: all factors that have transformed the health profile of populations.

While these average figures demonstrate considerable global progress, they also mask wide disparities at the local, national and regional levels. For example, for the past decade, largely due to the ravages of AIDS, life expectancy in Africa has been declining, reaching the current level of 45 years, more than 20 years lower than the global average. The gap in life expectancy between sub-Saharan Africa and the industrialized economies of Europe and North America in 2000 was wider than at any time since 1950 (World Bank, 2006a).

Quality of life questions gain in importance as average life expectancy grows, and here too the gaps between richer and poorer countries and regions are evident. People living in developing countries not only have lower average life expectancies, but also spend a greater proportion of their lives in poor health, than do those in industrialized countries. More than 80% of the global years lived with disability occur in developing countries, and almost half occur in high-mortality developing countries. Healthy life expectancy, that is, total life expectancy reduced by the time spent in less than full health due to disease or injury, ranges from a low of 41 years in sub-Saharan Africa to 71.4 years in Western Europe, with the proportion of lost healthy years ranging from 9% in Europe and the Western Pacific to 15% in Africa (WHO, 2005).

Infectious disease has ceded its place to noncommunicable illnesses, such as heart disease, cancer and degenerative conditions, as the primary cause of mortality worldwide. Noncommunicable diseases accounted for about 60% of all deaths and 47% of the global burden of disease in 2002, and figures are expected to rise to 73% and 60% by 2020 (WHO, 2003b). Yet, once again, sub-Saharan Africa is the striking exception to the rule, since more than 60% of deaths in that region are attributable to infectious disease, with HIV/AIDS as the number one killer of adults aged 15-59 (WHO, 2003b). The resurgence of infectious disease, whether due to the growth of drug-resistant germs, as in tuberculosis, or the transmission to humans of viral pathogens of animal origin continue to pose health threats worldwide.

Poverty, malnutrition and infectious disease take a terrible toll among the most vulnerable members of society. Of the 57 million deaths worldwide in 2002, 10.5 million were among children less than five years of age. More than 98% of those childhood deaths occurred in developing countries. The principal causes were peri-natal conditions, lower respiratory tract infections, diarrhea-related disease and malaria, with malnutrition contributing to all (WHO, 2003b). Infections and parasitic diseases accounted for 60% of the total (WHO, 2003b). The prevalence of malnutrition and infectious disease among the young has important implications for the health and well-being of the population as a whole, since the functional consequences of ill health in early childhood are likely to be felt throughout life, affecting the individual's physical and mental development, susceptibility to disease and capacity for work. In rural areas, in particular, where much work requires sustained physical effort, lack of strength and endurance can lower labor capacity, productivity and earnings. Much of the burden of death as a result of malnutrition is attributable to moderate, rather than severe undernutrition (Caulfield et al., 2004). Young children with mild to moderate malnutrition had 2.2 times the risk of dying compared to their better nourished counterparts, and for those who were severely malnourished the risk of death was 6.8 times greater (Schroeder and Brown, 1994). Children from poor households had a significantly higher risk of dying than those from richer households (WHO, 2003b).

Hunger

At the turn of the millennium, the world produced sufficient food calories to feed everyone, mainly because of increased efficiency brought about by the evolving plant science industry and innovative agricultural methods, including pesticides. The dietary energy supply for the global population was estimated to be 2803 kcal per person per day, comfortably within the range of average energy intake considered adequate for healthy living. Yet close to 800 million people were undernourished. Uneven distribution and consumption patterns across regions and among population groups, however, meant that the average actual food supply ranged from 3273 kcal per capita per diem in industrialized countries to 2677 in developing countries. Even these averages mask tremendous disparities. Dietary energy supply per capita per diem in Afghanistan, Burundi, the Democratic Republic of Congo and Eritrea was less than half that in Austria, Greece, Portugal and the United States (FAO, 2004a).

While global production of food calories has outpaced population growth, thanks to improved farming methods and advances in plant and animal sciences, the number of people potentially supported by the world's food supply depends heavily on the kind of diet people consumed. There are vast regional differences in the prevalence of undernourishment (see Figure 1-15), which is increasing the vulnerability to hunger and famine.

It has been calculated that the global food supply in 1993 was adequate to feed 112% of the world population on a near vegetarian diet, but only 74% of the population on a diet composed of 15% animal foods and just 56% of the population on a diet in which 25% of calories were derived from animal products (Uvin, 1995; DeRose et al., 1998). By the early 1990s, roughly 40% of the world's grain supply was consumed in animal feed, with grain-to-livestock ratios conservatively estimated at two kilos of grain to produce one kilo of chicken, four kilos for one kilo of pork and seven kilos for one kilo of beef (Messer and DeRose, 1998). Demand for meat is increasing in many parts of the world and feedlot livestock production will cause ever heavier demands on food resources as the proportion of industrially produced animal products increases.

Almost 60% of the world's undernourished people live in South Asia, whereas the highest incidence of undernourishment is in sub-Saharan Africa, where approximately one-third of the population is underfed and hunger is on the increase (FAO, 2006a). In sub-Saharan Africa, food production per capita has not grown in the past three decades. Indeed, it declined during the 1970s and has remained stagnant ever since (FAO, 2006a).

Poor households spend a proportionately larger share of their income on food than do wealthier households, and this budget share tends to decline as income rises. It is not unexpected, therefore, that per capita GDP is correlated with underweight of children under 5 (Haddad, 2000; see Figure 1-16).

In low-income countries, average expenditure on food, beverages and tobacco represented 53% of household spending, compared to 35% in middle-income and 17% in high income countries. The budget share ranged from 73% of total household budget in Tanzania to less than 10% in the United States. The composition of the foodstuffs purchased varied according to income levels as well, with households in low-income countries spending significant portions (over one-third) of their budget on cereals, and fruit and vegetables, including roots and tubers, whereas meat, dairy and tobacco took up higher shares in high-income countries. Low value staple foods accounted for more than a quarter of consumers' total food budget in low-income countries, compared to less than one-eighth in wealthier countries

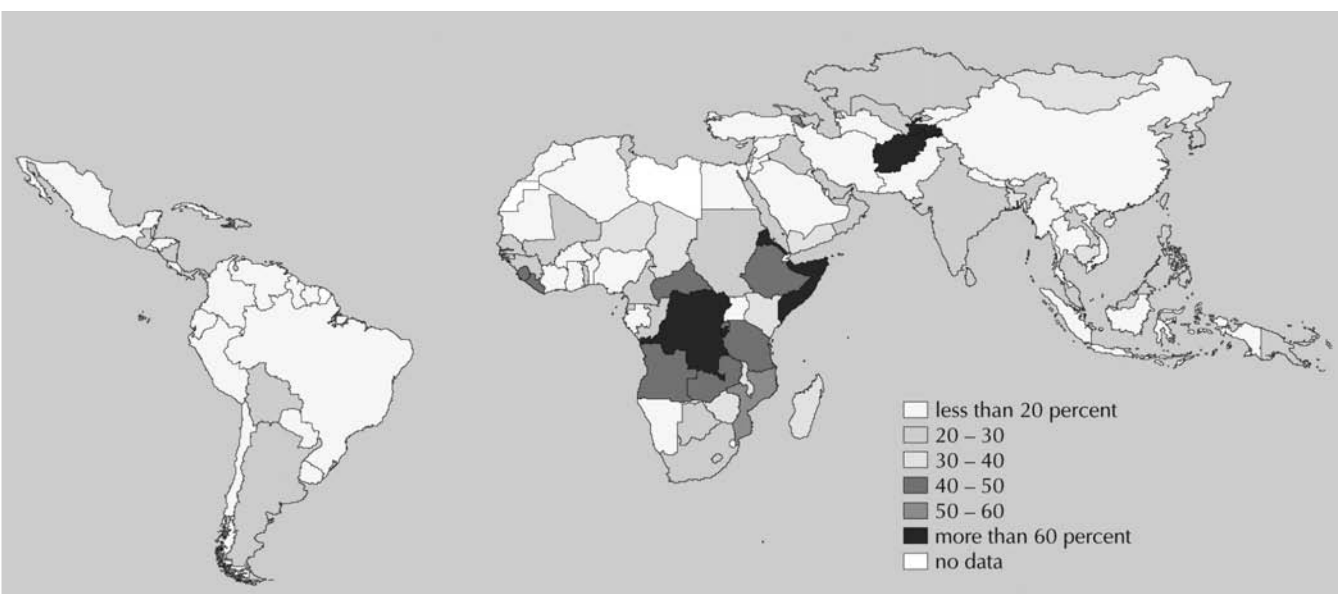


Figure 1-15. *Proportion of the population unable to acquire sufficient calories to meet their daily caloric requirements, 2003 estimates.*
Source: Rosegrant et al., 2006.

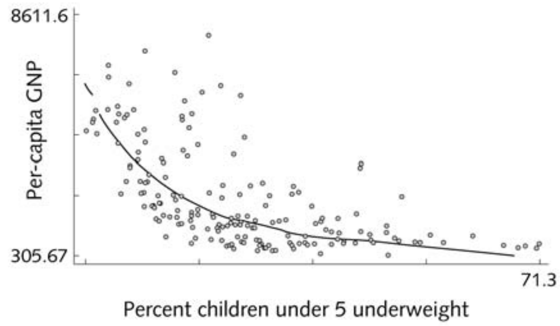


Figure 1-16. *Relationship between per capita gross national product (GNP) and nutrition.* Source: Haddad, 2000.

(Seale et al., 2003). Per capita meat consumption in high-income countries was more than 11 times higher than that in low-income countries in 2002 (WRI, 2006).

Poor rural infrastructure contributes to high food costs for rural poor people. For example, in the upper east region of Ghana, expenditure on food averages over 75% of the household budget. Farmers who lack storage facilities or access to credit are forced by necessity to sell their crops soon after harvest when prices are at their lowest. During the dry season, they buy food when prices are at their highest. In many cases it is women who spend the greatest effort in ensuring food security for the family, cultivating garden plots, carrying out income generating activities and spending the largest portion of their income on food, followed by health. In some cases, women's enterprises pay their women employees in food, in order to ensure that the household benefits directly from the woman's work and that cash earnings are not diverted to other purposes (IFAD, 1998).

Nutrition

Nutrition is one of the major components of health. A healthy diet is typically seen as one which provides sufficient calories to meet the individual's energy needs, as well as adequate protein, vitamins, minerals, essential fatty acids and trace elements to ensure growth and maintenance of life. While the volume of food intake is important, an adequate intake of calories does not in itself ensure that the need for micronutrients has been met. Good nutrition is based on principles of variety, proportion and balance in the choice of foods. Good nutrition has much to contribute to poverty reduction. It is intrinsic to the accumulation of human capital, since sound nutrition provides the basis for good physical and mental health, and is thus a foundation for intellectual and social development and a productive life.

Malnutrition is often linked to poverty and disease, for each one lays the groundwork for the others and contributes to its perpetuation. In developing countries where nutrient deficiencies are most prevalent, malnutrition in children is the result of a range of factors including insufficient food, poor food quality, and severe and repeated infectious disease. It is a contributing factor to childhood death from diarrhea, acute respiratory illness and to a lesser extent, malaria, all among the leading causes of under-five mortality. Even children with mild to moderate malnutrition are at an increased risk of dying (Rice et al., 2000; Caulfield et al., 2004). Improving nutritional status, particularly of biologically vulnerable groups such as infants, children, and pregnant and lactating women, weakens the transmission of poverty from one generation to the next. AKST has a role to play in developing food crops of high nutritional value that can be produced at affordable prices.

More than 50 nutrients are needed to maintain good health, but the scope and global impact of inadequate nutrition have been studied for only a few critical nutrients, such as iron, iodine, vitamin A and protein. Of these, iron deficiency anemia is the most prevalent nutritional deficiency worldwide and is associated with parasitic infestation, chronic infection as well as other micronutrient deficiencies. It impairs physical and cognitive development in children and leads to reduced capacity for work and lower productivity in adults. In pregnant women, iron deficiency anemia contributes to maternal morbidity and mortality and increases the risk of fetal morbidity, mortality and low birth weight (UNSCN, 2004). Inadequate iodine in the diet affects nearly two billion people, approximately 23% of the global population, and is the primary cause of preventable mental retardation in children (UNSCN, 2004). Vitamin A deficiency, which affects an estimated 140 million preschool children and seven million pregnant women every year, can lead to night blindness, anemia, growth retardation and increased vulnerability to infectious disease and death (UNSCN, 2004).

Malnutrition can result from either excessive or inadequate intake of nutrients. Protein-energy malnutrition, for example, results from an imbalance between the intake of protein and carbohydrates and the body's actual need for them. Inadequate intake leads to malnutrition in the form of wasting, stunting and low weight; excessive intake leads to excess weight and obesity. Child malnutrition is particularly serious and more prevalent in rural than in urban areas.

A healthy diet is often pictured as a pyramid of food groups, with cereals and other staples at the base and progressively smaller layers of fruits and vegetables, followed by meat, poultry, fish, eggs and dairy products, and finally culminating in small amounts of fats and sugar at the peak. A balanced diet would draw on a variety of foods from each of the main groups, respecting the proportions assigned to each. Current patterns of food consumption involving overconsumption of fat, sugar and salt coupled with inadequate intake of whole grains, fruits and vegetables as well as the trend towards excess weight and obesity in many countries demonstrate how far from the ideal the modern diet has become. As the global burden of disease shifts to chronic illnesses, such as diabetes, cardiovascular disease, hypertension and cancer, there is a growing recognition of the impact of dietary habits, environmental hygiene and lifestyle choices on health outcomes (WHO, 2003a).

In recent years, efforts have been directed to analyzing the nutritional content of traditional, locally produced foods, taking into account food availability and eating patterns, in order to draw up dietary guidelines that are culturally meaningful and easily applicable in local conditions. Such food-based guidelines go beyond nutrients and food groups to a more holistic vision of nutrition based on how foods are produced, prepared, processed and developed. The health implications of agricultural practices, production and distribution of food products, sanitary standards and common culinary practices are all considered. The guidelines encourage the consumption of locally available foods and healthy traditional dishes and suggest an increase in food variety based on healthy alternatives (WHO, 1999). "Eat local" campaigns geared towards supporting local agriculture have engendered awareness of the benefits of fresh foods, as well as renewed social interactions, contributing to overall community health.

Food safety

Food-borne disease is estimated to affect 30% of the population in industrialized countries and to account for an estimated 2.1 million deaths in developing countries annually (Heymann, 2002). Globally, the proportion of the population at high risk of illness or death from food-borne pathogens is rising in many countries due to factors such as age, chronic diseases, immunosuppressive conditions and pregnancy. Well-publicized incidences of bovine spongiform encephalopathy (BSE), hoof-and-mouth disease, avian influenza and the mass culling resulting from these outbreaks have raised public concerns with regard to intensified food production, particularly of meat. The reemergence of bovine tuberculosis and brucellosis as well as the outbreaks of illness due to food-borne pathogens, such as salmonella, e. coli, and listeria, that may contaminate fruit, vegetables, poultry, beef or dairy products, have pointed to the need for strict food safety standards "from the farm to the fork", and raised awareness of the fact that the distances from the point of production to the point of consumption continue to grow. As the general public has become increasingly interested in the linkages between agricultural production systems and human health, the list of food-related health concerns has continued to grow. It includes uncertainty with regard to the effects of GMOs on human health, fear of pesticide residues on foodstuffs, recognition of the role that widespread use of antimicrobial agents have had in the emergence of infectious pathogens resistant to antibiotics, and concern with the impact of intensive, industrial-style poultry production on animal health and welfare. Such public concerns have all begun to affect food purchasing decisions in many countries (FAO, 2001a).

Both industrialized and developing countries have made efforts to improve surveillance and investigative capabilities regarding food-borne disease outbreaks over the past two decades. The experience acquired so far, together with molecular biology techniques, ICT, as well as new risk assessment and mitigation methodologies have improved prospects for targeted interventions to control and prevent disease. Safety assurance systems, which provide complete traceability from food production units through to the ultimate consumer, are being put in place in many countries. Such upstream and downstream management systems augment food inspection systems, which have proven unable to cope with the rapidly expanding trade in food products.

Working conditions in agriculture

Much agricultural work is arduous by nature. It is physically demanding, involving long periods of standing, stooping, bending, and carrying out repetitive movements. Poor tool design, difficult terrain and exposure to heat, cold, wind and rain lead to fatigue and raise the risk of accidents. New technology has brought about a reduction in the physical drudgery of much agricultural work, but has also introduced new risks, notably associated with the use of machinery and the intensive use of chemicals without appropriate information, safety training or protective equipment. The level of accidents and illness is high in some countries and the fatal accident rate in agriculture is twice the average for other industries. Worldwide, agriculture accounts for some 170,000 occupational deaths each year. Machinery and equipment, such as tractors and harvesters, account for the highest rates of injury and death (ILO, 2000).

Exposure to pesticides and other agrochemicals constitutes one of the principal occupational hazards, with poisoning leading to illness or death. The WHO has estimated that between two and five million cases of pesticide poisoning occur each year and result in approximately 40,000 fatalities. Pesticide sales and use continue to rise around the world. In developing countries, the risks of serious accident is compounded by the use of toxic chemicals banned or restricted in other countries, unsafe application techniques, the absence or poor maintenance of equipment, lack of information available to the end-user on the precautions necessary for safe use and inadequate storage practices, and handling and disposal practices (ILO, 1999). The health risks associated with pesticides have spurred efforts to reduce or eliminate their use, for example, through the development of integrated pest management (IPM) and the increase in organic agriculture.

Farmers, agricultural workers and their families live on the land. Their living and working conditions are interwoven, raising the threat of environmental spillover from the occupational risks mentioned above. Wider community exposure to pesticides may come in the form of contamination of foodstuffs, the reuse of containers for food or water storage, the diversion of chemically-treated seeds for human consumption, and the contamination of ground water with chemical wastes. Extensive public education efforts are needed to raise awareness of the dangers involved in the improper handling, storage and disposal of agrochemicals as well as of safe work practices that can prevent accidents and reduce exposure. National systems of chemical safety management can help to ensure that agrochemicals are properly packaged and labeled throughout the distribution chain so that end users in rural communities have the information they need to handle these substances with the necessary precaution.

Animal handling and contact with dangerous plants and biological agents give rise to allergies, respiratory disorders, zoonotic infections and parasitic diseases. In developing countries, in particular, a number of well-known and preventable animal diseases, such as brucellosis, leishmaniasis and echinococcosis, are transmitted to those working closely with animals, affecting millions each year. New threats to human health are posed by pathogens originating in animals and animal products. Indeed, three-quarters of the new diseases that have emerged over the past decade have arisen from this source (WHO-VPH, 2007). Yet, many countries lack effective veterinary and public health systems, let alone the multisectoral environmental health practices, required to prevent the spread of disease.

The interaction between poor living and working conditions determines a distinctive morbidity-mortality pattern among agricultural workers. A large number of rural workers live in extremely primitive conditions, often without adequate food, water supply or sanitation or access to health care. Poor diet combined with diseases prevalent among the rural population (such as malaria, tuberculosis, gastrointestinal disorders, anemia, etc.), occupational disorders, and complications arising from undiagnosed or untreated diseases can be deadly and is certainly debilitating. A vicious circle of poor health, reduced working capacity, low productivity and shortened life expectancy is a typical outcome, particularly for the most vulnerable groups, such as those working in subsistence agriculture (i.e., wage workers in plantations, landless daily paid laborers, temporary and migrant workers and child laborers).

While difficult to quantify, child labor in agriculture is known to be widely prevalent. It is estimated that of the 250 million working children in the world, roughly 70% are active in agriculture. Many of these children work directly for a wage or as part of a family group, exposed to the same work hazards as adults; they endure long daily and weekly hours of work under strenuous conditions. Exposure to agrochemicals, injuries due to machinery or tools, and the repeated shouldering of heavy loads have a negative impact on their health and development with life-long consequences. Conditions of poverty, including poor housing, an inadequate diet and lack of sanitation, little access to health care and loss of educational opportunity, compound these health problems and mortgage their future (ILO, 2006).

HIV/AIDS and its effects on rural livelihoods

The HIV/AIDS epidemic provides a compelling example of the linkages among poverty, illness, food insecurity and loss of productive capacity as well as the differentiated effects on sufferers, caregivers, other family members and the wider community. An estimated 40.3 million people were living with HIV in 2005, two-thirds of whom were in sub-Saharan Africa, where agriculture is the mainstay of most economies and women comprise the backbone of the agricultural labor force. In that region, 57% of adults (15-49) living with HIV were women (UNAIDS and WHO, 2005).

While the epidemic affects people of all ages and in all walks of life, the disease cuts to the heart of the rural economy, afflicting adults in the prime of life, reducing their capacity to earn a living and provide for their families, whether from off-farm activities or from cultivation of the land. Women and girls, who already carry out the bulk of the work in small-scale, labor-intensive agriculture, split their waking hours between care for the sick and the orphaned, their traditional productive work and additional tasks taken on to compensate for the lost labor of family members struck down by the disease (UNAIDS and WHO, 2005).

The viability of rural households is undermined by the loss of family labor and the increased cash requirements to meet medical costs and eventually funeral expenses, which can trigger sales of crops, livestock, farm tools and other assets. The death of a male head of household can lead to destitution for wives and children in societies where customary law prevents women from inheriting property, or where "widow inheritance" transfers a surviving wife to another male family member. Stigmatization further marginalizes surviving family members from the community (UNAIDS, 2005).

HIV/AIDS has become a major factor in the pervasiveness of food insecurity, as it undermines farm families' ability to cultivate adequate food for their members. Irregular and poor quality nutrition, in turn, hastens the onset of AIDS in those weakened by HIV and increases vulnerability to opportunistic infections.

The global labor force had lost 28 million economically active people to AIDS by 2005, a figure which is expected to rise to 48 million by 2010 and 74 million by 2015. Two-thirds of these labor losses will be in Africa, where four countries are expected to lose over 30% of their workforce by 2015 (ILO, 2005). Fewer workers mean more families left without providers, more children left without parents, and the loss of transmission of knowledge, skills and values from one generation to the next. Orphans are left in the care of the elderly or to fend for themselves in poverty and without access to education.

Agriculture and health are interlinked in complex ways. Agriculture produces the products on which humanity depends for its health—food—and yet, most of the poverty and malnutrition in the world is found in rural areas among those who work in agriculture. AKST has an important role to play in ensuring that future food supplies are available to meet growing demand for nutritious, safe and health-giving foods so that these can be made available at affordable prices to those who need them most.

1.3.3 Environment and natural resources

Natural resource issues

Natural resources are an indispensable basis for agriculture. A range of ecosystems produce the wide range of goods and services on which human survival depends. Production of these goods and services, including those related to agriculture such as food, is supported by a range of basic natural resources including soil, water and air. The demand for food will continue to rise as the human population increases, and while in the short-to-medium term production is expected to rise to meet this demand, there is growing concern about the vulnerability of the productive capacity of many agroecosystems to stress imposed by intensification, e.g., water scarcity and soil degradation (Thrupp, 1998; Conway, 1999; MA, 2005c; CA, 2007). Thus for instance, loss of biodiversity through simplification of habitats when monocultures are established in large areas is a major concern (Ormerod et al., 2003). The negative impact of increased soil erosion on downstream aquatic ecosystems and other activities such as fisheries can also be discerned. The positive and negative impacts of chemical inputs, particularly inorganic fertilizers and pesticides, are also well documented.

Sustainable use of natural resources is critical for sustainable livelihoods, and it has a direct impact on the improvement of natural capital. Both the poor and the rich impact the environment. Where access is easy and extraction is not capital-intensive, poor people may overuse natural resources; the poor also tend to be the most vulnerable to the effects of environmental degradation. By contrast, where extraction is highly capital intensive—such as in the case of deep groundwater extraction—the rich tend to have the biggest impact (Watson et al., 1998).

Agriculture is sustainable if the productive resource base is maintained at a level that can sustain the benefits obtained from it. These benefits are physical, economic and social. Ecological sustainability thus needs to be defined in relation to the sustainable use of natural resources, i.e., maintaining the productive capacity of an ecosystem.

Pressures on ecosystems have important consequences for agricultural production. In turn, agriculture has ecological impacts on ecosystems, and on the services provided by ecosystems.

The IAASTD recognizes that in agriculture, there is most often a continuum between a farming system and a natural ecosystem, as the term agroecosystem indicates. Farmers have a pivotal role as managers of these systems, and as stewards of their resource base. Their role includes for example the conservation of soil properties and water availability, the development and maintenance of crop species and the pursuit of multipurpose production objectives. Issues relating to NRM management are often framed as specific problems such as soil degradation, water pollution, biodiversity loss. We should also frame agriculture's contribution to NRM positively: farmers create and enhance resources such as arable soil, agrobiodiversity, productive forest stands. Working with the natural resource base, they often enrich and enhance it.

Drivers of natural resource degradation and depletion. As with other ecosystems, a range of direct and indirect drivers influence changes in natural resources in agricultural ecosystems. These drivers can act directly or indirectly to cause change. They may range from well defined drivers to those involving complex interactions. Among the key drivers assessed here is the role of decision makers and identification of those drivers that influence their decisions. Also important are the specific temporal, spatial and organizational scale dependencies as well as linkages and interactions between these drivers. The approach adopted also assumes that decisions are made at local, regional and international levels. Many globally recognized drivers are likely to influence natural resources in the context of agriculture, including demographic, economic, sociopolitical, science and technology, cultural and religious, and physical, biological and chemical drivers (see Figure 1-7).

Definition of natural resources

No unanimously accepted definition of natural resources exists. Natural resources can be defined as "factors of production provided by nature. This includes land suitable for agriculture, mineral deposits, and water resources useful for power generation, transport and irrigation. It also includes sea resources, including fish and offshore minerals" (Black, 2003). Natural resources may also be more broadly referred to as resources that "include all functions of nature that are directly or indirectly significant to humankind, i.e., economic functions as well as cultural and ecological functions that are not taken into account in economic models or which are not entirely known" (CDE, 2002). Climate can also be considered as a natural resource.

In these broader definitions, resources such as timber or fish are part of ecosystems that are living environments containing forests, rivers, wetlands and drylands as well agroecosystems embedded in broader ecosystems that make use of selected resources within the ecosystem (WRI, 2005). From here, it is a short step to integrating natural resources in the "ecosystem services" concept (MA, 2005a), i.e., to describe natural resources as system elements that ensure human well-being through a range of interdependent regulating, supporting, provisioning and sociocultural functions.

Availability of natural resources. The Millennium Ecosystem Assessment concluded that the global availability of natural resources is shrinking. "Over the past 50 years, humans have changed ecosystems more rapidly than in any comparable period of time in human history, largely to meet rapidly growing demand for [natural resources]. This has resulted in a substantial and largely irreversible loss in the diversity of life on earth" (MA, 2005a). Ecosystem change means that availability of natural resources should not be expressed exclusively in terms of physical availability. Their functional availability needs to be indicated as well.

Natural resource dynamics. As a result of intensifying global interactions, spatial and temporal effects become more interlinked and these are related to the weak recognition of the multifunctional nature of agroecosystems at all hierarchical levels. Resource degradation in one location may lead to pollution in another location. High discount rates for agricultural investments, in particular in developing countries, have been an incentive for short-term decision making, with the effect that farmers undervalue both future benefits and the costs of their present resource use. However, hunger may influence a household's view of the agricultural discount rate. Thus, while many households are aware that their decision-making is short term, the severe cost of hunger makes long-term considerations of benefits of natural resources irrelevant to them. Both poverty-induced expansion of agricultural activities into fragile and vulnerable lands (Bonfiglioli, 2004), and capital-intensive extraction of resources such as groundwater can contribute to increased vulnerability of natural resources.

The functionality of ecosystems and the temporal effects of system alterations are insufficiently understood. For example, understanding and using ecosystem functions in agriculture could result in enormous ecological savings while at the same time contributing to sustainable production of food (e.g., Costanza et al., 1997). There is an increased risk of non-linear changes as a result of system alteration (MA, 2005a). Therefore, the understanding of spatial and temporal effects of natural resource use for agricultural production is an increasingly important issue for science and technology in agricultural development.

Vulnerability and resilience of natural resources. The loss of ecosystems such as wetlands and mangroves has reduced natural protection of resources by destroying all or part of the inherent system functionality (MA, 2005a). The differences between damage caused by the December 2004 tsunami on shores protected by functional coral reefs and shores where reefs had been degraded exemplifies the increase of vulnerability as a result of unsustainable human activity (IUCN, 2005).

Natural ecosystems often have had to bear the brunt of intensification in agriculture. The degradation of forests, grasslands, coastal ecosystems and inland waters threatens their services to, and thus the long-term productive capacity of, agroecosystems. It is known that in many cases agricultural activities have depleted natural resources (forests, soil, water) to an extent that has resulted in net productivity losses; these developments are caused by a wide range of drivers. In other cases (e.g., rainfed agriculture or sustainable soil conservation) agricultural practices have been operated by generations of successive farmers in a sustainable way.

Natural resources and their management

Forestry. Agriculture has had an intimate and productive relation with forests: many historical and contemporary farming systems are built partly on that relationship. Swidden agriculture in tropical areas, for example, uses forests as a means of soil and nutrient restoration.

Agroforestry and home garden systems are ways of combining trees and other species with crop production or animal husbandry. Up to the present, forests and agroforests have played an important role in contributing to the food security of a large part of the world's food insecure people. They provide products (timber, fuelwood, food, and medicines), inputs for crop and livestock production (fodder, soil nutrients, and pollination) and services (watershed protection, climate regulation, carbon storage, and biodiversity conservation) (FAO, 2006a).

Some 350 million of the world's poorest people are considered to be largely dependent on forests for their living, including for food production (WCSFD, 1999). A majority of farmers manage some trees on their land, or benefit from forests adjacent to their land, often for environmental services (e.g., to shelter or shade homes, crops and livestock, or for soil conservation), as well as for diverse products (such as fuelwood and fruit) (Scherr et al., 2004; Molnar et al., 2005). Approximately 1.5 billion people use products from trees as key elements of their livelihoods (Leakey and Sanchez, 1997).

Deforestation has been identified as a major problem facing forest resources. The expansion of agriculture in its many forms at the expense of forestland is one of the factors contributing to deforestation, though not the only one. The conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum 10% threshold is one definition of forestry. The rate of deforestation is proceeding at 13 million ha per year (FAO, 2007a).

Recent estimates show that forests cover about 31% of global land surface (FAO, 2007a). Since pre-agricultural times, forests have been reduced by 20 to 50% (Matthews et al., 2000). Patterns of forest management and use vary across the globe. Thus, for instance, while the last two and a half decades have seen an increase in forest area in industrial countries, developing countries have on average witnessed a decline of about 10% (FAO, 2007a; Figure 1-17). An increasing trend is also the rapid expansion of mixed forest/agriculture zones encroaching on formerly intact forest areas. 80% of the fiber and fuelwood production is derived from primary and secondary growth forests and therein lies the importance of management of this important resource. In addition to fiber and fuel, forests provide a range of ecosystems services. Forests make up two thirds of the more than 200 ecoregions identified by WWF as outstanding representatives of the worlds' ecosystems that include important endemic bird areas and more than three quarters of the centers of plant biodiversity (Olson and Dinerstein, 1998). Forest soils and vegetation store about 40% of all carbon in the terrestrial biosphere. However, due to deforestation rates that exceed growth, forests are currently a net source of atmospheric carbon. Loss of forest cover in watersheds has secondary effects on water resources through increased erosion, and alteration of water quantity and possibly floods. It has been estimated that roughly 0.75 ha of forest is now needed to supply each person on the planet with shelter and fuel (Lund and Iremonger, 1998).

Biological corridors play an important role in mitigating incidental or secondary effects. Thus, in some regions in Central America, using local and foreign funds, international organizations, governing institutions and rural committees are working to connect natural reserves by planting native tree species in deforested areas. These new green spots will open routes for the safe migration and mating of wild animals, as well as preserve the wild and native flora.

Grasslands

Grasslands are mostly associated with drylands where plant production is limited by water availability—the dominant users are large mammals, herbivores including livestock, and cultivation. Drylands include cultivated lands, scrublands, shrublands, grasslands, semideserts, and true deserts (MA, 2005c). They are, as their name implies, natural landscapes where the dominant vegetation is grass. Grasslands usually receive more water than deserts, but less than forested regions. Worldwide, these ecosystems provide livelihoods for nearly 800 million people. Grasslands are also a source of

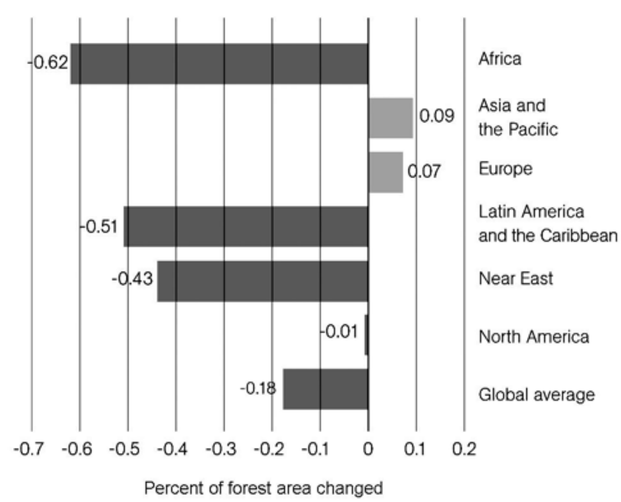


Figure 1-17. *Annual net change in forest area, 2000-2005.* Source: FAO, 2007a.

forage for livestock, wildlife habitat, and a host of other resources (White et al., 2000).

Grasslands provide feed for livestock farming across the globe as well as a wide range of ecosystem services. For instance, grasslands provide part of the cover to some of the world's major watersheds. Most of the world's meat comes from animals that forage on grasslands. World meat production has doubled since 1975, from 116 million to 233 million tonnes in 2000 (UNEP, 2002). Grasslands are also a major component of important areas of bird endemism and wildlife sanctuaries, and store approximately 34% of the global stock of carbon in terrestrial ecosystems.

Nearly 49% of grasslands are lightly to moderately degraded and at least 5% are considered strongly to extremely degraded (White et al., 2000). The degree of degradation is dependent on geographical location and management practices as well as on characteristics of the soil, vegetation, and grazing patterns. Cultivation and urbanization of grasslands, and other modifications can be a significant source of carbon to the atmosphere. For instance, biomass burning, especially on tropical savannas, contributes over 40% of gross global carbon dioxide emissions (Baumert et al., 2005).

Fisheries

Fish play a key role as an economic commodity of significance to a great number of farming households and rural poor people. Inland fisheries and aquaculture—for example in irrigated rice agroecosystems—are not only important as a direct food source: fish are also a high value commodity that can be traded for cash, for other needs and cheaper foods, by small-scale farmers and the poor, and provide a source of direct employment for 38 million and indirect employment for about 160 million people (FAO, 2004b; ICTSD, 2006). The highest share of fish workers (fishers and aquaculture workers) is in Asia (87%), followed by Africa (7%), Europe, North and Central America and South America (about 2% each) and Oceania (0.2%) (FAO, 2004b).

In 2002, about 76% (100.7 million tonnes) of estimated world fisheries production was used for direct human consumption. The remaining 24% (32.2 million tonnes) was destined for non-food products, mainly the manufacture of fishmeal and oil, slightly (0.4%) above levels in 1999 but 5.8% below levels in 2000 (FAO, 2004b). In 2002, total capture fisheries production amounted to 93.2 million tonnes. Marine capture fisheries production contributed 84.5 million tonnes. Between 2000 and 2003, the reported landings of marine capture fisheries have fluctuated between 80 and 86 million tonnes: a slight increase over the preceding decade (mean = 77 million tonnes). Production from different capture and culture systems varies greatly (CA, 2007).

At the global level, inland capture fisheries have been increasing since 1984. In 1997, inland fisheries accounted for 7.7 million tonnes, or almost 12% of total capture available for human consumption, a level estimated to be at or above maximum sustainable yields (Revenga et al., 2000). In 2000-2002, inland capture fisheries were estimated at around 8.7 million tonnes. However, there is still a lack of reliable data on global inland fisheries production, which are therefore estimated to be underreported by two or three times (FAO, 2004b).

In 2004, aquaculture accounted for 43% of the world's food fish production and is perceived as having the greatest potential to meet the growing demand for aquatic food (FAO, 2006c). World aquaculture has grown at an average annual rate of 8.8% from 1950 to 2004. In recent years, Asia and Africa have shown the highest growth with Latin America displaying only moderate growth. Production in North America, Europe and the former Soviet states has however declined. The average growth rate for the Asia and the Pacific region was 9.8%, while production in China, considered separately, has grown at a rate of 12.4% per year (FAO, 2006c).

In 2004, freshwater aquaculture was the predominant form of aquaculture, accounting for 56% of the total production while mariculture contributed 36% and brackish-water aquaculture 7.4% (FAO, 2006c). During the last decade, inland capture production has remained relatively stagnant. For instance, during the period 2000-2005, production ranged between 8.8-9.6 million tonnes. During the same period, aquaculture grew from 21.2 to 28.9 million tonnes. Similar trends have been observed in marine environments. Thus overall, the total aquaculture production grew from 35.5 to 47.8 million tonnes. Despite this increase in landings, maintained in many regions by fishery enhancements such as stocking and fish introductions, the greatest overall threat for the long-term sustainability of inland fishery resources is the loss of fishery habitat and the degradation of the terrestrial and aquatic environment.

About 40% of the world's population lives within 100 km of a coast. Because of the current pressures on coastal ecosystems, and the immense value of the goods and services derived from them, there is an increasing need to evaluate trade-offs between different activities that may be proposed for a particular coastal area. This important habitat is increasingly becoming disturbed due to human activity. Many coastal habitats such as mangroves, wetlands, sea-grasses, and coral reefs, which are important as nurseries, are disappearing at a fast pace. About 75% of all fish stocks for which information is available are in urgent need of better management (Burke et al., 2001; FAO, 2004b).

A recent assessment of fish stocks by the FAO indicates that only 20% of fish species is moderately exploited and only 3% is underexploited. Of the remaining 76%, 52% of stocks is fully exploited, 17% is overexploited and 7% is depleted (FAO, 2004b).

Depletion of marine resources is so severe that some commercial fish species, such as the Atlantic Cod, five species of tuna, and haddock are now threatened globally, as are several species of whales, seals, and sea turtles. The scale of the global fishing enterprise has grown rapidly and exploitation of fish stocks has followed a predictable pattern, progressing from region to region across the world's oceans. As each area in turn reaches its maximum production level, it then begins to decline (Grainger and Garcia, 1996).

Apart from being an important food source, fish can also be a source of contamination. In heavily polluted areas, in waters that have insufficient exchange with the world's oceans, e.g., the Baltic Sea and the Mediterranean Sea, in estuaries, rivers and especially in locations that are close to industrial sites, concentrations of contaminants that exceed natural load can be found. These increasing amounts may also be found in predatory species as a result of biomagnifications, which is the concentration of contaminants in higher levels of the food chain, posing a risk for human health (FAO, 2004b).

Water resources

In the hydrological cycle water resources can be divided into "blue" and "green" water. The main source of water is rain falling on the earth's land surfaces (110,000km^3) (CA, 2007). Blue water refers to the water flowing or stored in rivers, lakes, reservoirs, ponds and aquifers (Rockström, 1999). Globally, about 39% of rain (43,500 km^3) contributes to blue water sources, important for supporting biodiversity, fisheries and aquatic ecosystems. Blue water withdrawals are about 9% of total blue water sources (3,800 km^3), with 70% of withdrawals going to irrigation (2,700 km^3). The concept of green water (Falkenmark, 1995) is now used to refer to water that is stored in unsaturated soil and is used as evapotranspiration (Savenije and van der Zaag, 2000). Green water is the water source of rainfed agriculture. Total evapotranspiration by irrigated agriculture is about 2,200 cubic kilometers (2% of rain), of which 650 cubic kilometers are directly from rain (green water) and the remainder from irrigation water (blue water). To date, sub-Saharan Africa has the smallest ration of irrigated to rainfed water and more than half of irrigated land is in Asia (HDR, 2006; see Figure 1-18).

Technological advancements, especially in the construction of dams, have markedly increased the volume and availability of blue water for consumption and irrigation purposes. Similarly, improvements in pumping have motivated farmers to extract more and more groundwater. Moreover, the demand for water has increased at more than double the rate of population increase, leading to serious depletion of surface water resources (Penning De Vries et al., 2003; Smakhtin et al., 2004). Seventy percent of blue water abstraction is for irrigation; given increasing competition from other users water productivity is a priority concern. Furthermore, much of water used in irrigation is lost to less-than-optimal evaporation, not profiting plant growth.

On the other hand, half of the world's wetlands are estimated to have been lost during the last century, as land was converted to agriculture and urban use, or filled to combat

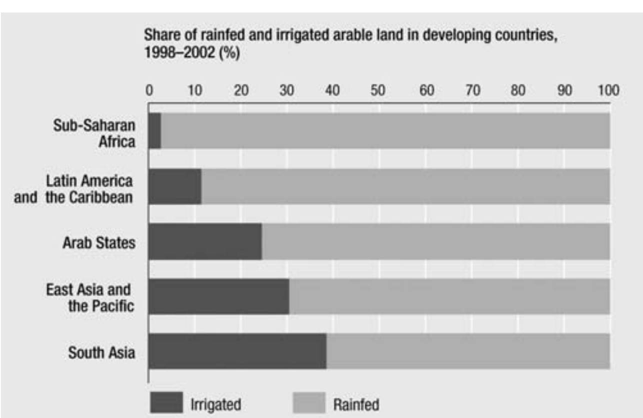


Figure 1-18. *Rainfed and irrigated arable land in developing countries, 1998–2002.* Source: HDR, 2006.

diseases, such as malaria. Yet these freshwater wetlands provide a range of services including flood control, storage and purification of water as well as being an important habitat for biodiversity. Worldwide water quality conditions appear to have been degraded in almost all regions with intensive agriculture and other developments (Molden and de Fraiture, 2004). Pollution is a growing problem in most inland water systems around the world while waterborne diseases from fecal contamination of surface waters continue to be a serious problem in developing countries (Revenga et al., 2000).

There is no agriculture without water. Agriculture's sustainability agenda as regards water is twofold: access to clean water for the poor on the one hand, improvements in water productivity and institutional arrangements on the other (CA, 2007).

Half of the world's 854 million malnourished people are small-scale farmers who depend on access to secure water supplies for food production, health, income and employment. Improving their access to clean water potentially has an enormous impact on their livelihoods and productive strategies by reducing poverty and vulnerability (HDR, 2006). With scarcity and competing demands for water increasingly becoming evident, growing more food with less water is a high priority. There is much scope for better water productivity both in low-production rainfed areas and in irrigated systems (CA, 2007). Blue water used in irrigation has a particularly important role, as 40% of global crop production is produced on irrigated soils (WWAP, 2003). In addition, irrigation often depends on dams that impact the environment in various ways, leading to disturbance or destruction of habitats and fisheries (WCD, 2000). To mitigate these impacts, water use efficiency is also paramount. Responses by AKST aiming at improving water use effectiveness include developing micro-irrigation systems (Postel, 1999) and more precise management techniques generally, but also breeding of drought-tolerant crop varieties such as in maize (Edmeades et al., 1999).

Soils

Soil is the source of nutrients required for plant growth and itself the result of organic processes of living organisms. It is therefore the primary environmental stock that supports agriculture. Soil condition varies widely but global estimates suggest that 23% of all used land is degraded to some degree, which is a cause of serious concern (Oldeman, 1994; Wood et al., 2000). The key soil degradation processes include: erosion, salinization and water logging, compaction and hard setting, acidification, loss of soil organic matter, soil nutrient depletion, biological degradation, and soil pollution. Agricultural activities influence all these processes (Scherr, 1999).

In crop cultivation, the resilience of arable soils is an issue of great concern. Different soil types have very different erodibility characteristics, i.e., their ability to resist soil erosion caused by water, wind, or plowing varies a great deal. Some soils will hardly recover once eroded, while others may regenerate within a relatively short time. There are two dimensions to the degradation of soils: first their sensitivity to factors causing degradation, and second their resilience to degradation, which is their ability to recover their original properties after degradation has occurred. Sensitivity and resilience depend on climate and the biophysical structures of the soil, and whether degradation has exceeded a threshold of resilience (such as loss of all organic matter or severe compaction) beyond which recovery is not possible without active intervention (Blaikie and Brookfield, 1987).

Soil, just like water, is a key resource for agricultural production. Sometimes erroneously subsumed under "land" issues, the availability of soils for growing crops often seem to be taken for granted. Yet in both the developing and the industrialized world, the loss of productive agricultural soils to urban development is enormous. In addition, according to an estimate by the Global Assessment of Human-induced Soil Degradation (GLASOD), degradation had affected 38% of the world's cropland, to some extent as a result of human activity (Oldeman et al., 1991). However, GLASOD did not estimate productivity losses associated with land degradation. In the absence of data on the productivity impacts of land degradation, estimates based on different methods vary widely (Wiebe, 2003).

The direct influence of agricultural practices cannot be neglected: they account for about a quarter of total soil degradation (GACGC, 1994). AKST is, and always has been, crucial to address these problems both through more classical approaches (e.g., proposing mechanical protection such as bunds and terraces to control surface runoff) and through more comprehensive frameworks aiming at greater integration of water conservation and soil protection and the use of biological methods (Shaxson et al., 1989; Sanders et al., 1999; WOCAT, 2006).

The impact of nitrates from fertilizers and livestock production on soil and water resources is a related issue. This impact can be described in general terms as the nitrification of the global ecosystem from inorganic fertilizers and alteration of the global nitrogen cycle. Eutrophication as a consequence of nutrient runoff from agriculture poses problems both for human health and the environment. Impacts of eutrophication have been easily discernible in some areas such as the Mediterranean Sea and northwestern Gulf of Mexico (Wood et al., 2000).

Some agricultural activities have led to a reduction of system productivity. For instance, irrigated agriculture has contributed to water logging and salinization, as well as depletion and chemical contamination of surface and groundwater supplies (Revenga et al., 2000; Wood et al., 2000; CA, 2007). Manure from intensive livestock production has exacerbated the problem of water contamination. Misuse of pesticides has led to contamination of land and water, to negative impacts on non-target species, and to the emergence of pesticide-resistant pests. These problems compound to reduce system productivity (Thrupp, 1998; Conway, 1999). The capacity of coastal and marine ecosystems to produce fish for human harvest is highly degraded by overfishing, destructive trawling techniques, and loss of coastal nursery areas. This is exacerbated by the decline of mangroves, coastal wetlands, and seagrasses with resultant loss of pollutant filtering capacity of coastal habitats.

Biodiversity

Biodiversity underpins agriculture by providing the genetic material for crop and livestock breeding, raw materials for industry, chemicals for medicine as well as other services that are vital for the success of agriculture, such as pollination. The last century has seen the greatest loss of biodiversity through habitat destruction, for instance through conversion of diverse ecosystems to agriculture. Other factors such as the growing threat from introduction of invasive alien species, fostered by globalization of trade and transport, have further exacerbated the situation. On small islands, introduction of invasive alien species, many through agriculture-related activities, is the main threat to biodiversity. In freshwater systems, an estimated 20% of fish species have become extinct (Wood et al., 2000). Globally, the cost of damage caused by invasive species is estimated to run to hundreds of billions of dollars per year (Pimentel et al., 2001). In developing countries, where agriculture, forestry and fishing account for a high proportion of GDP, the negative impact of invasive species is particularly acute. Globalization and economic development through increasing trade, tourism, travel and transport also increase the numbers of intentionally or accidentally introduced species (McNeely et al., 2001). It is widely predicted that climate change will further increase these threats, favoring species migration and causing ecosystems to become more vulnerable to invasion.

While agriculture is based on the domestication and use of crop and livestock species, the continuum between (wild) biodiversity and agrobiodiversity has been recognized both in research on plant genetic resources and in conservation efforts for many decades—starting with the hypothesis of "centers of diversity" of crop species proposed by Vavilov in the 1920s. More recently an emphasis on the provisioning services of biodiversity has been added: "Biodiversity, including the number, abundance, and composition of genotypes, populations, species, functional types, communities, and landscape units, strongly influences the provision of ecosystem services and therefore human well-being. Processes frequently affected by changes in biodiversity include pollination, seed dispersal, climate regulation, carbon sequestration, agricultural pest and disease control, and human health regulation. Also, by affecting ecosystem processes such as primary production, nutrient and water cycling, and soil formation and retention, biodiversity indirectly supports the production of food, fiber, potable water, shelter, and medicines" (MA, 2005c).

Agrobiodiversity is the very stuff of food production and an essential resource for plant and animal breeding. Yet it is a resource that is being lost *in situ*: in farms and agro-ecosystems (FAO, 1996b; Thrupp, 1998; CBD, 2006). Its conservation is somewhat framed by a paradox: new breeds have boosted agricultural productivity, but simultaneously they displaced traditional cultivars. In response, gene or seed banks have been created to fulfill a double function: to resource plant breeders with the agrobiodiversity needed for further crop development, and to conserve crop diversity that may have disappeared from agricultural systems. *Ex situ* conservation in seed repositories and gene banks has long been considered to be the central pillar of agrobiodiversity conservation.

To be effective, agrobiodiversity management needs to operate at several levels: local, national, and international. Against the overall trend of declining diversity in agricultural systems, crop diversity is still being created and preserved locally, and the importance of local *in situ* conservation efforts has more recently been acknowledged under Article 8 of the CBD. *In situ* conservation of crops and seeds on the farm or community level operates under a number of constraints, partly organizational, partly economic. These constraints can more easily be overcome if biodiversity management is part of an integrated approach—such as sustainable land management.

It is notable that plant varieties and animal breeds —very much like farming systems—are intricately linked to languages, environmental knowledge, farming systems, and the evolution of human societies. They embody history, both in their form which is a result of selection and adaptation to human needs, and through the knowledge that is associated with them. In participatory research and selection, such knowledge has increasingly been validated and valued.

In the contemporary context of rapid land use change, the complex coevolution of agrobiodiversity, ecosystems and human societies needs to be documented, analyzed and validated. An appropriate level for this task is the landscape. Cultural landscapes are complex but spatially bounded expressions of ecosystems that have evolved under the influence of biophysical factors as well as of human societies. They provide the context to understand how management practices have shaped the productive and characteristic landscapes of cultivated systems, and how crop knowledge fits into these patterns (Brookfield et al., 2003).

Agriculture and climate change

Agriculture contributes to climate change through the release of greenhouse gases in its production processes. It is a significant emitter of CH_4 (50% of global emissions) and N_2O (70%) (Bathia et al., 2004). The levels of its emissions are determined by various aspects of agricultural production: frequency of cultivation, presence of irrigation, the size of livestock production, the burning of crop residues and cleared areas. In many cases, emissions are difficult to mitigate because they are linked to the very nature of production; in a number of cases, however, technical measures can be adopted to mitigate emissions from specific sources.

Agricultural activities account for 15% of global greenhouse gas (methane, nitrous oxide and carbon dioxide) emissions (Baumert et al., 2005). Two-fifths of these emissions are a result of land use or soil management practices. Methane emissions from cattle and other livestock account for just over a quarter of the emissions. Wetland rice production and manure management also contribute a substantial amount of methane. Land clearing and burning of biomass also contributes to carbon dioxide production.

Changes in land use, especially those associated with agriculture, have negatively affected the net ability of ecosystems to sequester carbon. For instance the carbon rich grasslands and forests in temperate zones have been replaced by crops with much lower capacity to sequester carbon. By storing up to 40% of terrestrial carbon, forests play a key role, and despite a slow increase in forests in the northern hemisphere, the benefits are lost due to increased deforestation in the tropics (Matthews et al., 2000).

There is considerable potential in agriculture for mitigating climate change impacts. Changing crop regimes and modifying crop rotations, reducing tillage, returning crop residues into the soil and increasing the production of renewable energy are just a few options for reducing emissions (Wassmann and Vlek, 2004).

Climate change poses the question of risks for food security both globally and for marginal or vulnerable agroecological zones. People's livelihoods are threatened, as we know, if they lack resilience and the purchasing power to bridge production losses on their farms. The magnitude of the threat to the agricultural sector, and to small-scale farmers in particular, is thus also dependent on the performance of the non-agricultural sectors of developing economies, and on the opportunities they provide. Adaptation to climate change is therefore an important topic for AKST. The need and the capacity to adapt vary considerably from region to region, and from farmer to farmer (Smit, 1993; McCarthy et al., 2001).

Change in water runoff by 2050 is expected to be considerable (Figure 1-19). Some regions will have up to 20% less runoff, while others will experience increases of the same order, and only few countries will have similar conditions as at present (HDR, 2006). Improving water use efficiency, adapting to the risks related to topography, and changing the timing of farming operations are some examples of adaptation that will be required.

Adaptation has a cost and often requires investments in infrastructure. Therefore, where resource endowments are already thin, adverse impacts may be multiplied by the lack of resources to respond. Farmers are masters in adapting to changing environmental conditions because this has been their business for thousands of years. This is a knowledge base farmers will need to maintain and improve, even if climate change may pose challenges that go beyond problems tackled in the past.

Sustainability implications of AKST

A key objective of agricultural policies since the 1950s, both in industrialized and in developing countries, has been to increase crop production. In its production focus, these policies have often failed to recognize the links between agricultural production and the ecosystems in which it is embedded. By maximizing provisioning services, crop production has often affected the functioning of the supporting ecosystem services.

In the 1960s and 1970s, for instance, irrigated agriculture was intensified in Asia and elsewhere to boost production of one major food crop: rice. The effort was underpinned with massive public investments in crop research, infrastructure and extension systems. While successful in terms of production and low commodity prices, this Green Revolution led in some cases to environmentally harmful practices such as excessive use of fertilizers or pesticides. As evidence of negative impacts on the environment—particularly on soil and water—emerged, a number of corrective measures were envisaged.

In Indonesia, for example, a major effort was undertaken in the 1980s to introduce integrated pest management (IPM) in intensive rice production (Röling and van de Vliert, 1994). This required that farmers have better knowledge of pests and their predators—knowledge that could be used to reestablish pest-predator balances in rice agroecosystems,

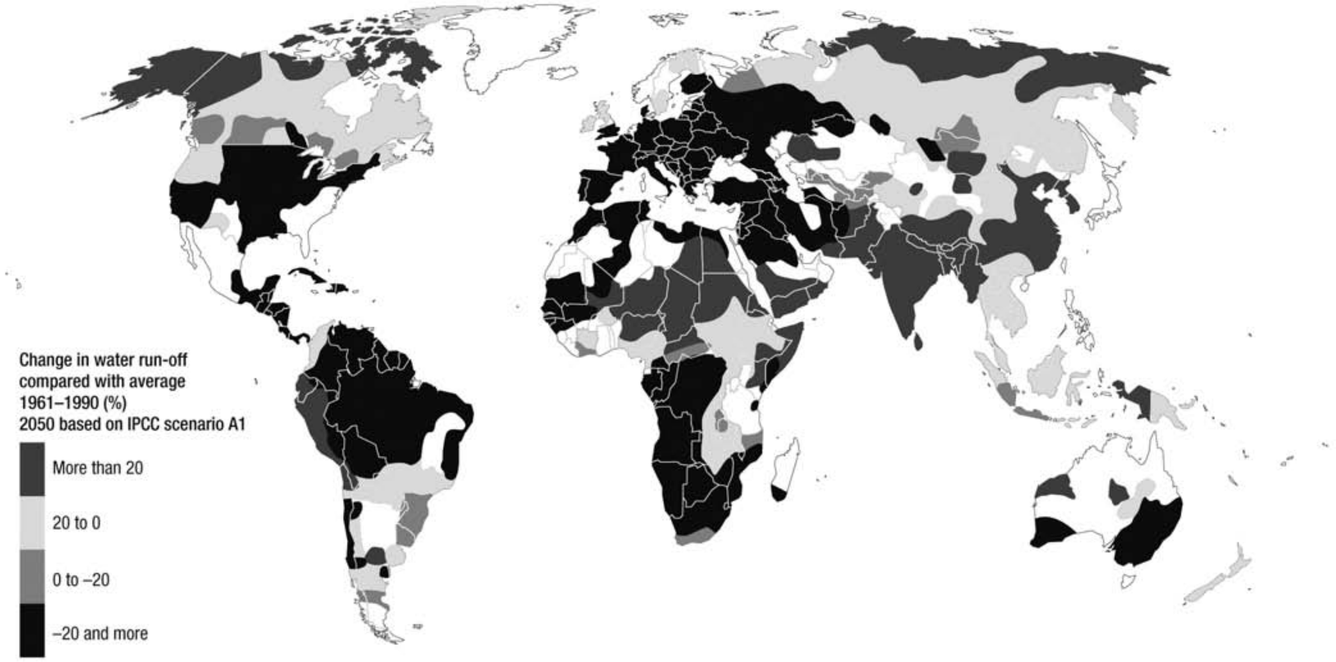


Figure 1-19. *Climate change and water run-off.* Source: HDR, 2006.

and to avoid the harmful use of pesticides. The successful, practical application of IPM is an example of the ecological services provided by agroecosystems, and the monetary, health and environmental benefits they provide.

In the 1990s, management has become a key term in most debates on natural resources, agriculture included. The multifunctional character of agriculture implies a serious consideration of the links with the ecosystems in which agricultural systems are embedded, beyond measures and policies addressing specific resources such as water and soil. This is a very complex challenge concerning a multitude of actors.

AKST and natural resource management (NRM)

There is now a strategic understanding that "the management of natural resources clearly has social and behavioral components, the understanding of which is indispensable for orienting biophysical research to these resources. Behavioral and sociocultural variables of resource management are no less important for resource sustainability than physical parameters" (CGIAR, 2000).

Practitioners of NRM research in agricultural development have adjusted their research agendas to address this problem, often under the headings "policies", "institutions", and "processes". This allows them to frame the debate on how access to resources should be regulated, and what types of institutional regimes are needed to ensure environmental sustainability of resource use in agriculture. Management of natural resources is articulated on at least two levels: the household and its livelihood, and the larger resource regimes on the community, the national and the international levels. For this aspect, AKST has benefited from research that deals with common property and common pool resources (Ostrom, 1990). A balanced research agenda focusing both on institutional aspects of resource management and on biophysical parameters of the systems is key for managing the multifunctional base and effects of agricultural production. AKST has also benefited from research on traditional agricultural systems and their knowledge base. While local knowledge forms are rarely equipped to respond to all the changes in contemporary agricultural systems, participatory research in AKST has demonstrated its value for grounded and adapted solutions.

While national policies are evidently key in these areas, some approaches have become agreed notions in multilateral processes, like Agenda 21. Sustainable Land Management (SLM), for example, is defined as "the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while ensuring the long-term productive potential of these resources and the maintenance of their environmental functions" (UN, 1993a). This is a pertinent and comprehensive definition. However, its impact on the promotion of innovative management strategies and on national and international policies is scarcely visible to date. We may also note that efforts are devoted on the one hand to soil and water conservation, and on the other to conservation of biotic resources (agrobiodiversity), with little interlinkages between the two.

In sum, a shift towards the integrated analysis of natural resource management has begun to transform the agricultural research agenda and AKST. However further progress in integrating biophysical with sociocultural and behavioral variables, and the recognition—in practice—of the multifunctional nature of agriculture may be needed. In addition to techniques aiming at specific resources, the overall management of natural resources has become a concern in agricultural development.

1.3.4 Social equity

The sense of justice and injustice is a universal feature of human society; yet complexity, stratification and inequality are enduring hallmarks of social organization. Nowhere is this more evident than in agriculture, where patterns of land ownership, land tenure, social status, employment and division of labor have evolved in highly diverse ecological, social and cultural contexts.

Social equity is intimately linked to a sense of justice both in terms of processes and outcomes. In its ideal form, it incorporates notions of equality, as in equal rights under the law, and of equivalence as in differentiated treatment that produces outcomes of comparable value or significance for beneficiaries in disparate circumstances. In legal terms, equity originated as a system of jurisprudence developed to correct injustices caused by inflexibility in the law. It was based on the principle of natural justice. In this sense, equity serves to bridge the gap between legality and legitimacy of outcomes, for example, when equal treatment would result in the perpetuation of injustice.

Political, economic and cultural factors contribute to greater or lesser degrees of equity in society, sometimes mitigating, sometimes reinforcing inequality. Many sources of inequality are determined by the circumstances of birth. Sex, ethnicity, the wealth or poverty of parents, their educational status, birth in a rural or urban setting are among these. Other sources of inequality are cultural constructs. These include gender roles in the world of work; the rights and duties of family members as defined by age, sex or birth order; parental expectations of sons and daughters; the loci of decision-making power within households and in the wider community; and the formal and informal rules that determine access to land, water and other resources. Whether determined by birth or culture, these sources of inequality tend to widen or narrow the opportunities that individuals have to develop their inherent talents and their productive potential. Combating corruption can help improve equity, as corruption is undermining justice in many parts of the world. Corruption is the abuse of entrusted power for private gain; this may include material and non-material gain from political interference to bribery (TI, 2007). This will occur unless society develops institutions of governance, legal systems and social policy tools that tend to lessen disparities and equalize opportunities. With improved women's economic and social rights corruption is generally reduced.

While economic forces tend to favor some to the detriment of others, it is common for social policy instruments to attempt to redress the balance in some measure by promoting equality of opportunity, ensuring that basic services are available to all and assisting vulnerable groups in meeting their needs. Equity concerns underpin efforts to eliminate discrimination, widen opportunities for social and economic advancement, increase access to public goods and services, such as education and health care, provide fairer access to resources and promote empowerment through participation in decision-making (ILO, 1962). All of these are critical to reducing poverty and building a just society based on rights for all.

Rights-based approach. Since the adoption of the Universal Declaration of Human Rights in 1948, there has been a growing worldwide consensus that abject poverty, hunger, and deprivation are an affront to human dignity and that conditions must be created whereby all persons may enjoy basic human rights (UNICCPR, 1966; UNICESCR, 1966). Whether these rights are of a civil, political, economic, social or cultural nature, they are considered to be "universal, indivisible and interdependent and inter-related" (UN, 1993b).

Civil and political rights—such as political voice and representation, freedom of association, and equal protection under the law—are important in themselves, but also in their function as enabling rights. Such rights enable individuals and groups to participate in public debate, influence the decisions that affect the life of their communities, defend their common interests, build more responsive economic and social institutions, and manage conflicts through peaceful, democratic means. Economic, social and cultural rights—such as the right to education, health care, food and an adequate standard of living—help to create the conditions under which civil and political rights can be freely exercised.

Social equity concerns and agriculture. Social equity concerns are gaining in importance in countries where large numbers of people are engaged in agricultural production and where productivity improvements are needed to keep pace with or exceed population growth, in other words, in most developing countries. Globalization has placed the agricultural sector in many countries under tremendous pressure as generally declining commodity prices, rising input costs, low levels of investment and lack of credit take their toll, particularly on small-scale farmers, their families and agricultural workers. Loss of status, uncertainty of income, indebtedness, unfulfilled needs and the deterioration in their economic and social condition are among the factors that have spurred able-bodied men and youth to leave rural areas in search of opportunities elsewhere. Many swell the ranks of the urban unemployed, lacking the skill sets needed to prosper in the new environment, subsisting through informal activities. Those remaining in agriculture—particularly, ethnic minorities, women, the elderly, children and youth—find themselves increasingly on the margins of economic, social, and political life. They form the majority of the world's poor.

Potential beneficiaries of AKST are a heterogeneous group living in highly diverse social, economic and environmental contexts. Research, development and dissemination efforts need to take their capacities and constraints into account in order to ensure that innovations are practical, affordable and offer real benefits to the poor among them. Social equity concerns challenge policy-makers, researchers, practitioners and donors to work together across their respective disciplines to provide not only the technological means, but also the social support needed to encourage and enable uptake of new techniques by those who may not previously have had access to skills training, extension services or credit facilities.

A major social equity issue in agriculture is the perpetuation of poverty from one generation to the next due to the high incidence of child labor. Approximately 70% of all child labor is found in agriculture. Unpaid work on the family farm may or may not have an incidence on the child's school attendance and performance, depending on the hours and conditions of work. However, time lost to education, particularly if low achievement levels lead to early drop-out, has lifelong consequences on earnings. Much child labor in commercial agriculture is invisible and unacknowledged, although it may account for a considerable portion of family earnings (WDR, 2007).

Social equity issues, such as child labor, must be addressed if broad-based agricultural development is to contribute positively to both economic growth and poverty reduction. The principal challenges are twofold: raising the living standards of those working in agriculture, particularly the poorest among them, and lessening the demographic burden on agriculture by providing opportunities for more diversified and rewarding economic activity outside the sector. Educating rural children and preparing them for a productive future addresses both those concerns and AKST can be instrumental in achieving this in a number of ways. For example, well targeted AKST can enable poor farmers to increase their earnings sufficiently to keep their children in school, rather than at work. The adoption by parents of innovative farming practices can teach children the experience of lifelong learning, openness to technological change and the benefits of applying knowledge to production. Incorporating AKST into rural school programs could provide young people with practical skill sets to help them make the transition to more productive work in agriculture or in rural support services, or could inspire them to pursue other science based studies.

The labor requirements of various crops or cultivation methods are an important variable that needs to be considered. AKST is not employment-neutral, nor can it be if it is to improve the livelihoods of the rural poor. In some poor communities and households, the greatest challenge is to generate productive employment for able-bodied workers. In such circumstances, the development of high-value, highly nutritious, labor-intensive crops may offer opportunities for improving livelihoods and well-being. In other cases, labor-saving crops and techniques may offer better outcomes, for example, for labor-poor female headed households, or rural communities suffering from a high incidence of HIV/AIDS or other debilitating illnesses.

Many observers note a dichotomy between small-scale agriculture and industrialized agriculture. Indeed, the uneven competition that has emerged between small- and large-scale production systems raises serious social equity issues within the agricultural sector as a whole. The two systems differ greatly in terms of resource consumption, capital intensity, access to markets and employment opportunities. The economic and political power of agribusiness enterprises and their relative importance in national economies enable them to influence decisions regarding domestic support packages, infrastructure investment, the direction of agricultural research and development and the setting of international trade rules in ways that small-scale farmers cannot. Another major difference lies in their capacity to provide employment. Large-scale production systems are often in a position to offer better terms of employment, but they tend to shed labor as productivity gains are realized through technology and more efficient work organization. Although the number of persons working in small-scale agriculture has decreased as a percentage of the global population in recent decades, it has steadily increased in absolute numbers and is estimated to include approximately 2.6 billion people or 40% of the world's population (Dixon et al., 2001).

While the notion of dichotomy may be useful in drawing out such contrasts, it tends to mask the wide range of ownership patterns, relationships to the land, forms of labor force participation and employment relationships that generate profound social equity issues. It is instructive to consider how just one set of rights—property rights—affects the livelihoods of various stake-holders in the agriculture sector: plantation owners, medium to small-scale owner-cultivators, tenant farmers, share-croppers, squatters, landless laborers, bonded laborers, migrant workers, or members of an indigenous community sharing common lands. These categories are not discrete; indeed, there is frequent overlap among them, and cutting across all these categories are issues of gender, which further define or delimit rights of ownership, access, use and inheritance of the land.

Choices to be made: agricultural productivity and poverty reduction

Most discussions of broad-based agricultural development focus on the interaction of five main factors—innovation, inputs, infrastructure, institutions and incentives (Hazell, 1999). Equity issues are inherent, though they may not be explicitly evoked, in the policy decisions that guide the investment of resources in these areas. For example, agricultural research and development is needed to generate productivity-enhancing technologies, but choices must be made as to the orientation of research efforts. The improvement of local food crops to better satisfy nutritional needs, the development of drought-resistant breeds to provide a more reliable harvest to those living on marginal lands, or the development of horticultural produce suitable for export may all be worthy goals in themselves, but have very different potential beneficiaries. Whether or not these activities lead to improved livelihoods for the poor depends on many factors, not least among them being the social characteristics of particular rural communities and the convergence of innovation with other productivity factors. Ownership or control of land and other assets, knowledge and skill levels, roles and responsibilities with regard to production, access to affordable credit, and rights with regard to distribution of services vary considerably across and within social groups. Ethnicity, class, sex and age all affect the capacity of those who work the land to access and use new technologies effectively and profitably, but take-up can be modified with well-targeted interventions. Productivity enhancement is not so much a technical issue, as one of political, economic and social choices and constraints, hence an issue of equity (HDR, 2006).

This is well illustrated by a number of "equity modifiers" that have been suggested as a means to reduce poverty and contribute to growth through broad-based agricultural development. These include targeting small and medium-sized family farms as priority beneficiaries for publicly funded agricultural research and extension, marketing, credit and input supplies; undertaking land reform, where needed; investing in human capital to raise labor productivity and increase opportunities for employment; ensuring that agricultural extension, education, credit and small business assistance programs reach rural women; setting public investment priorities through participatory processes; and actively encouraging the rural non-farm economy (Hazell, 1999). It is noteworthy that all six modifiers imply some form of human capital enhancement.

Adoption and implementation of such transformational policies would require political will and political power, but the potential beneficiaries, indeed, the major actors, are largely absent from the decision-making process. The geographical locus of decision-making tends to be in the country's capital or major commercial centers and competition for government resources tends to be heavily weighted in favor of urban areas, where populations are concentrated, vocal and potentially active. Rural poor people in general and rural women in particular tend to be "invisible" to policy makers and service providers, and are without voice or representation in political decision-making.

Perhaps as a result of this, the rural sector has suffered years of neglect, notably during the course of structural adjustment. Lack of investment in roads, water systems, education and health services, and the dismantling of public extension systems have all left their mark on rural areas and on the people who live there. Rural poverty rates consistently exceed those in urban areas. In all 62 countries for which data sets were available, a greater percentage of rural people were living below the national poverty line compared to their urban counterparts. In several cases, the rural-urban poverty gap was more than 30% (World Bank, 2006b). If it were measurable, the urban-rural disparity in political power would most likely be greater. The male-female power disparity certainly is.

Government ministries dealing with agriculture and rural development have a minority of women among their professional and technical staff, and only a small percentage at decision-making levels. For example, a 1993 study of women in decision-making positions found that overall, women held 6% of decision-making positions in ministries and government bodies in Egypt. Cooperative agricultural societies had an almost exclusively male membership, agrarian reform societies were entirely within male hands, and land reclamation societies had no women members. In Benin, women held only 2.5% of high-level decision-making positions in government, and comprised only 7.3% of the decision-making and technical staff at the Ministry of Rural Development (FAO-CDP, 2007).

Local government might appear to provide opportunities for greater involvement of women in political life, yet proportional representation is nowhere the rule. In many countries, patriarchal social systems, cultural prejudices, financial dependence and lack of exposure to political processes have made it difficult for women to participate in public life. The maleness of political institutions and the high cost of campaigning prevent many women from entering electoral politics. When they do so, however, many see themselves as role models whose political actions should have a positive impact on people's lives. A survey of women in local government in 13 Asian and Pacific countries found that women also brought a more transformational political agenda to the fore, one more attuned to social concerns, such as employment, care of the elderly, poverty alleviation, education, health care and sanitation—all subjects of critical importance to rural people. Women in politics understood the positive impact that female decision makers had on women's participation generally (UNESCAP, 2001).

Gender

Gender is a key category for understanding agrarian societies, as anthropological and historical research has consistently shown (Boserup, 1965; Linares, 1985; McC Netting, 1993). The category refers not, as is often assumed, to the role of women as such, but to the specific social ascription of roles and functions according to gender. In agrarian societies, these roles and responsibilities have been, in most cases, clearly and specifically assigned to either men or women in productive households. In addition, not only work, but also assets are as a rule accessed and controlled according to gender-based patterns. These patterns vary with time and place; a persistent feature is that women have a key role in agricultural work, yet they have often limited access to, or control over, the resource base such as land.

Hence, the management of resources in agriculture is related to gender. What does this imply for sustainability? It certainly means that research needs to closely look at existing gender-related patterns of resource access and control, to arrive at meaningful conclusions (Linares, 1985). While sustainability has to be a target of farm operations, there may be differential factors at work here.

Agricultural development has sometimes strengthened patterns that do not favor women. Two factors are considered in this context. First, the double male bias of agricultural extension systems: it is mainly men who represent the state and its agencies, so men control information and communications; and it is men who are considered to represent the community or farming household, so they are the ones addressed. Second, as agricultural industrialization often implies a need for investments, market integration—handling larger sums of money—has favored men in many contexts, as women are usually not considered eligible for credit.

With growing awareness of this imbalance, the international agricultural research community has developed research to address the issues of women and discriminating gender roles in agriculture. This has often implied establishing a participatory research agenda (Lilja et al., 2000), such as in the CGIAR Systemwide Program on Participatory Research and Gender Analysis (CGIAR, 2005). While this is a welcome trend towards research products that have been developed with a greater involvement of women, it is not a sufficient condition to change a social fabric that discriminates against women.

Gender and other identity issues in natural resource management

The status and development potential of an individual depend on many social factors. In particular, they depend on a person's assigned gender, defined as the economic, social, political and cultural attributes and opportunities associated with being male and female (OECD, 1998). Other aspects of social identity such as caste, ethnicity, age and religion are just as influential with regard to an individual's status and development potential, and therefore need to be taken into account in much the same way as outlined below in the case of gender.

As a result of the gender division of labor, women and men relate to different economic spheres. In addition, they do not have the same stake in natural resources, social institutions and decision-making processes in the household and society. Nor do women and men have the same power to act and make decisions. Women and men are therefore affected differently by development. The dichotomy between men's and women's spheres is, on the one hand, a social challenge, but on the other hand it is an opportunity to make resource management truly stakeholder-oriented. Hence, for the assessment it is necessary to differentiate between male and female spheres by integrating disaggregated data.

In many instances and for a number of reasons women's access to natural resources is limited and their power to make decisions regarding natural resource management is socially restricted (Worldwatch Institute, 2003). Yet the majority of women in developing countries live and work in close association with natural resources (UNDP, 2005) and are particularly affected by ecosystem changes (MA, 2005a). Therefore, demands for a gender focus in natural resource management range from "experimentation with institutional forms that are more hospitable to women and marginalized groups" (Colfer, 2005), to demands calling for increased emphasis on the needs of women when addressing aspects of natural resource sustainability (Müller, 2006) and calls for a strategy for making women's as well as men's concerns and experiences an integral dimension of the policies and programs in all political, economic and societal spheres so that women and men benefit equally, and inequality is not perpetuated (UN, 1997).

Much has been written in recent years regarding the feminization of agriculture. As men have migrated to urban areas to seek better livelihoods, small-scale farming has been gradually feminized, with a larger percentage of women acting as head of household in rural areas, although their percentage in relation to all economically active women has been dropping since 1980 worldwide, in developing countries as well as in low-income food-deficit countries (FAO, 2001b; Figure 1-20). Feminization does not represent an equalization of opportunities, but rather a further marginalization of small-scale farms, since many female heads of household are younger and less educated than male heads of household, have less land, less capital and less access to credit. Fewer than 10% of women farmers in India, Nepal and Thailand own land and credit schemes in five African countries award women less than 10% of the credit awarded to male small-scale farmers (FAO-Gender, 2007) In most countries, the proportion of female-headed households is far less than 50% of the total.

A lack of sex-disaggregated data means that women's roles in agriculture and their specific needs are still poorly understood. It is noteworthy that about one-fifth of farms are headed by women. It is clear, however, that rural women are not a homogeneous group. Gender roles and the gender division of labor are highly specific to location, farming systems and peoples, but they are not fixed. Men and women constantly renegotiate their roles and relationships as circumstances change, both within the household and in the wider community. Their relative bargaining power can be influenced by many factors, their economic importance within the household, kinship relations, cultural norms of behavior, not to mention their individual character. Women as well as men have the capacity to exercise agency, that is, to make choices and decisions that can alter outcomes in their lives. In many countries, however, institutions of governance, legal systems and social policies have not equalized opportunities between men and women or created greater social equity between urban and rural dwellers, but have reinforced disparities instead.

A growing body of evidence suggests that economic efficiency gains can be realized through more widespread enjoyment of rights and more just distribution of opportunity. Conversely, persistent inequality is increasingly seen to limit the rate and quality of economic growth, threaten national unity and fuel social conflict (WDR, 2007). The challenge facing policymakers and practitioners is to mediate the modernization of agriculture in such a way that it leads to improved social and economic outcomes for those working in the sector, while supporting the transition to more value-adding activities for others. Investing in people will be the key to achieving these goals.

1.4 Sustainability Indicators

1.4.1 Indicators for the IAASTD

Indicators are part of what we observe in the world around us as we attempt to detect patterns and extract information meaningful for directing action. Indicators are quantitative and qualitative variables that provide a simple and reliable means to track achievement, reflect changes connected to an intervention or trend, or help assess the performance of an organization, an economic sector, or a policy measure with respect to set targets and goals.

In science, state variables of high precision and generality tend to be favored as indicators. In everyday life, there is a strong preference for trend indicators. An indicator, however, does not exist independently of the observer. Once an indicator is established, there still remain multiple issues of interpretation and meaning. Experts use indicators to inform policy and to increase their own scientific understanding (Table 1-4).

On a methodological level, an assessment is not simply a review of relevant literature; it can be based, in part, on a literature review, but also needs to provide an assessment of the veracity and applicability of the information and the uncertainty of outcomes within the context of the identified questions or issues within a specified environment. To be effective and legitimate, an assessment process should be open, transparent, reviewed, and include a broad representation of stakeholders and relevant experts.

Additional methodological elements include the selection of units of analysis, integrating biophysical and human systems as the context of agricultural practice, temporal and spatial scales of assessments from regional to global, issues

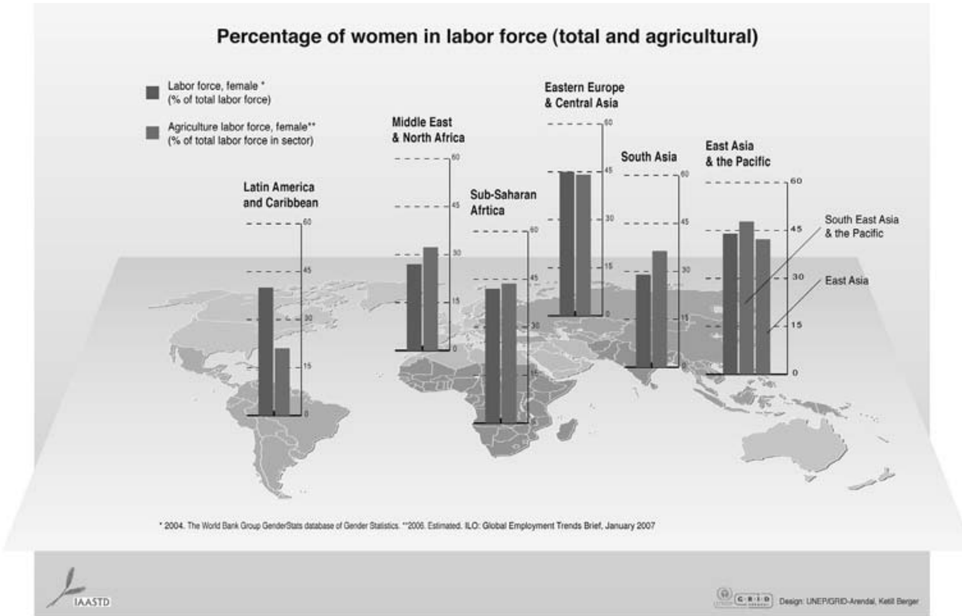


Figure 1-20. *Percentage of women in labor force (total and agricultural).* Source: World Bank, 2004b; ILO, 2007.

of values and valuation, dealing with uncertainty, dealing with different knowledge systems, as well as modeling issues and developing scenarios.

1.4.2 Working with indicators

What are indicators for? Indicators are used both for specialist purposes and in everyday life. In specialist applications the purposes are defined within the domain of expertise. In everyday life, they form part of the repertoire of heuristics—simple rules for making decisions when time is pressing, information limited or partial, and deep reflection a luxury (Gigerenzer et al., 1999). Indicators become part of what we observe in the world around us as we attempt to detect patterns and extract information relevant to effective action. In this everyday sense, they can be accurate and powerful (Gigerenzer et al., 1999) but also, if wrongly observed or interpreted, contribute to systemic failures (Dörner, 1996).

Referents and contexts. All indicators require a referent measurement situation. To allow meaningful interpretation of indicators and utilization that will appropriately inform policy processes, there is also a need for awareness of the context of use. Strictly speaking, indicators require application in a controlled environment (with/without, before/after). Rarely, however, is such a design possible in reality, for obvious practical and ethical reasons. Thus the present assessment has to accept that information is not perfect. One approach to handle uncertainty is through scenarios that are built on available indicators and assumptions.

State variables and trend indicators. The IAASTD uses two kinds of indicators, describing either state or trends. State variables, of high precision and generality, tend to be favored in science, as they represent the current state of an object or process and are thus measurable. In everyday life, there is a strong preference for accurate trend indicators. Especially at policy level, information is required on whether situations are improving or worsening, and whether policy objectives are getting closer to their goals or farther away. Trend indicators tend to focus more on identifying thresholds that might indicate an imminent change of state, and less on constant values—the more favored emphasis of many sciences. In many usages trend indicators are also used as learning devices, leading to reestimation of achievement and redefinition of goals as trend data move through time.

Precision, accuracy, and generality. There is agreement in the philosophy of logic and statistics that precision, accuracy, and generality cannot be simultaneously optimized. Any pair of the three may be. The construction and choice of indicator thus has to take into consideration which combination is the most pertinent to the problem or situation for which the indicator might be used. There is a need to identify appropriate indicators and the relationships of these when used at various spatial and temporal hierarchical levels. This is partly a matter of scale and structure of systems hierarchies, and partly a matter of whether it is the state variables or dynamics that the user considers important to observe and monitor.

The dilemmas of interpretation and meaning

An indicator does not exist independently of the observer: as mentioned above, a range of pre-analytic choices are made before an indicator is constructed or brought into use. These choices are inevitably value-laden, and enriched with meaning that the indicator itself does not possess. Take, for example, poverty indicators: one can construct income-based, nutrition-based, gender-based (etc.) indicators. Each type of indicator both reveals what is important for the user's purpose but also conceals what is not considered pre-analytically to be of importance.

Table 1-4. **Overview of issues addressed by indicators in the IAASTD framework.**

IAASTD framework components	Issues addressed by indicators
Development and sustainability goals	• Decreased hunger and poverty • Improved nutrition and human health • Sustainable economic development • Enhanced livelihoods and equity • Environmental sustainability
AKST systems	• Research/Innovation policies • Local and institutional setting of AKST • Social organization • Generation, dissemination, access to, adoption and use of AKST • Agricultural markets
Agricultural outputs and services	• Biomass, livestock, fish, crop production • Forestry for food • Fiber • Carbon sequestration • Energy • Ecosystem services
Indirect drivers	• Economic • Demographic • Sociopolitical
Direct drivers	• Economic • Demographic • Availability and management of natural resources

Once an indicator is established, multiple issues of interpretation and meaning remain to be solved. Is an increasing mechanization in agriculture that contributes to increased area productivity on the one hand, yet increases externalities of various kinds on the other, an indicator of agricultural modernization or an indicator of the increasing lack of sustainability of that particular food system? Available indicators for agricultural mechanization in most cases provide inadequate information. Only if indicators are placed in a context of meaning determined by prior adoption of frameworks that incorporate value systems and perceptions, can indicators be used for decision making. Unfortunately, frameworks are rarely articulated explicitly, thereby greatly decreasing the utility of indicators.

The conceptual framework of IAASTD does indeed provide tools to interpret indicators for agricultural mechanization, for example. While on the one hand, an increase in mechanization could contribute to food production in the component "Development and Sustainability Goals" and "Food System and Agricultural Products and Services", on the other hand, such an increase generates a number of negative externalities in the component "Direct / Indirect Drivers". The four components of the IAASTD conceptual framework, in turn, influence rules, norms and processes where actors are involved. This, i.e., the outer ring of the AKST component in the conceptual framework, is exactly the level at which the implications of a given indicator need to be negotiated, agreed upon and fed into the policy process.

Similarly, an indicator on female employment in agriculture needs to be interpreted in terms of the components of the conceptual framework. An increased employment rate could have a positive impact on family nutrition, but might be negatively interpreted in terms of an increased workload for women. Therefore, an interpretation of the meaning of an indicator as suggested by the outer ring of the conceptual framework needs to take place in order to equip the indicator with context and meaning.

Expert-based versus participatory indicator construction and use. Experts use indicators all the time to inform policy and to increase their scientific understanding. These are legitimate and powerful usages. Problems arise, however, when assumptions are made about indicators as information tools, and as motivators of the actions of others, because indicators rapidly lose their originally intended meaning when they are moved to other domains. A further implication of the IAASTD conceptual framework is that indicators are powerful in developing our understanding and in motivating reflection and action when they are constructed with, rather than extended to, other actors.

1.4.3 Indicators in the IAASTD

The scope of the AKST assessment includes the relevance of agricultural systems and encompasses major aspects of human well-being and environmental sustainability. This extended view of agricultural development is in line with the major international initiatives addressing sustainable development, such as the MDGs and the Millennium Ecosystem Assessment (MA). The assessment thus suggests indicators that assist in observing critical changes in the area of human development, the environment, agriculture, and AKST. The particular challenge for indicators is that they must be able to link AKST with these three areas of sustainable development in a meaningful way.

This broad, sustainable development-oriented view of the process of agricultural development has also been adopted by major international actors in development for the past two decades, e.g., the Agenda 21 of the UN Conference on Environment and Development (UNCED) in 1992 and the World Summit on Sustainable Development (WSSD) in 2002. The indication of effects of agricultural development on the broader aspects of human development and the environment poses major challenges to the identification of impact and process indicators.

Identification of indicators for the AKST assessment

This global assessment occasionally uses some key indicators to show how different global and sub-global trends and drivers—including effectiveness of investments in AKST systems—affect the main agricultural outcomes and services, and more importantly, how they impact on the global population and their well-being, and on the ecological systems used and/or affected. A global assessment like IAASTD gains in efficiency and effectiveness if it focuses on a limited number of representative indicators. Indicators are quantitative and qualitative variables that provide a simple and reliable means to track achievement, reflect changes connected to an intervention or trend, or help assess the performance of an organization, an economic sector, or a policy measure against set targets and goals. Tracking changes over time relative to a reference point ("baseline") using indicators, can provide useful feedback and help improve data availability and thus support decision-making at all levels.

For the purpose of the assessment, two main types of indicators have been considered:

Impact indicators show impacts of AKST on society and the environment in terms of poverty, livelihoods, equity, or hunger. These impacts are influenced by various technical, environmental and socioeconomic drivers and pressures, e.g., immediate outcomes of AKST investments. The targets and goals used in this assessment are closely linked to the internationally agreed MDGs.

Process/performance indicators show the influence of key drivers on AKST, on AKST and main agricultural outputs/services, and on AKST and human well-being as defined in the MDGs.

Because of their considerable policy relevance and practical use, the selection and presentation of the indicators is of critical importance in the assessment. However, most of the underlying data that is needed to derive the desired indicators is either organized along individual sectors (agriculture, health, and environment), or highly aggregated into indexes like the Human Development Index (HDI) or the Gender Empowerment Measure (GEM). Therefore, the challenge is to identify indicators which clearly describe the relationship between agricultural science and technology and sustainable development in the various aspects described above.

Indicator characteristics. As indicators are used for various purposes, it is necessary to define general criteria for selecting indicators and validating their choice. Indicators (Hardi and Zdan, 1997; Prescott-Allen, 2001) can be characterized by their:

Relevance to measure change: for an indicator to be relevant, it must cover the most important aspects of the topic "human capacity for AKST". It must also be a sign of the degree to which an objective is met.

Reliability from well-established data sources: an indicator is likely to be reliable if it is well founded, accurate, and measured in a standardized way using an established or peer-reviewed method, and sound and consistent sampling procedures.

Feasibility: an indicator is feasible if it depends on data that are readily available or obtainable at reasonable cost.

To be consistent, an indicator must illustrate trends over time, as well as differences between places and groups of people. The usefulness of indicators depends on how well they meet the above criteria. When no direct indicators can be found that adequately meet these criteria, then indirect indicators or "proxies" and/or a combination of indicators or aggregate indices can be used. The selection of variables and indicators, together with underlying methodologies and data sets, must also be clearly documented and referenced. The more rigorous and systematic the choice of indicators and indices, the more transparent and consistent an assessment will be. And the more involved decision makers and other stakeholders are in the selection process, the higher the chance of acceptance of assessment results.

However, three potential problems need to be noted here:

1. Not all potential indicators are practical: data may not be available; and data may be either too difficult or too expensive to collect. For this reason, more distant (proxy) indicators need to be selected. These may not be the most appropriate and reliable indicators, but they can be interpreted to reflect the issue being monitored. For example, if one is comparing innovation levels in different countries, the proxy indicator of the number of patents issued per million people per year may be used to save time and resources, making use of existing reliable data sources in order to give an approximate idea of different innovation levels in different countries.
2. Experience with indicator identification for this assessment shows that one cannot expect to find clear and concise indicators for many of the critical IAASTD areas such as (1) AKST and sustainable development in general, exemplified through the MDGs; (2) AKST and human health; (3) AKST and social equity, etc. Therefore, indicators selected for this assessment will often

need to compromise between being "exactly wrong or approximately right".

3. The time and technical skills required for selecting indicators might make it difficult for decision makers and stakeholders to participate fully in the selection of indicators. At the same time, experts carrying out the assessment have the responsibility of ensuring that the selection of indicators and the assessment as a whole are technically and scientifically sound.

Hence, in the area of indicators, a way must be found to maximize both the technical excellence of the assessment and the commitment of participants from government, civil society, and business.

The focus of this assessment on poverty, sustainable livelihoods and sustainable ecosystems marks a clear trend that future agricultural development is moving away from the exclusive production focus of the past. However, indicators available today can support assessment of these broadened goals of agricultural development only partially: more efforts are needed to develop sufficiently appropriate indicators.

Units of analysis and reporting. The IAASTD uses indicators which measure at several scales, from individual to farm, nation, region and global levels. Numeric indicators use metric units while qualitative indicators are descriptive. Information from smaller units will be aggregated up to sub-global and global assessment levels. The results will thus be generic but presented in such a way that it makes sense to other units of analysis.

Dealing with systems

The IAASTD basically deals with two different sets of systems, a biophysical and a socioeconomic set. On the one hand, there is the biophysical set with the underlying ecosystem in which the agricultural system and the unit-based production system is established. Primary ecosystems have been altered to a greater or lesser extent by agricultural production systems that define themselves according to economic criteria of efficiency as opposed to the multifunctional character of ecosystems. Usually, forest ecosystems are converted into grassland for livestock rearing, or a system with bare soils for cultivation. Depending on the capacity and suitability of this new agricultural land, production takes place over shorter or longer periods of time, from a single or a few years to decades and even centuries on the most suitable land. Assessing the future of these production systems requires taking into account their current suitability, including the degradation of ecosystems or parts thereof which has taken place, and the potential of these land areas to support agricultural production of goods. In addition, the multifunctional character of ecosystems has to be considered as a crucial aspect important to societies and the global community.

On the other hand, political, economic, social and cultural sets of systems shape human livelihoods and agricultural production systems in the different contexts in which the latter operate. A large disparity exists between these contexts. A majority of agricultural workers are poor small-scale farmers in developing countries, with a high degree of dependence on subsistence systems, i.e., production by households for their own consumption, and a high degree of dependence on both the biophysical and socioeconomic systems. A minority of agricultural workers live on larger production units and in industrialized nations, profiting from wealthy economies and a variety of subsidies to maintain their production and/or production systems. Assessing the future of agricultural systems will require thorough analysis and evaluation of these different contexts and the livelihoods derived from them through agricultural activities.

Many of these contexts and systems are evolutionary; shifts in parameters must be expected, and the state of natural and human environments will continuously change, be it through factors such as opportunity (e.g., new business options or access to new resources) or constraints (such as further decapitalization of small-scale farmers). The degrees of uncertainty are rather great and difficult to foresee.

Dealing with scales (spatial and temporal)

Assessments need to be conducted at spatial and temporal scales appropriate to the process or phenomenon being examined. Analysis of issues must take place across several spatial scales simultaneously because an analysis at a single scale will miss important interactions. For example, national policies embedded in a global system have an impact on local decisions regarding AKST. Moreover, vulnerabilities are related to various scales. A comparison of a larger scale poultry production system with a decentralized backyard poultry system reveals different scales. While an infection of the former system is relatively easy to prevent, a possible outbreak would be catastrophic. In the latter system an infection of the flock is harder to prevent while an outbreak would affect a smaller number of poultry. Most of the analysis in the IAASTD is carried out at national and regional levels, but informed by experience from ground realities.

The IAASTD is structured as a multiscale assessment in order to enable its findings to be of greater use at the many levels of decision-making. A global assessment cannot meet the needs of local farmers, nor can a local assessment meet the collective needs of parties to a global convention. A multiscale assessment can also help remedy the biases that are inevitably introduced when an evaluation is done at a single geographic scale. For example, while a national AKST assessment might identify substantial national benefits from a particular policy change, a local assessment would be more likely to identify whether that particular community might be a winner or loser as a result of the policy change. For example, in contrast to privately funded research, where the donor derives benefits, benefits derived from public goods research does not go to the funding agency itself, rather to other members of society, and there is no direct incentive to do more (CGIAR Science Council, 2005).

Dealing with values and valuation

The IAASTD deals with two valuation paradigms at the same time. The utilitarian paradigm is based on the principle of human preference for satisfaction (welfare). AKST systems provide value to human societies because people derive utility from their use, either directly or indirectly. Within this utilitarian concept of value, people also give value to AKST aspects that they are not currently using (non-use values), for example people value education systems even though they themselves have completed their school education. Non-use values often rely on deeply held historical, national, ethical, religious, and spiritual values. A different, non-utilitarian value paradigm holds that something can have intrinsic value; that is, it can be of value in and for itself, irrespective of its utility for someone else. For example, birds are valuable, regardless of what people think about them. The utilitarian and non-utilitarian value paradigms overlap and interact in many ways, but they use different metrics, with no common denominator, and cannot usually be aggregated, although both value paradigms are used in decision-making processes.

How decisions are made will depend on the value systems endorsed in each society, the conceptual tools and methods at their disposal, and the information available. Making the appropriate choices requires, among other things, reliable information on current conditions and trends of ecosystems and on the economic, political, social, and cultural consequences of alternative courses of action. Assessments strive to be value free, using evidence-driven results. But in fact, all people involved in assessments come with value systems and need to explicitly state these values wherever they are at work. Another way to take advantage of different ways of thinking is to create diversity in the assessment in terms of background, region, gender, and experience in order to balance views.

Dealing with different knowledge systems

The IAASTD aims to incorporate both formal scientific information and traditional or local knowledge. Traditional societies have nurtured and refined systems of knowledge of direct value to those societies and their production systems, but also of considerable value to assessments undertaken at regional and global scales. To be credible and useful to decision makers, all sources of information, whether from scientific, local, or practitioner knowledge, must be critically assessed and validated as part of the assessment process through procedures relevant to the specific form of knowledge.

Substantial knowledge concerning both AKST and policy interventions is held within the private (and public) sector by "practitioners" of AKST, yet only a small proportion of this information is ever published in scientific literature, and much is kept in less accessible gray literature. Again, broad participation can help include as many sources of knowledge as possible.

Effective incorporation of different types of knowledge in an assessment can both improve the findings and help to increase their adoption by stakeholders if the latter believe that their information has contributed to those findings. At the same time, no matter what sources of knowledge are incorporated in an assessment, effective mechanisms must be established to judge whether the information provides a sound basis for decisions.

Modeling issues

Models are used in the IAASTD to analyze interactions between processes, fill data gaps, identify regions for data collection priority, or synthesize existing observations into appropriate indicators of ecosystem services. Models also provide the foundations for elaborating scenarios. As a result, models will play a synthesizing and integrative role in the IAASTD, complementing data collection and analytical efforts.

It is relevant to note that all models have built-in uncertainties linked to inaccurate or missing input data, weaknesses in driving forces, uncertain parameter values, simplified model structure, and other intrinsic model properties. One way of dealing with this uncertainty in the IAASTD is to encourage the use of alternative models for computing the same ecosystem services and then compare the results of these models. Having at least two independent sets of calculations can add confidence to the robustness of model calculations, although it will not eliminate uncertainty.

It should be stressed that the majority of "human system models" focus on economic efficiency and the economically optimal use of natural resources. Thus the broader issues of human well-being, including such factors as freedom of choice, security, equity and health, will require a generation of new models. To deal with these issues IAASTD must rely on qualitative analysis.

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