IAASTD Global Report Chapter 1

Context, Conceptual Framework and Sustainability Indicators

Coordinating Lead Authors: Hans Hurni (Switzerland) and Balgis Osman-Elasha (Sudan) *Lead Authors*: Audia Barnett (Jamaica), Norman Clark (UK), Ann Herbert (USA), Anita Idel (Germany), Moses Kairo (Kenya), Ian Maudlin (UK), Dely Pascual-Gapasin (Philippines), Juerg Schneider (Switzerland), Keith Wiebe (USA)

Contributing Authors: Cissé Guéladio (Mauritania), Markus Giger (Switzerland), Udo Hoeggel (Switzerland), Boniface Kiteme (Kenya), Janice Jiggins (Netherlands), David Molden (USA), Cordula Ott (Switzerland), Brigitte Portner (Switzerland), Riikka Rajalahti (Finland), Stephan Rist (Switzerland), Gete Zeleke (Ethiopia)

Key Messages

1. Agriculture accounts for the livelihood of 40% of the world's population, and 85% of all farms world-wide have a size of less than 2 hectares. Agriculture provides food for all of humanity, and in addition, it provides feed, fiber and fuel of importance for the economy, as well as essential services for ecosystems and the wider environment.
2. Achieving the IAASTD goals for agriculture depends on the choices made by the many different actors (e.g. governments, farmers, and private enterprises) with regard to the availability of and access to natural, human and other resources.
3. Agricultural Knowledge, Science and Technology (AKST) plays a key role in shaping the quality and quantity of and access to natural, human and other resources, as well as the efforts of actors at different levels (household, national, and international) to reduce poverty and hunger in a sustainable manner.
4. AKST is more than just R&D; it encompasses varied sources and uses of knowledge and promotes effective use of all types of knowledge. A useful metaphor is that of the innovation system, broadly defined to mean the network of organizations of relevance to technology development and how integrated that system is in any given context. AKST is best used if all its elements are applied in a balanced manner.
5. The conceptual framework of IAASTD can help decision makers to appreciate the complex relationships between agriculture, AKST and the IAASTD goals and how these relationships are embedded in production systems, agricultural systems and ecosystems on the one hand, and in political, economic, social and cultural contexts on the other hand.
6. Use of the conceptual framework of IAASTD draws on the expertise of a multidisciplinary group of experts from around the world. The framework as an assessment tool may involve modeling of complex dynamic systems; while indicators are analytically useful tools but have to be used with care.
7. Recognizing the linkages between the local, national, regional and global contexts, and between agriculture and the wider food system, is important for understanding issues related to AKST.
8. The goal of AKST is to contribute to the reduction of hunger and poverty, the improvement of rural livelihoods, and to more equitable and sustainable development. AKST can best serve this goal when economic, social and environmental policies are developed in an integrated manner.

1.1 Context and Goals

1.1.1 What is an assessment?

International assessments are very useful when they address complex issues and when international agreements are needed, e.g. in agriculture (Watson and Gitay, 2007). A number of assessments have been undertaken by many organizations and individuals in the past two decades: the Global Biodiversity Assessment (GBA), Ozone Assessment, Intergovernmental Panel on Climate Change (IPCC) reports, 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, Science and Technology for Development (IAASTD).

The scientific 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 literature: it can be derived from a literature review, but also needs to provide an assessment of the veracity of the information and the uncertainty of the outcomes within the context of the identified questions or issues within a specified authorizing environment. A summary of common differences between a review and an assessment is shown in Table 1.1.

[Insert Table 1.1 Differences between a review and an assessment (Watson and Gitay, 2004)]

To be effective and acceptable, the assessment process needs to be open, transparent, reviewed, and widely representative of stakeholders and relevant experts. Obtaining a balance of opinions and expertise in a global assessment is an ongoing and iterative challenge to ensure that it encompasses a broad range of disciplinary and geographical experience and different knowledge systems (Watson and Gitay, 2004). The IAASTD has been designed in a way that ensures this effectiveness and acceptability.

Role of Agricultural Knowledge, Science and Technology (AKST). AKST are seen as key factors and instruments for future adjustment of indirect and direct drivers of agricultural outputs and services towards ecosystem management. Assessing AKST sets the stage for an informed choice among various options for development. It indicates how to adequately adjust policy and institutional frameworks at all organizational levels. Specifically, it provides the basis for designing AKST in a way that mitigates detrimental development dynamics such as increasing 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 wellbeing, or 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, i.e., asking what agricultural goods and services will society 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. The result will be an evidence-based guide for policy and decision-making.

IAASTD commitment to sustainable development. IAASTD sees the assessment of agriculture as a prerequisite for knowledge-based decision-making for future sustainable development portfolios. Specifically, IAASTD aims to contribute to knowledge-based, well thought-through 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, innovation and adaptation of ecosystem management;
3. Supporting the integration of agricultural knowledge, science and technology (AKST) within international and national development policies and strategies.

IAASTD 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 adequate AKST can play a major role in efforts to achieve the MDGs, particularly that of eradicating extreme poverty and hunger (MDG1) by improving the competitiveness of smallholders and marginalized groups in the expanding global, national and local markets, and by creating employment among rural poor people and making food available to consumers. AKST can also contribute directly or indirectly to social and gender equity, reducing child mortality, improving maternal health, combating HIV/AIDS, malaria and other diseases (MDG4-6), and ensuring environmental sustainability (MDG7) by delivering a variety of supporting, regulating and cultural services (MDG 8). The AKST assessment enables a more adequate consideration of the linkage between poverty reduction and environmental change. Thus it is a necessary addition that brings in the interface of human-nature interaction and outlines steps for strengthening global governance architecture.

Key questions for the IAASTD. The major question for this assessment is: ‘How can we reduce hunger and poverty, improve rural livelihoods, and facilitate equitable, environmentally, socially and economically sustainable development through the generation, access to, and use of AKST?’

Three questions will recur throughout the global and sub-global assessments of IAASTD. They concern:

1. *Disparities:* How have changing markets and changing access to markets affected the development and sustainability goals? How and by what has social equity

(including gender equity) been influenced? What are projected implications of market changes in the future?

2. *Ecology:* How has availability of, access to and management of natural resources (particularly water and soil resources, but also plant, animal, genetic and other resources) affected the development and sustainability goals of IAASTD?
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 ownership of knowledge? How will AKST influence social, environmental and economic outcomes of agricultural and food systems?

Other central issues include: hunger, nutrition and human health; poverty, livelihoods and the economy, and productivity and technologies.

1.1.2 Global context for agriculture

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, 2005). Approximately 2.5 billion people – men, women and children – live directly from agricultural production systems, be it farming, animal agriculture, forest use or fishery. Food security for a growing world population is positioned to remain a challenge in the next few decades. The IAASTD will address issues important to tackling poverty reduction, which is central to the Millennium Development Goals. In parallel with the spread and growth of human population, particularly during the last 300 years, the transformation of natural ecosystems into agriculturally used and managed land has accelerated, at a particularly impressive rate since 1950, when 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. World agricultural output, 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 – while the total cultivated area increased much less, i.e. from 1.4 to 1.5 million ha (Wood et al., 2000: 42, based on FAO data). For similar figures indicating equally moderate growth of crop area see also the Millennium Ecosystem Assessment (MA, 2005a: 778). However, the Millennium Ecosystem Assessment also states that “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 used on the planet has been used since 1985 and phosphorus use tripled between 1960 and 1990 (MA, 2005b: 33). Globally, agricultural output has been growing at about two% 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 industrial countries and in Asia (FAO, 2006a: 90).

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 hectares (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 forest land 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, shrub land and tundra (about 25%), inland water surfaces and wetlands (about four%), and built up land for human settlement and other infrastructure (about five%). 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).

Multifunctionality of agriculture. Agricultural resource management involves more than maintaining production systems. Activities and services such as mitigating climate change, regulating water, controlling erosion; and support services such as soil formation, providing habitats for wildlife, as well as cultural activities such as use and preservation of landscapes and spiritual sites are also involved. Issues which play a pivotal role relate to agricultural knowledge, science and technology (AKST), in particular with regard to effective use of all types of knowledge, promotion of stakeholder involvement, agribusiness opportunities, legal frameworks and institutional issues. Agriculture strongly relies on the use of natural resources (landscapes, plants, animals, soils, minerals, water and atmospheric N and C) for the production of private goods (food, feed, fiber, fuel). But at the same time, these natural resources are public goods, produced, managed and distributed through public entities. Agriculture is therefore always bound to a specific, socially defined relationship between the production of private goods and the use of public goods.

Globalization in agriculture. Globalization in agriculture, aided by information and communication technologies (ICT), has resulted in opportunities as well as challenges for economic activities particularly in developing countries. Globalization is typified by the increased interlinkage and concentration at almost all stages of the production and marketing chain. It is also characterized by "the expansion of foreign private investment in agriculture, food processing and marketing, to a large extent but not only, through transnational corporations and an increasing international trade in food facilitated by the reduction in trade barriers" (FAO, 2003). The privatization of public goods, including research, and the creation of new intellectual property has become an increasingly important source of competitive advantage and accumulation in agriculture. 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 WTO's Agreement on Agriculture (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. Three phenomena related to globalization, 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). A steady erosion of local and traditional 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 particularly Africa, average farm sizes have decreased significantly in the late 20th century (Eastwood et al., 2006), although they were already very small around 1950. 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 in livestock, grains, oil crops, sugar and horticulture, and small, labor-intensive household production systems becoming less productive and only slowly integrated into the market system. In First World countries, farmers are now a small percentage of the population and have experienced a loss of political and economic influence. In the Developing World, agricultural populations are also declining, at least in relative terms – in 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, followed by Africa with 14%. Women make up an increasing fraction of the labor force in agriculture, especially in sub-Saharan Africa where hoe agriculture is practiced extensively. 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 diminished share of the economy in many countries.

Trade and the agricultural sector. International trade and economic policies can have positive and negative effects on different IAASTD goals. Examples include the potential trade-offs among decreasing agricultural subsidies, rural farm livelihoods, food import bills for Net Food Importing Developing Countries (NFIDCs) and deforestation. The challenge is to balance these trade-offs through appropriate policies.

Despite the impressive gain in production, the economic role of the agricultural sector has been declining constantly since the industrial revolution. This began with the increasing significance of fossil fuel related to industrialization and was accelerated by the use of petrol and its dominance in economic development. The decreasing share of added value contributed by the agricultural sector puts pressure on rural economies, i.e. particularly on small-scale farmers throughout the world.

Small-scale farming as a particular challenge for agriculture. Despite the crucial role that agriculture will keep 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 to about 40% of the World's population. About 85% of these are small farms defined as having less than two hectares of land (Nagayets, 2005). Small farms contribute substantially to global farm production. For Africa, Spencer (2002) estimated that 90% of agricultural production is derived from small farms. This high percentage, which also occurs in many countries in other regions, suggests that subsistence-orientation is very frequent in the agricultural sector in most developing countries, making livelihoods extremely vulnerable to any change in direct drivers such as diseases, pests, or climate. Worldwide, small farms occupy about 60% of the arable land.

Growing disparities have developed over the last 50 years between small-scale farming and the industrial agricultural systems: a key factor is the tremendous increase in labor productivity in industrialized agriculture and the stagnating labor productivity in most smallholder systems in developing countries (see Mazoyer and Roudard, 1997). The smallholder systems have not been able to compete with modern production systems, resulting in impoverishment of rural populations and countries. Countries and communities based mainly on smallholder economies are the poorest in the world today, as wells 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 is an increase in average farm size (from about ten hectares to more than 100 hectares), it is the opposite in developing countries (from about two hectares to less than one hectare). It is clear that such farm sizes hardly make investments, innovation or change possible.

Historical trends suggest that small-scale farms will continue to dominate the agricultural landscape in the developing world, especially in Africa and Asia, 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. In the long run however, a positive relation between GDP and average farm size has been postulated (Eastwood et al., 2006). The AKST assessment will therefore critically review the implications of these historical trends for the future of agriculture and human development.

Ecological changes induced by all types of agriculture. Agricultural activities require change of the natural ecosystem to an agricultural system that optimizes production for human use. This concerns traditional agricultural practices as well as industrial models. 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 induced by this human activity. Soil degradation is highest on cropland, but it also affects grazing land and even forest plantations and other agricultural practices (Hurni et al., 1996). Small-scale farming, particularly when practiced under increasing population pressure and scarcity of suitable land, involving shortened fallow periods and expansion of cropland areas into unsuitable environmental situations such as steep slopes, can be highly damaging the environment. This was particularly accelerated during the past 100 years, despite 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 species grown and variability within species. Increased specialization at the field, farm, and landscape levels produces monocultures that add environmental risk and reduce resilience. This has contributed to sustainability problems in many industrial production systems. 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 and other environmental impacts. Run-off 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, and recreational amenities (FAO, 1996a; FAO, 2006b; WWAP, 2003). Commercial pesticides affect the health of farm workers and many other non-target organisms and their habitats (WWAP, 2003). The international transportation of crops, livestock and food products has promoted the global spread of agricultural pathogens and disease organisms. The global atmospheric transport of pollutants, including greenhouse gases, means that environmental costs are borne by populations far removed from the site of production (UNEP, 2005; Commoner, 1990).

Impacts of AKST. In the last 50 years, knowledge and technology provided by science have induced noticeable changes in the outputs produced in agricultural ecosystems, with consequences on the management of natural resources for agriculture (Pardey and

Beintema, 2001). Agricultural Knowledge, Science and Technology (AKST) has a good track-record of delivering real benefits to resource users, e.g. new crop, livestock, fish, forest and farming technologies that both improve productivity and mitigate poverty (Evenson and Gollin, 2003; Raitzer, 2003; Johnson, 2005). Its most prominent example is the Green Revolution, which significantly increased agricultural production in many developing countries.

A challenge for AKST is the great imbalance in numbers of researchers per million inhabitants: this number is 65 times smaller in Africa than in developed countries (Hurni et al., 2001). Nearly half of public agricultural research expenditures, amounting to US$ 21.7 billion (1995), are spent in developed countries, i.e. benefiting only a few million, though highly productive farmers (Pardey, 2001). While private agricultural research spending is about equal to public spending in developed countries, i.e. each nearly 3% of GDP, private spending in developing countries is insignificant, i.e. 0.1% of GDP on average, while public spending is at 0.7% only (Pardey, 2001).

In general, research and development (R&D) investments have so far generated high returns (Byerlee and Alex, 2003). For example, trends in cereal production since 1960 show that area productivity increased by a factor of 2.5 in developed countries, from 2.1 to 4.9 metric tons per hectare 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 one to 2.8 metric tons per hectare on a total cropped area of 440 million hectares (Cassman, 2003). It must be noted, however, that stagnation in land productivity increase has been observed in many areas since about 1985 (Cassman, 2003).

Since the development of cell culture, new discoveries at the molecular level have led to advances in genomics, transgenics, and molecular markers. Public and private sector research organizations in both high- and low-income countries are using biotechnology for genetic improvement. Transgenic plants include a limited number of crop/trait combinations approved in both developed and developing countries. A number of concerns remain, and national biosafety regulatory systems are growing also among developing countries to monitor, evaluate and provide guidance on biotechnology applications.

1.1.3 Agricultural systems, food systems and the environment

Agricultural systems, outputs and services. The major outputs generated by the multiple agricultural systems worldwide may be referred to as ‘provisioning services’, as in the 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;

- 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 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 flowers used as ornamentals; and
- Freshwater from springs and other sources, as an example of the linkage between provisioning and regulating services.

Agricultural systems are complex, embracing economic, biophysical, socio-cultural and other parameters. They are characterized by a high degree of complexity, 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 1.2).

[Insert Table 1.2. Positive functions of agriculture]

Diversity of agricultural systems

There is a multitude of agricultural systems worldwide. Among the very different examples are the traditional fishing and hunting of the Inuit in the Arctic, the highly mechanized precision agriculture on large farms in Canada and the USA, biofuel cropping systems in Brazil, extensive livestock breeding in Argentina, forestry management systems in Europe, mixed livestock and crop subsistence farming on very small farms in Ethiopia, intensive irrigation farming in the Middle East, or small-scale irrigation farming in Asia. All these agricultural systems have evolved over time and are principally based on larger agricultural systems that were generally adapted to the original ecosystems, although converted at various degrees and scales. For example, at least 20 major farming systems exist on the African continent (Spencer, 2003), all based on a diversity of broader agricultural systems, be it small- or large-scale, irrigated or non-irrigated, crop- or tuber-based, hoe- or plough-based, in highland or lowland situations. Table 1.3 lists major categories of agricultural systems and their related agroecosystems.

[Insert Table 1.3. Broad categories of agricultural systems, their characteristics and related agroecosystems]

Agricultural systems are embedded in a multiplicity of different economic, political and social contexts worldwide, depending on national economies, the importance of the agricultural sector in these economies, or the amount of subsidies provided to farmers. It is worth noting that the gross national product (GNP) per capita is exponentially correlated to the percentage of the agricultural sector in a country: the higher this percentage is, the smaller the GNP (Hurni et al., 1996; Vali, 2000). It is thus crucial to gain a clear knowledge of the state of agriculture in the different ecological and socio-economic contexts to be able to assess the potential for further development of this sector in relation to the IAASTD development and sustainability goals. Similar to what happens in the different socio-economic contexts, the impacts of 'research and development' (R&D) have not been equally distributed either. This has led to economic disparities within and among regions, countries and especially between industrial and small-scale farmers (FAO, 2000). Apart from the differences in labor productivity mentioned above, examples of disparities are average farm sizes (121 ha in North America vs. 1.6 ha in Asia and Africa, see von Braun, 2005) and the crop yield gap between high and low income countries (Watson, 2006).

The last 50 years have seen a tremendous increase in agricultural production, at a rate more rapid than human population growth. 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 what is not sufficiently perceived is that in a monetarized economy, the central functions of agriculture support the performance of other sectors; moreover, there is insufficient understanding of the regulating and supporting functions of global ecosystems. The findings of the Millennium Ecosystem Assessment (2005b) clearly point to the key role of agriculture in both preserving and endangering ecosystem functions.

The role of women in agricultural production has been important in many agricultural systems and may increase in future. Women make up 51% of the agricultural labor force worldwide but in many countries, women's extensive contribution to agricultural output remains largely unrecorded. Furthermore the effect of out-migration from rural areas often leads to female-headed households, a phenomenon that is called “feminization of agriculture”. The share of female agricultural laborers is rising rapidly in all countries, except in Eastern and Central Europe, where high levels are falling. In sub-Saharan Africa where hoe agriculture has been a tradition, 80% of economically active women work in the agricultural sector, and most of them are responsible for all farm activities. It is estimated from studies in Kenya that greater financial support for both female and male farmers would increase yields by more than 20%. In Latin America raising women's wages to the same level as men's would increase national output by 5% (Hemmati and Gardiner, 2001).

The fishery component of agriculture. Fisheries play a very important role in agriculture and the world economy. 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 (WorldFish Center, 2006; Kurien, 2006). Fish contributes to national food self-sufficiency through direct consumption and through trade and exports. Fishery exports have become a significant foreign currency earner for developing countries.

World capture fishery production was 95 million tonnes in 2005, an increase of about 5% from 2003 (FAO, 2006c). Aquaculture may substitute wild catch but creates environmental problems that need to be addressed. Aquaculture – the farming in captivity of fish previously caught only in the wild – has expanded globally at an average annual rate of 8.9% since 1970, making it the fastest growing animal food source and providing about 50% of the fish for human consumption (WorldFish Center, 2006).

The forestry component of agriculture. Forests are intensively linked to agriculture, providing products (wood, fuelwood, food, medicines, etc.), inputs for crop and livestock production (fodder, soil nutrients, pollination, etc.), and services (watershed protection, climate regulation, carbon storage, biodiversity conservation, etc.). All types of forests contribute to all forms of farming in two main ways: 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 they are a principal source of biodiversity.

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 are harvested in the forest; and two billion people rely on traditional medicine, much of which depends on forest products (CIFOR, 2006). The rapid development of agriculture has proceeded through converting 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 an alarmingly high rate, at 13 million hectares per year (FAO, 2005). Net global change in forest area in 2000-2005 is estimated at -7.3 million hectares per year, down from -8.9 million hectares per year in 1990-2000 (FAO, 2005).

The livestock component of agriculture. The volume of livestock production in developing countries has steadily increased since the early 1980s, both for internal consumption and for export (COAG, 2005). It accounts for about 40% of the agricultural GDP (FAO, 2006e), 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). Global livestock production continues to grow more rapidly than crop agriculture, with growth rates of five% in the 1990s, but has slowed down since 2004 (FAO, 2006e). 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's contribution to environmental problems is massive, considering its negative impact on land, climate, water quality and quantity and biodiversity (FAO, 2006e).

Much of the 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 but also in Asia, where livestock has continued to be the primary source of livelihoods; but these systems are hardly integrated in market systems.

Agriculture and food systems

Food 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). Food systems have a strong influence on culture, politics, societies, economics and the environment, and their interactions affect food systems activities. Zurek (2006) describes four food systems activities: producing, processing and packaging, distributing and retaining food and consuming food. Food systems are directly linked to food security issues which do not only depend on food production but also on food access and utilization.

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, or loss of biodiversity. Conversion of land for production of food, fresh water, timber, fiber, feed and fuel is a main driver of biodiversity loss (MA, 2005b: 2). Many agricultural production systems worldwide, both traditional and modern, have not sufficiently adapted their systems to the local/regional ecosystems, which has led to severe disturbances of ecosystem services that are vital both for agricultural production and for humankind.

Soil degradation has direct impacts on soil biodiversity, on the physical basis of plant growth and on water storage. 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 (Oldeman et al., 1990). About 2,000 million ha were reported to be 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 the various farming systems, both subsistence and mechanized.

Water quality and quantity changes. Access to enough, safe and reliable water is crucial for food production and poverty reduction. But putting more water into agricultural services threatens environmental sustainability. Water management in agriculture thus has to overcome this dilemma (CA, 2006). Livestock 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). Crop based agriculture is an even higher consumer of water resources, e.g. each person is responsible for converting between 2000 to 5000 liters of liquid water to vapor each day just because we have to eat. This is because of evaporation, necessary for the growth of food and feed producing plants on rainfed and irrigated lands (Molden 2003). According to the Millennium Ecosystem Assessment, irrigation for agriculture is by far the greatest consumer of water (MA, 2005b). Water conservation and harvesting is also an important potential for rain-fed 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 even more importantly, to seasonal variability and extreme events. Global mean temperature is projected to increase between 1.4-5.8 degrees Celsius by the end of the 21st century. The outcomes of this change will vary heavily by regions. Livestock production is one of the major contributors to climate change within agriculture (Steinfeld et al., 2006). Global organic carbon storage was estimated as 1,555 Gt in the upper 100 cm of soil (Wood et al., 2000: 77). On the other hand, agriculture contributes 15% (Baumert, 2005) of greenhouse gas emissions, not including land use changes such as deforestation, which contribute 18% (Baumert, 2005). Most of greenhouse gas is from soils (40%), enteric fermentation (27%), and rice cultivation (10%) (Baumert, 2005). The reduction of these emissions to mitigate impacts on the global climate is one of the challenges of agricultural development. There exists a great potential for further absorption if sustainable land management practices that increase soil organic matter are introduced on all degrading lands (Liniger and Critchley, 2007).

Energy: Energy resources and demand are both a challenge and an opportunity for agriculture, particularly in the face of rising and volatile energy prices and climate change. Various forms of agriculture use different levels of energy; with transitions in agricultural production systems in general leading to a substitution of energy for labor. Increasing energy prices and changing subsidies are likely to be important for trends in agricultural production systems. At the same time, agriculture may become an important producer of energy in the form of bioenergy, based on both energy security and climate change considerations.

Bioenergy is being promoted in many countries to enhance energy security, reduce greenhouse gas emissions, and stimulate rural development.

1.1.4 Development and sustainability goals

Origin of IAASTD. The World Bank announced at the World Summit on Sustainable Development in August 2002 that an international consultative process based on a proposed international assessment of the role of agricultural science and technology in reducing hunger, improving rural livelihoods and stimulating economic growth over the coming decades would be cosponsored by the World Bank and FAO. Regional consultations were subsequently held in all regions of the world. Based on the outcomes of these consultations, FAO, the GEF, UNDP, UNEP, UNESCO, WHO and the World Bank agreed to cosponsor the IAASTD.

The 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, access to and use of agricultural knowledge, science and technology. 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 and human health and nutrition, and

(3) promote equitable, 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). Achievement of the IAASTD goals will depend upon the choices of different actors (e.g. governments, farmers, and private entrepreneurs) related to availability of and access to natural, human and other resources.

The IAASTD concentrates on agriculture because of the prominent role it plays for human well-being on earth. The IAASTD 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, i.e. well thought-through decision making for future sustainable development by: (1) assessing interrelations between AKST with regard to sustainable development; (2) assessing knowledge and scientific development, technology diffusion, innovation, and adaptation of ecosystem management;

and (3) assessing the integration of AKST within international, regional, national and local development policies and strategies.

Reduction of poverty and hunger. Worldwide, about 1,200 million people live on less than US$1 per day; the percentage is expected to drop from 19% of the world population in 2002 to ten% by 2015 (World Bank, 2006a), although in absolute numbers the difference will be smaller because the total population will be higher by about 800 million people by then. However, as pointed out by the World Bank: “Many countries, particularly in Africa and South Asia, are off track to reach the Human Development Goals” (Global Monitoring Report, 2006). An estimated 800 million persons, more than half of the people living in extreme poverty, are occupied in agriculture (CGIAR Science Council, 2005). Their livelihood is usually derived from small-scale farming. In 1996, around 2.5 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 predominantly 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 lead to an increase in female-headed households and raised the already immense workload of rural women (García, 2005)

De-capitalization, such as the 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) was, and still is, the consequence of the combined effects of competition from the modern sector (leading to low prices), direct and indirect taxation of agriculture, and the inherent investment-blocking structure of small-scale farms, which explains much of the persistence of poverty in many countries (Mazoyer and Roudard, 1997). On the other hand, research has also shown that agricultural growth can, despite this difficult context, lead to important benefits for poverty alleviation (Byerlee et al., 2005), but not necessarily for those people remaining in small-scale agriculture.

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. Chambers and Conway (1991) describe livelihoods in terms of “people, their capabilities and their means of living.” Livelihoods encompass income as well as the tangible and intangible resources used by the household to generate income. Livelihoods are basically choices about 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.

Even though a large number of people depend entirely on agriculture, off-farm income is important even for many households that depend on agriculture for their livelihoods. Different 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. For example, two households that have the same endowments in 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 may plant a riskier variety—expecting higher yields, yet knowing its additional financial capital can help it sustain its income (and consumption levels) even if it suffers a poor harvest.

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.

The components of health are multiple and their interactions complex. The health of an individual is strongly influenced by genetic make-up, nutritional status, access to health care, socio-economic 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. For example, in most societies, biomass fuel collection is a woman's task. Women often spend hours collecting and carrying fuel wood back home over long distances. Poor women are the majority of 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; their health suffers from hauling heavy loads and from cooking over smoky fires (Lambrou and Piana, 2006).

A direct consequence of extreme poverty is undernourishment, an issue not only for the urban poor and for landless persons, but particularly for the underprivileged such as women and children. It also affects rural people who are 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 for good physical and mental health, and thus for 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 sustainable development. 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 its development and sustainability goals. This broad sense serves the primary goal of providing sufficient and nutritious food for humankind, in the present and in future. It is indisputable that agriculture as a sector cannot meet this goal on its own. 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, has so far been a societal strategy at the national and international levels with obvious advantages (Sen and Drèze, 1990; 1991). Agriculture, however, fulfills a series of additional goals besides food production. It produces feed for livestock and fiber for clothing and industrial use. It provides occupation, employment and socio-cultural meaning. It has started to help develop sustainable use of energy by producing biofuel crops. 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 of this role may increase and become central for human survival on this planet.

1.2 Conceptual Framework of the IAASTD

1.2.1 Key concepts for the AKST assessment

Conceptual framework of the AKST assessment. The IAASTD framework for this assessment of AKST is shown in Figure 1.1. The agricultural systems and services have been described in subchapter 1.1.3, and the development and sustainability goals of IAASTD in subchapter 1.1.4. What follows here is a description of the other elements of the conceptual framework, particularly the central concept of AKST.

[Insert Fig. 1.1. Conceptual framework of the IAASTD]

Centrality of knowledge. There is a huge diversity and dynamics of agricultural production systems, which depend on agroecosystems and are embedded in diverse political, economic, social and cultural contexts. Knowledge about these systems is complex; moreover, the AKST assessment considers that knowledge is co-produced by researchers, 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, are affected by or excluded from access to, control over and distribution of knowledge, technologies, financial and other resources required for agricultural production and livelihoods. This puts policies relating to science, research, higher education, 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. However it is important to note that this inner dynamics depends on how the actors involved respect, reject or re-create the rules and norms implied in the networks through which they interrelate. The AKST considers that its own dynamics strongly depends 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 is understood in the sense of the International Council for Science (ICSU, 2003), which offers the following definition: “Knowledge – in whatever field – empowers those who create and possess it with the capacity for intellectual or physical action. 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”. 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 use of such knowledge in economic production (defined broadly to include social welfare goals). In most developing countries institutional and organizational arrangements are founded on this distinction.

However, this traditional distinction is now widely criticized in contemporary 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 conducting of 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.

Innovation and innovation systems. A World Bank study (2006b) noted that 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. An innovation system may be defined as the network of agents, usually organized in an inter- and transdisciplinary manner, whose interactions 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 inter-organizational 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 the 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. 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 a certain innovation.

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, is thus far more important. Conventional 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 AKST model considers that rules and norms that are relevant for 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 co-production of knowledge share, exchange, compare and eventually socialize their individually realized perceptions of what is important, good, or bad, and hinders or enables 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 make policies – for example a local NGO’s policy about who is eligible for its programs” (DFID, 2001). In order to achieve the successful implementation of a policy it is usually necessary to have a ‘strategy’ that sets out the appropriate steps that need to be taken (and the order they need to be taken in). In turn these strategic steps will involve a range of specific ‘policy instruments’, such as fiscal, regulatory and other legal measures. Sometimes the whole process from problem to policy instrument specification is set out in a ‘plan’ or ‘planning document’. ‘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 co-production of knowledge for more sustainable and pro-poor agriculture and food production.

1.2.2 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 a result of a multitude of factors at a variety of scales. For example, change for a particular household may occur as a direct result of a better harvest due to use of an improved technology. But 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 careful distinction between direct and indirect drivers of change.

Following the framework, direct drivers of change in terms of IAASTD's development and sustainability goals include, food demand and consumption patterns, land use change, the availability and management of natural resources, climate and climate change, energy, labor, as well as the development and use of agricultural knowledge, science, and technology (AKST).

Relevant natural resources include land, i.e. soil, water, flora and fauna, as well as 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, as well as 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, control and distribution of AKST, such as extension and dissemination efforts, credit markets and capital assets, or 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 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, 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 consume and what they value) may also influence decisions regarding direct drivers.

Besides distinguishing direct and indirect drivers of change, it is also useful to distinguish exogenous drivers from endogenous drivers of change. Exogenous drivers are those that are independent of the current and future actions of policy makers or farmers. These may include both direct drivers (e.g. natural disasters) and indirect drivers (e.g. existing laws and institutions). Understanding of exogenous drivers is important because they define the environment in which policy makers and farmers make choices that affect the goals of the IAASTD. Endogenous drivers are those that depend on the current and future actions of policy makers or farmers. Endogenous drivers may be either direct (farmer’s choice of farming practice) or indirect (such as a government’s policy on trade). Understanding of endogenous drivers is important because they reflect the actual strategies chosen by policy makers and farmers in seeking to achieve the goals of the IAASTD.

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 three% of the tax-paying workforce, a small-scale farmer with an average farm size of 16 hectares which (s)he may use for livestock breeding will not generate sufficient income for the family for a decent livelihood. Because of the importance of agriculture for non-productive services such as cultural landscape preservation, recreation forests, and water management, Swiss farmers are subsidized by society for over 50% of their income, thus reaching the minimum national income standard of about 35,000 US$ in 2005 (BFS, 2006). A farming household in Ethiopia, by contrast, typically survives on one hectare of cultivated land and some communal pasture land for livestock rearing. This family produces about one metric ton 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 context, having an average annual per capita GNP of less than 200 US$.

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 can fall back on knowledge generated 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). The Millennium Ecosystem Assessment defines an ecosystem 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 IAASTD uses the ten categories of ecosystems described in the MA framework (2003). These categories take into account climatic conditions, geophysical conditions, dominant use by humans, surface cover, species composition, resource management systems, and institutions. Their specific characteristics and the related agricultural activities are described in Table 1.4.

[Insert Table 1.4. Categories of ecosystems and their importance for agriculture]

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, then 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 use 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 is of greater importance than the forests’ production value alone.

1.2.3 Issues and challenges under AKST

Some recent changes in thinking have raised a number of cognate issues in AKST. The policy agenda has evolved from a traditional “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 seeking a stronger inter-institutional support for development projects that the private sector may be interested to invest in. Largely, this has been driven by changing contexts and circumstances since the days of the Green Revolution. 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 that is based on the idea that knowledge is co-produced by all actors involved. The most important of these issues are summarized in the present subchapter.

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 developing 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. 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. Moreover the difficulties of more equality-based engagement with farmers, peasants, or ‘clients’ has also to do with a too narrow understanding of the reasons guiding rural actors’ decisions, actions and livelihoods (see Wiesmann, 1998 for Africa; Yapa, 1993 for Asia; and Trawick, 2003 for Latin America).

Promotion of other stakeholder’s 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 (IAC, 2004; Farrington et al., 2002). There is also evidence of an increased need to engage in partnerships in order to re-conceptualize (in theory and practice) the delivery of technology in the context of an AKST system that is based on the paradigms of knowledge co-produced by scientists, policy makers and client groups. These partners include private sector organizations, but they also involve NGOs and community-based organizations (CBOs) 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 smallholder's skills s to enable them to participate in the agriculture supply chain are urgent tasks.

Co-production 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', indigenous 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 up-scaling participatory processes into the meso- and macro-levels of social organization (Gaventa, 1998).

When taking into account the centrality and value of endogenous, indigenous 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 (Rist and Dahdouh-Guebas, 2006; Dove and Kammen, 1997; Olesen et al., 2000). Integration of, or 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, against the background of the different actor-specific epistemologies and ontologies, i.e., it needs to be integrated into (and by) the different knowledge systems involved. Dove and Kammen (1997) and Olesen et al. (2000) have shown that this is also particularly important for innovations in rural development.

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 (Rist and Dahdouh-Guebas, 2006; Röling and Wagemakers, 2000). As a consequence participatory forms of co-production of knowledge, based on social learning among actors involved, have become a key feature of sustainable agriculture and resource management (Pahl-Wostl and Hare, 2004; Rist et al., 2003; Wollenberg et al., 2001). 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 (a) goes beyond specific disciplines by combining natural, technical, economic and social sciences, and (b) 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? By distinguishing analytically among basic, applied and transdisciplinary research, the challenges that have to be tackled in transdisciplinary projects are analyzed (Hirsch Hadorn et al., 2006).

Engagement with agribusiness opportunities. Agricultural research partly faces the agenda of an agricultural research system which is simply not suited to the emerging realities of the 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 biofuel 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 in 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) has emphasized 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 improved intellectual property protection regimes and technical advances in biotechnology. But also significant are the opportunities that economic and trade liberalization and globalization are now offering for private investments in agro-industries 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 from international companies 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 socio-political debates that perhaps define the societal preconditions which influence the amounts, use and allocation of financial and human resources available for research and development in rural areas. Technocratic, top-down and disciplinary-based definitions of research and development policies are definitely 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, from being considered as an 'obstacle' for development, is now considered an important resource that contributes to better targeted development efforts (Blaikie et al., 1997; Scoones and Thompson, 1994).

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 socio-economic ends. 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 as Glowka et al. (1994) have shown there is often a severe shortage of technological capacity to realize these opportunities. The important point is the need for developing countries to increase AKST capacity implied in the new contexts that such agreements imply.

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. Yet while large international companies have moved forward in this respect, many developing countries still have great difficulties to ensure 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 stuck in a 'mode 1' world (Gibbons et al., 1994) where they see their responsibilities ending with the publication of scientific papers in refereed journals.

Questions that therefore arise in this context have to do with the creation of capacity and related initiatives that ensure that knowledge co-production and technology development in developing countries is as fully informed as possible in these respects. However, the question remains of 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 developed 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" but at the same time "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"(Millennium Project, 2005).

A report by the Inter-Academy 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, the growth of student numbers (by 8% a year), with funding falling short of this increase and funding decline accentuated by structural adjustment. Fortunately, 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 fit the needs of less developed 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 mention the gender disparity in training as well as the lack of focus in curriculum of agricultural universities in developing and, most often, also in developed countries on gender analysis.

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 with further capacity development of actors involved in research and extension aiming at a qualitative shift towards more societal modes of knowledge production emphasizing inter- and transdisciplinary approaches (Hurni and Wiesmann, 2004).

Measurement of 'knowledge' categories. Table 1.5 (Pardey and Beintema, 2001) offers basic data regarding investment in AKST. It shows a large gap in research intensity between developing and developed countries. Research intensities have been growing for developing countries as a group, but unevenly.

[Insert Table 1.5. Selected public research intensity ratios (Pardey and Beintema, 2001)]

However, 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 obtains on the output side since these 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 how much resources are allocated to local and indigenous components of the AKST systems. They must also make visible to what degree the resources allocated to these components of the AKST system reflect the overall relationship that local or indigenous knowledge and external knowledge actually have in ensuring the livelihood systems of rural people in general and of poor and marginalized people in particular.

A wide range of policies for organizational reforms may be necessary to deploy AKST effectively in the future. The inclusion of medium- to high-level scientific resources may be suggested for formal higher and tertiary education systems. Also included are organizational changes 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. The aim of such changes would be to enable more adequate analysis of agroecosystem services apart from the production orientation of AKST, and to find strategies to mitigate negative impacts (‘damages’) caused by agricultural practices to such services. Also needed is 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. Section III will deal especially with policy measures that may be appropriate in this context. Capacity development is here broadly defined and includes building: a) common understandings of problems, solutions and ways to approach them using a variety of interpersonal and intra-social processes; b) social and cultural resources, not just human resources; c) multiple, strategic skills across a range of areas to intervene and advocate, not just to be a passive recipient of programs and policies, and d) institutional and organizational bases of power.

1.3 Key Themes of IAASTD

1.3.1 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. Quality of life questions gain in importance as average life expectancy grows, and the gaps between richer and poorer countries and regions are evident. 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 was defined by WHO (1946) as ‘a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.’ 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. The components of health are multiple and their interactions complex. The health of an individual is strongly influenced by genetic make-up, nutritional status, access to health care, socio-economic 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, 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.

Societies at different stages of development exhibit distinct epidemiological profiles. The major, but not necessarily the most frequent, cause 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 live from hunting and gathering typically have short average life expectancy and death due to accident or injury is more prevalent than in other types of society. Agrarian societies show high rates of 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 socio-economic development and human health: the heavy burden of infectious disease in poor, predominantly agrarian countries; the double burden of both infectious and non-communicable 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, but where great differences still exist in the health status of rural and urban population groups; and advanced developed economies, with ageing 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 developed 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 developed 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 portion of their lives in poor health, than do those in developed countries. More than 80% of the global years lived with disability (YLDs) 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 portion of lost healthy years ranging from nine% in Europe and the Western Pacific to 15% in Africa (WHO, 2005).

Infectious disease has ceded its place to non-communicable illnesses, such as heart disease, cancer and degenerative conditions, as the primary cause of mortality worldwide. Non-communicable diseases accounted for about 60% of all deaths and 47% of the global burden of disease in 2002, figures 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).

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 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 modern agricultural methods, including pesticides. The dietary energy supply for the global population was estimated to be 2803 k/cal 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 k/cal per capita per diem in developed 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: 157-161).

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 consume. 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 on the rise in many parts of the world and feedlot livestock production will make ever heavier demands on food resources as the portion 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, 2005). 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, 2005).

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. In low-income countries, for example, 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 ten% 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 (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 in 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 benefit 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 thus builds the platform 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: 1207). 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 (IDA) 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, IDA 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 pre-school 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) AKST can contribute to the development of fortified foods to meet these nutritional needs.

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 underweight; excessive intake leads to overweight and obesity.

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 over-consumption of fat, sugar and salt coupled with inadequate intake of whole grains, fruits and vegetables as well as the trend towards overweight 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 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 health traditional dishes and suggest in 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). 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 BSE, foot-and-mouth disease and avian flu and the mass culling that has resulted have raised public concerns with regard to intensified food production, particularly of meat. 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, battery-style poultry production on animal health and welfare. Such concerns have all begun to affect food purchasing decisions in many countries.

Both industrialized and developing countries have improved surveillance and investigative capabilities regarding food-borne disease outbreaks over the past two decades. The experience acquired so far, together with modern 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.

Food insecurity. Food security has been defined in terms of availability, access, and utilization. Food insecurity occurs when insufficient food is assured 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. It can be limited to small pockets or affect entire regions.

Temporary food insecurity may be overcome when a harvest comes or when conditions such as weather, wages or employment opportunities improve, or 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, or 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, draw on informal social networks, seek food aid, or even be forced to sell assets - perhaps achieving temporary food security only at the expense of its 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 that households face, the resources and external conditions that influence those choices and the livelihood strategies that could enable families to meet their food needs over time.

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 in awkward body positions. 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, 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, such as tractors and harvesters, accounts 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, handling and disposal practices (ILO, 1999).

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 need to be in place 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 handles these substances with the necessary precaution.

Animal handling and contact with dangerous plants and biological agents which 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 the veterinary and public health systems 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, gastro-intestinal 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, wage workers in plantations, landless daily paid laborers, temporary and migrant workers and child laborers.

While difficult to quantify with accuracy, child labor in agriculture is known to be widely prevalent. It is estimated that of the world's 250 million working children, 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. Children working in agriculture 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, care-givers, 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 poor nutrition as it undermines farm families' ability to cultivate adequate food for their members. Poor nutrition, in turn, hastens the onset of AIDS in those weakened by HIV and increases vulnerability to opportunistic infections. Women are particularly affected as they tend to offer the better foodstuffs to male family members.

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 very stuff 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.

1.3.2 Poverty, livelihoods and economy

First among the Millennium Development Goals is the eradication of extreme poverty and hunger. 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 in developing (i.e. low- and middle-income) countries has already declined from 28% in 1990 to 19% in 2002, and is projected to fall further to ten% by 2015 (World Bank, 2006c). Progress has been particularly striking in East Asia and the Pacific, where the target has already been achieved, and 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).

Hunger is inextricably linked to poverty and here again progress is evident but uneven. 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). 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. These interactions are summarized in Figure 1.2.

[Insert Fig. 1.2. Dynamic links between household choices and outcomes (adapted from Maxwell and Wiebe, 1999]

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. Alternatively, income may allow the 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 could reduce the amount of crops or labor a household has to sell, while low wages or prices could 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, the household made 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. In a subsistence household, food usually absorbs 80-90% of the means available for 'spending', which is mostly non-monetary.

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. Chambers and Conway (1991) describe livelihoods in terms of "people, their capabilities and their means of living." Livelihoods encompass income as well as the tangible and intangible resources used by the household to generate income. 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).

Income. Livelihoods and economic well-being are 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 $1,502 in developing countries in 2004, or about $4 per day (World Bank, 2006c: 22); half the people in developing countries live on less that $2 per day, and 19% live on less than $1 per day (World Bank, 2006c). By contrast, income per capita in high-income countries averaged $32,112 in 2004, or about $88 per day.

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 was 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 in responding when incomes fluctuate in response to changing economic conditions or natural disasters. Resources can be grouped in various ways. Serageldin (1996), for example, identifies four types of capital, namely natural, human, social, and "man-made" capital, while Chambers and Conway (1991) further divide man-made capital into physical and financial forms. We describe each in turn.

Natural capital is "the stock of environmentally provided assets… that provide a flow of useful goods and services" (Serageldin, 1996), and includes land and soil resources, water and climate, energy, biodiversity and genetic materials, and ecosystem services (MA, 2005a). Different forms of natural capital may be renewable (such as solar energy) or nonrenewable (such as topsoil), and they may be marketed (such as oil) or non-marketed (such as climate). These distinctions affect the choices that households make in combining natural resources with other forms of capital in their livelihood strategies.

Of the Earth's 129,663 square kilometers of land area, forest accounts for about 31% and cropland for about 12% (World Bank, 2006c). Developing countries have an average of about 0.2 hectares of arable land (i.e. cropland not under permanent crops) per capita. About 20% of cropland in developing countries is irrigated, and about 12% is irrigated in high-income countries (World Bank, 2006c). About 15% of the earth's total territorial surface (including territorial sea area up to the 12 nautical miles from the coastline) is now classified as protected to maintain biological diversity (UNEP, 2006).

Renewable internal freshwater resources averaged 6,872 cubic meters per capita globally in 2004, but varied widely—from 761 cubic meters per capita in the Middle East and North Africa to 24,619 cubic meters per capita in Latin America and the Caribbean, averaging 6,358 cubic meters per capita for developing countries as a group and 9,703 cubic meters for high-income countries (World Bank, 2006c). Agriculture accounts for 70% of freshwater withdrawals globally, and for 78% in developing countries.

The world produced energy equivalent to 10.7 billion metric tons of oil in 2003, 60% of it in developing countries, and used about 1.7 tons per capita (World Bank, 2006c). Energy use averaged 1.0 ton per capita in developing countries and 5.4 tons per capita in high-income countries. Emissions of carbon dioxide, which account for the largest share of greenhouse gases, averaged 2.2 tons per capita in developing countries and 12.8 tons per capita in high-income countries in 2002 (World Bank, 2006c).

Human capital consists, in its most basic form, of human labor power. Labor power depends in turn on factors such as age, food security, and health, as well as the education, training, knowledge, skills, and experience embodied in the household and its members. Some of these aspects, such as health and nutrition, have already been introduced in previous sub-chapters.

About 64% of the global population is of working age, i.e. between the ages of 15 and 64; this figure is slightly higher (67%) in high-income countries (World Bank, 2006c). The labor force is growing by 1.0% per year in high-income countries and 1.7% per year in developing countries, although this conceals considerable variation: from -0.2% per year in the low- and middle-income countries of Europe and Central Asia to 3.4% per year in the Middle East and North Africa (World Bank, 2006c).

Education. The second MDG is to ensure universal primary education by 2015. Reported gross primary school enrollment 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 enrollment 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). Expenditures for research and development (R&D) average about 0.9% of GDP in developing countries and 2.5% of GDP in high-income countries (World Bank, 2006c: 308), 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 countries as were published by authors from developing countries in 2001 (World Bank, 2006c).

Physical capital encompasses tools, technologies, and other produced items. These may include bicycles, buildings, a weaver's loom or a farmer's hand hoe or tractor, chemical fertilizers, pesticides, as well as transportation and communications infrastructure.

Fertilizer consumption averaged 99 kilograms per hectare of arable land globally in 2000-02, but ranged from 14 kilograms per hectare in sub-Saharan Africa to 215 kilograms per hectare in East Asia and the Pacific (World Bank, 2006c). Developing countries averaged 91 kilograms per hectare and high-income countries averaged 121 kilograms per hectare. A similar disparity is evident in the use of agricultural machinery, with an average of 0.1 tractors in use per square kilometer of agricultural land in sub-Saharan Africa compared with ten per square kilometer in high-income European countries (World Bank, 2006c). Developing countries averaged one tractor per square kilometer in 2001-03, high-income countries averaged four, and the global average was two (FAOSTAT, 2006).

Transportation and communication infrastructure is a critical foundation for markets to function well. About 30% of roads in developing countries are paved, while the corresponding figure for high-income countries is 92% (World Bank, 2006c). Port traffic, as measured by standard shipping containers handled annually, was more equally distributed between developing and high-income countries, but the vast majority of developing-country traffic is accounted for by East Asia and the Pacific (World Bank, 2006c). Residents of high-income countries consume about eight times as much electric power as do residents of developing countries, and are about four times as likely to have access to a fixed mainline or mobile telephone (World Bank, 2006c: 300). Residents of high-income countries are also twice as likely to have a television, five times as likely to read a newspaper, and around ten times as likely to have access to a personal computer or the Internet (World Bank, 2006c).

Financial capital may include savings as well as access to credit and insurance opportunities, through either formal or informal channels. One measure of access to financial capital is the difference between the interest rate at which banks lend money and the rate they pay on deposits: the higher the lending rate, the more costly it is to borrow money; the lower the rate on deposits, the less incentive there is to save. In 2004, the difference between these two rates was highest in sub-Saharan Africa, at 12.5%, and lowest in the high-income countries, at 4.1%. Developing countries as a group had an average difference of 7.4% (World Bank, 2006c).

Social capital encompasses informal kinship and social networks and norms as well as formal public institutions and laws, including property rights. As such it is the least easily measured form of capital, but perhaps the most important, because it helps shape individuals' and households' access to all the other forms of capital. Possible indicators of social capital include government expenditures on pensions. Regional aggregate data are not available, but national expenditures vary from less than 1% of GDP in many developing countries to more than 10% of GDP in many high-income countries as well as in several middle-income countries of Europe and Central Asia (World Bank, 2006c).

The World Bank also collects and reports data on institutional dimensions of the business environment, including the number of procedures and the time involved in starting a business, registering property, and enforcing contracts. By most measures, these processes are simpler and quicker in high-income countries than they are in developing countries (World Bank, 2006c). Of course many common resources embody aspects of more than one form of capital. Seeds, for example, embody natural capital in the form of genetic material but also human capital in the form of the selection and breeding that have improved them over many generations. Water is a natural resource, but it may reach a farmer's field via physical infrastructure built and managed by social institutions.

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. Livelihoods are basically choices about 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 again. Household needs and goals depend on the characteristics of their members, while household opportunities depend on their resource endowments, including their social setting. Livelihood strategies are driven by the interaction of these goals and opportunities.

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 $161 billion in 2004 and accounting for more than three% of GDP in South Asia (World Bank, 2006c).

Different livelihood strategies can be thought of in terms of adjustments in the quantity and composition of an individual's or household's resource endowment. 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 down 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 having 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 plants a riskier variety—expecting higher yields, yet knowing its additional financial capital can help it sustain its income (and consumption levels) even if it suffers 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 in the preceding paragraph, the first household may suffer smaller losses in a drought year, but also smaller gains in average and good years. Even when both 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 incomplete understanding of household 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 Serageldin (1996) notes that even such an intuitively appealing definition raises difficult operational questions regarding both needs and ability. 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 the 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. Serageldin (1996) describes three different levels of sustainability, depending on how particular components of the resource endowment are regarded.

Strong sustainability involves maintaining each component of the resource endowment at its current level or higher. In its strictest sense this would mean that nonrenewable 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. Serageldin (1996) notes that such a requirement would preclude extraction of oil to improve human capital, for example by investing in education for girls. A less strict interpretation of strong sustainability would be based on categories of resources rather than specific resources; this would allow depletion of oil reserves, for example, if proceeds were invested in alternative (and sustainable) energy sources.

Weak 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.

Serageldin (1996) proposes a third alternative, “sensible sustainability”, that lies intermediate between the two extremes. Like weak sustainability, it involves maintaining the total stock of capital. Like strong sustainability, however, it also recognizes 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.

As noted earlier, 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 ten% per year over the past several decades - less than traditional measures of investment, but still positive (and thus sustainable, at least in the weak 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 genuine savings rates of - 5 to 10% per year.

Such patterns and concerns continue today (see Fig. 1.3. 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 (World Bank, 2006c). 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%). These findings reinforce concerns about sustainability by any of the measures described above (Fig. 1-2). Similarly, despite recent growth in crops, livestock, and aquaculture production, the Millennium Ecosystem Assessment (2005a) finds that these have come at the expense of declines in the status of most other provisioning, regulating, and cultural services of ecosystems.

[Insert Fig. 1.3] Adjusted net savings (World Bank, 2006c)]

1.3.3 Environment and natural resources

Natural resource issues.

Natural resources are the indispensable base for agriculture. Pressures on ecosystems have important consequences for agricultural production. In turn, agriculture has ecological impacts on ecosystems, and on the services provided by ecosystems. Both of these aspects - the wider ecosystem context and the direct impacts of agriculture on ecosystems - are discussed in this sub-chapter.

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 multi-purpose production objectives. Issues relating to NRM management are often framed as specific problems of soil degradation, water pollution, biodiversity loss, etc. We should however also take the opposite view and frame agriculture's contribution to NRM positively: farmers create and enhance resources such as arable soil, agrobiodiversity, productive forest stands, etc. 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, socio-political, science and technology, cultural and religious, and physical, biological and chemical drivers (see the IAASTD conceptual framework).

Definition of natural resources. No unanimously accepted definition of natural resources exists. Black (2003) defines natural resources 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". 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).

In these broader definitions, resources such as timber or fish are part of ecosystems that are living environments containing e.g. forests, rivers, wetlands, drylands on the one hand, and agroecosystems, embedded in the broader ecosystem and making use of selected resources of the ecosystem on the other hand (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 wellbeing through a range of interdependent regulating, supporting, provisioning and socio-cultural 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. 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. 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 only insufficiently understood. 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 whose 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 (forest, 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.

Agriculture depends on natural resources. 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 (MA, 2005c; Thrupp, 1998; Conway, 1997). Thus for instance, loss of biodiversity through simplification of habitats is a major concern. 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.

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 had an important role in contributing to the food security of a large portion of the world's food insecure. 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). According to Scherr et al. (2004) and Molnar et al. (2005), 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). Estimates have indicated that 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 forest land is one of the factors contributing to deforestation, though not the only one. FAO has defined deforestation as: 'The conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum 10% threshold.' A recent FAO report (FAO, 2006a) indicated that the rate of deforestation is proceeding at 13 million hectares per annum.

Recent estimates show that forests cover about 31% of global land surface (FAO, 2006a). 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%. 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 three-fourths of a hectare of forest and 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.

Grassland. 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, shrub lands, grasslands, semi-deserts, 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 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 nearly doubled since 1975, from 116 million metric tons to 233 million metric tons 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 five% 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 smallholders and the poor, and provide a source of direct employment for 38 million and indirect employment for about 160 million people (ICTSD, 2006; FAOb, 2004). The highest share of fish workers (fishermen and aquaculture workers) are in Asia (87%), followed by Africa (7%), Europe, North and Central America and South America (about 2% each) and Oceania (0.2%) (FAOb, 2004).

In 2002, total capture fisheries production amounted to 93.2 million tones. 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 tons with an average of 84 million tons. This is a slight increase over the preceding decade with an average of 77 million tons.

At the global level, inland capture fisheries have been increasing since 1984. In 1997, inland fisheries accounted for 7.7 million metric tons, 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 2000-02 inland capture fisheries were at around 8.7 million tons. 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 (FAOb, 2004).

Aquaculture, currently accounts for almost 50% of the world's food fish 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. Overall, Latin America and the Caribbean region had the highest average annual growth of 21.3%, followed by and the Near East, with 110.8% and North Africa and sub-Saharan Africa with 10.7%. 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 2002, about 76% (100.7 million tones) of estimated world fisheries production was used for direct human consumption. The remaining 24% (32.2 million tones) 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).

Freshwater aquaculture currently has a higher production than capture fisheries, contributing 17.7 million metric tons of fish and 'sea'food in 1997. In 1997, marine and inland aquaculture production provided 30% of the fish for human consumption; 60% of this production comprised of freshwater finfish or fish that migrate between fresh and saltwater. 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; FAOb, 2004).

A recent assessment of fish stocks by the FAO indicates that only 20% of fish species is moderately exploited and only three% is under-exploited. Of the remaining 76%, 52% of stocks is fully exploited, 17% is overexploited and seven% is depleted (FAOb, 2004).

[Insert Fig. 1.4. Global trends in the state of world marine stocks: 1974-2003 (FAO 2004b)]

Depletion of marine resources is so severe that even 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. Blue water refers to the water flowing or stored in rivers, lakes, reservoirs, ponds and aquifers (Rockström, 1999). Irrigated agriculture typically uses blue water. The concept of green water was introduced by Falkenmark (1995) and 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.

Technological advancements especially in the construction of dams have markedly increased the volume and availability of blue water for consumption and irrigation purposes. Similarly, advancement of pumping has 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). About 70% of the water is used by very inefficient irrigation systems, where only about half the water withdrawn reaches the plants.

On the other hand, half the world's wetlands are estimated to have been lost during the 20th century, as land was converted to agriculture and urban use, or filled to combat diseases, such as malaria. Yet these fresh water 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 degraded in almost all regions with intensive agriculture and other developments (Molden and de Fraiture, 2004). Pollution events are being documented more frequently in most inland water systems around the world while water-borne diseases from fecal contamination of surface waters continues to be a serious problem in developing countries.

There is no agriculture without water; the question just how much water agriculture needs, and will need in the future, is a key not only for sustainable food production, but for human welfare in general. 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.

Half of the world's 840 million malnourished people are smallholder farmers who depend on access to secure water supplies for food production, health, income and employment. Improving their access to clean water has potentially a tremendous impact on their livelihoods, and productive strategies. With scarcity and competing demands for water increasingly becoming evident, growing more food with less water is of high priority. There is large scope for better water productivity both in low producing rain-fed areas and in irrigated systems (CA, 2006). "Blue" water used in irrigation has a particularly important role, here, as 40% of global crop production is produced on irrigated soils (UNWWAP, 2003). In addition, irrigation often depends on dams that impact the environment in various ways such as 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).

Soil. 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. The condition of the soil resource 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 large differences in erodibility, i.e. their ability to resist soil erosion caused by water, wind, or ploughing. 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 is as much as water 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 developed world, the loss of productive agricultural soils to urban development is enormous. In addition, according to an estimate by the Global Assessment of 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).

While water and wind erosion are important causes of soil degradation, the direct influence of agricultural practices cannot be neglected: they account for about a quarter of total degradation (GACGC, 1994). AKST is - and always has been - crucial to address these problems both through more classical approaches - proposing mechanical protection such as bunds and terraces to control surface run-off - 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). Many 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. 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, 1997). The capacity of coastal and marine ecosystems to produce fish for human harvest is highly degraded by over-fishing, destructive trawling techniques, and loss of coastal nursery areas. This is exacerbated by the decline of mangroves, coastal wetlands, and sea-grasses 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 activities 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 major threat to biodiversity. In freshwater systems, an estimated 20% of fish species have become extinct (Wood et al., 2000). Intentional as well as non intentional introduction of alien species is another major problem (McNeely et al., 2001).

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 (high certainty). 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).

Agro+biodiversity is the very stuff of food production and an essential resource for modern plant and animal breeding. Yet it is a resource that is being lost *in situ*: in farms and agroecosystems (Thrupp, 1998; FAO, 1996b; 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, 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 co-evolution 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 bio-physical 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 CH4 (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 or 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 and 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, increasing the production of renewable energy are just a few options for reducing emissions (Wassmann and Vlek, 2004).

It is projected that climate change will increasingly influence future agricultural production. In all climate change scenarios, the effects of climate change on crop yields vary greatly from region to region. The main outputs of these models (Bazzaz and Soembroek, 1996) predict that a doubling of atmospheric CO2 is likely to cause a shift of agroecological zones because of temperature increase and changing water availability, an increase of crop yields and winter grazing in mid- and high-latitude regions, a decrease in crop productivity in most developing countries, and an increase in climate- and weather-related risks in tropical and subtropical regions.

Assuming that relative productive potentials of agriculture are likely to change in favor of developed countries, further scenarios were analyzed, for example to asses what the impact on markets in staple food crops may be. An FAO study concluded that net imports of cereals in developing countries might increase by 20 to 50% compared to trade in the reference scenario.

Climate change poses the question of risks for food security both globally and for marginal or vulnerable agroecological zones. 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 smallholders 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). Improving water using 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 tap, 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 developed 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 - soil and water in particular - emerged, a number of corrective measures were envisaged, in particular by relying on AKST systems.

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 better knowledge of pests and their predators among farmers - knowledge that could be used to reestablish pest - predator balances in rice agroecosystems, 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). AKST needs to shift towards the integrated and systemic analysis of natural resources and towards management regimes that respect to a greater extent the multifunctional base and effects of agricultural production. Such efforts can be informed by traditional knowledge systems, which as a rule have recognized the links between production and the larger ecosystem. While local knowledge forms are rarely equipped to respond to all the changes in contemporary agricultural systems, participatory research in AKST has clearly demonstrated its value for grounded and adapted solutions. Also needed is a balanced research agenda focusing as much on institutional aspects of resource management as it does on bio-physical parameters of the systems. As noted by Michael Cernea in a review of social research in CGIAR, 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 socio-cultural 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 heading 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 can benefit from research that deals with common property and common pool resources (Ostrom, 1990).

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, 1993b). This is a pertinent and comprehensive definition. Its impact, however, 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 inter-linkages 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 bio-physical with socio-cultural 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.

To be relevant, research on NRM has to be articulated both at the household and livelihood systems level, and at the level of regimes – or institutions – that govern natural resource use. At the international level, regimes for the management of biodiversity and climate for example have grown in complexity. Agriculture has an interest in both, as it is seen both as a driver of change and a (potential) provider of ecosystem services that contribute to conserving the resource (or mitigating the problem).

Agricultural policies have sustainability implications as they are linked to environmental and social outcomes. Where policies fail to recognize these links, environmental impacts can be severe. But policies can also address these impacts by taking corrective measures through AKST systems.

Gender issues, in particular the role of women. Gender is a key category for understanding agrarian societies, as anthropological and historical research has consistently shown (Boserup, 1965; McC Netting, 1993; Linares, 1985). 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 (exceptions confirming the rule).

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 male bias of agricultural extension systems: it is men who are usually considered to represent the state and its agencies, so men are talked to; and it is men who are considered to represent the community or farming household, so they are the ones addressed here, too. Second, as agricultural modernization 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 credits.

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).

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. That is, unless society develops institutions of governance, legal systems and social policy tools that tend to lessen disparities and equalize opportunities.

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) How successful these efforts are depends in large measure on the degree of political commitment that exists to 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 of a civil, political, economic, social or cultural nature, these rights are considered to be "universal, indivisible and interdependent and inter-related" (UN, 1993a).

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.

Sources of inequality. Agriculture is characterized by many inherent sources of inequality. Among them are climatic conditions and the natural endowments of the geophysical environment – the richness of the soil, the availability of water – that give one region a natural advantage over another. But most sources of inequality arise from the diverse ways that agricultural communities structure themselves, the productive systems they adopt; and the human relationships that these engender. Agricultural communities and their members vary greatly in terms of their vulnerability to external shock or their resilience, through traditions of mutual assistance or other forms of social solidarity.

Many observers note a dichotomy between smallholder agriculture and so-called modern 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 impact on prices. 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 smallholders 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 total 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 stakeholders 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.

One might also consider the principle of equal pay for work of equal value and how the form of employment can undermine this right in practice. The self-employed may derive both food and cash income from their work, but not a wage. Unpaid family members contribute to the earnings of the household, but may never receive cash for their efforts. Temporary or casual workers are wage-takers with little or no bargaining power. Contract laborers, and many migrant workers, are hired through intermediaries, such as gangmasters, and have few if any rights and no bargaining power. Hired laborers on small holdings often work for food, lodging and a small income disproportionate to the hours they work. Waged workers in large agricultural enterprises, particularly those covered by collective bargaining agreements, have regular earnings and some social benefits, although wage levels are often lower than those in other sectors.

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 life-long 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: 97) When adults are paid on a task-rate basis – i.e. per kilo of crop picked, row weeded, or hectare sprayed – and able bodied adults are unable to earn sufficient income to meet their families’ basic needs, there is a strong financial incentive for parents to bring their children to the fields, rather than to send them to school.

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 smallholders, 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. The social equity issues facing these groups must be addressed if broad-based agricultural development is to contribute positively to both economic growth and poverty reduction. The principal challenges are two-fold: 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. Closing the urban-rural poverty gap is both a goal and an instrument for achieving this.

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 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 the domestic market, 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 to a great extent on the country's overall economic profile, the specificities of its agricultural sector, the characteristics of particular rural communities and on 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. Productivity enhancement is not so much a technical issue, as one of political, economic and social choices and constraints.

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 a 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 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 wider than 30 percentage points, (World Bank, 2006a: 278-279) 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).

Much has been written in recent years regarding the feminization of agriculture. As men have migrated to urban areas to seek better livelihoods, smallholder farming has been gradually feminized, with a larger percentage of women acting as head of household in rural areas. Feminization does not represent an equalization of opportunities, but rather a further marginalization of smallholder 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. FAO has found, for example, that fewer than ten% of women farmers in India, Nepal and Thailand owned land and that credit schemes in five African countries awarded women less than 10% of the credit awarded to male smallholders. (FAO-Gender, 2007) In most countries, the portion 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 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, 2006) The challenge facing policy-makers 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 effective 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 against 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 all the time, to inform policy and to increase their own scientific understanding. Table 1.6 lists the different issues of each component of the IAASTD conceptual framework for which indicators were identified.

[Insert Table 1.6. Overview of issues addressed by indicators in the IAASTD framework]

In Annex 2, concrete indicators are proposed for each issue. The challenge was to identify indicators that clearly describe the relationship between agricultural science and technology on the one hand, and sustainable development on the other, according to the various aspects described in the framework.

As indicators are used for various purposes, it is necessary to define general criteria for selecting indicators and validating their choice. Among the criteria are relevance, reliability, and feasibility.

On a methodological level, an assessment is not a review of the literature; it can be derived from a literature review, but also needs to provide an assessment of the veracity of the information and the uncertainty of the outcomes within the context of the identified questions or issues within a specified authorizing environment. To be effective and acceptable, the assessment process needs to be open, transparent, reviewed, and widely representative of stakeholders and relevant experts.

Further methodological elements are the handling of units of analysis, dealing with bio-physical and human systems as the context of agricultural practice, temporal and spatial scales of assessments from global to regional, the issue of values and valuation, dealing with uncertainty, dealing with different knowledge systems, as well as modeling issues and developing scenarios.

1.4.2 Dealing with indicators

What are indicators for? Indicators are used both for specialist purposes and in everyday life. In specialist usages 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 meaningful for effective action. In this everyday sense, they can be accurate and powerful, as Gigerenzer et al. (1999) demonstrate, 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. The IAASTD uses these scenarios as well as a selected set of available indicators. However, it also calls for the identification of more focused indicators in future.

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 further 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 re-estimation of achievement and re-definition 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. 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.

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 unsustainability 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 Millennium Development Goals (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. In Annex 2, concrete indicators are proposed for each of the different components of the conceptual framework, grouped according to the issues listed in Table 1.6.

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 uses 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 wellbeing, 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 socio-economic 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. According to Hardi and Zdan (1997) or Prescott-Allen (2001) good indicators are 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 be not 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 globe level. 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.
Units of analysis disaggregated by gender, ethnic group, age, etc. will provide a more thorough AKST analysis, and lead to recommendations appropriate to achieving MDGs. It is important to understand how issues of gender and diversity (ethnic group, age group, social group, discipline, etc.) influence AKST, and likewise how AKST systems influence diverse groups in different manners. The IAASTD explicitly includes analysis of gender and diversity.

Dealing with systems. The IAASTD basically deals with two different sets of systems, a bio-physical and a socio-economic set. These are introduced as contexts in the conceptual framework in sub-chapter 1.2.

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 for effective use by agricultural production systems that used to define themselves according to economic criteria of efficiency, thus severing the link to the broader 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 smallholders 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 bio-physical and socio-economic systems. A minority of agricultural workers live on larger production units and in developed 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 de-capitalization of smallholders). 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 be less catastrophic. Most of the analysis in the IAASTD is carried out at national and regional level, 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, 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. Where these values are at work, they should be explicitly stated. 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 uncertainty. This paragraph is based on input from Gitay (2005) for the Comprehensive Assessment of Water Management in Agriculture (CA, 2006). Given the need for synthesis and judgments on the veracity and uncertainty of evidence, uncertainty has to be clearly labeled and the uncertainty associated with the conclusions and outcomes of the assessment must be stated. This can be done quantitatively or qualitatively. In the IPCC assessment that deals with the physical system and is based on running models of the coupled atmosphere-ocean systems, a quantitative scale with probabilistic outcomes is used. However in an assessment such as the IAASTD, the qualitative scale is considered to be more useful. It is based on the qualitative scheme for judging uncertainty and was developed for the Intergovernmental Panel on Climate Change (Moss and Schneider, 2000) and subsequently used in the Millennium Ecosystem Assessment.

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 grey 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 wellbeing 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.

References

Alcamo, J. 2001. Scenarios as tools for international assessments. Prospects and Scenarios No. 5. European Environment Agency, Copenhagen.

Basu, K. 1986. The market for land: An analysis for interim transactions. J. Dev. Econ. 20(1):163-177.

Bathia, A., H. Pathak, and P.K. Aggarwal. 2004. Inventory of methane and nitrous oxide emissions from agricultural soils of India and their global warming potential. Curr. Sci. 87(3):317-324.

Baumert, K.A., T. Herzog, and J. Pershing. 2005. Navigating the numbers. Greenhouse gas data and international climate policy. World Resources Institute, Washington DC.

Bazzaz, F., and W. Sombroek (ed) 1996. Global climate change and agricultural production. Direct and indirect effects of changing hydrological, pedological and plant physiological processes. Food and Agriculture Organization of the United Nations and John Wiley & Sons, Rome and Chichester, New York, Brisbane, Toronto, and Singapore.

BFS. 2006. Statistical data on Farming and Forestry. (In German or French). [Online]. Available at http://www.bfs.admin.ch/bfs/portal/de/index/themen/07.html (accessed 23 Jan 2007; verified 25 Feb 2007). Swiss Federal Statistical Office, Neuchâtel.

Black, J. 2003. A Dictionary of Economics [Online]. http://www.oxfordreference.com/views/ENTRY.html?entry=t19.e2083&srn=2&ssid=205945865#FIRSTHIT (accessed 15 May 2006, verified 20 July 2006). Oxford Reference Online, Oxford University Press, Oxford UK.

Blaikie, P. and H. Brookfield. 1987. Land degradation and society. Methuen, London and New York.

Blaikie P., K. Brown, M. Stocking, L. Tang, P. Dixon, and P. Sillitoe. 1997. Knowledge in action: Local knowledge as a development resource and barriers to its incorporation in natural resource research and development. Agric. Syst. 55:217-237.

Bonfiglioli, A. 2004. Land of the poor. Local environmental governance and the decentralized management of natural resources. United Nations Capital Development Fund, New York.

Boserup, E. 1965. The conditions of agricultural growth: The economics of agrarian change under population pressure. George Allen & Unwin, London.

Brookfield H., H. Parsons, and M. Brookfield (ed) 2003: Agrodiversity, Learning from Farmers across the World. The United Nations University Press, Tokyo.

Burke, L., Y. Kura, K. Kassem, M. Spalding, C. Revenga, and D. McAllister. 2001. Pilot analysis of global ecosystems: Coastal ecosystems. World Resources Institute, Washington DC.

Byerlee, D., and G. Alex. 2003. Designing investments in agricultural research for enhanced poverty impacts. Agriculture and Rural Development Working Paper No. 6. The World Bank, Washington DC.

CA. 2006. Comprehensive Assessment of Water Management in Agriculture [Online]. http://www.iwmi.cgiar.org/assessment/ (accessed 19 April; verified 20 July and 25 Feb 2007). Comprehensive Assessment Secretariat, Colombo.

Cassman, K.G., A. Dobermann, D.T. Walters, and H. Yang. 2003. Meeting cereal demand while protecting natural resources and improving environmental quality. Annu. Rev. Environ. Resour. 28:315-358.

Caulfield, L.E., M. de Onis, M. Blössner, and R.E. Black. 2004. Undernutrition as an underlying cause of child deaths associated with diarrhea, pneumonia, malaria and measles. Am. J. Clin. Nutr. 80:193-8.

CBD. 2006. Global Biodiversity Outlook 2. Convention on Biological Diversity, Montreal.

CDE. 2002. NRM - Natural Resource Management [Online]. http://www.cde.unibe.ch/Themes/NRM_Th.asp (accessed 16. May 2006; verified 20 July 2006). Centre for Development and Environment, Berne.

Cernea, M. 2005. Studying the culture of agriculture: The uphill battle for social research in CGIAR. Cult. Agric. 27(2):73-87.

CGIAR 2005. CGIAR Systemwide Program on Participatory Research and Gender Analysis [Online]. Available at http://www.prgaprogram.org/ (accessed 16 May 2006; verified 20 July 2006). CGIAR, Rome.

CGIAR Science Council. 2005. Science for agricultural development. Changing contexts, new opportunities. Science Council Secretariat, Rome.

Chambers, R. and G. Conway. 1991. Sustainable rural livelihoods: practical concepts for the 21st century. IDS Discussion Paper 296. Institute of Development Studies, Brighton.

CIFOR. 2006. Earning a living from the forest [Online]. Available at http://www.cifor.cgiar.org/Publications/Corporate/FactSheet/livelihood.htm (accessed 23 February 2007). Center for International Forestry Research, Bogor Barat.

COAG. 2005. The globalizing livestock sector: Impact of changing markets. Committee on Agriculture, Food and Agriculture Organization of the United Nations, Rome.

Colfer, C.J.P. 2005. The Complex Forest: Communities, Uncertainties, and Adaptive Collaborative Management. RFF Press, Washington DC.

Commoner, B. 1990. Making Peace With the Planet. Pantheon, New York.

Conway, G. 1997. The doubly Green Revolution: Food for all in the 21st century. Cornell University Press, Ithaca.

Crawford, D. 2005. Managing and reporting sustainability [Online]. Available at http://www.managementmag.com/index.cfm/ci_id/2167/la_id/1.htm (Accessed 23

February 2007). Certified Management Accountants (CMA) Management, Mississauga.

Delgado, C.L., N. Nikolas, M.W. Rosegrant, S. Meijer, and A. Mahfuzuddin. 2003. Fish to 2020. Supply and demand in changing global markets. International Food Policy Research Institute and WorldFish Center, Washington DC and Penang.

DeRose, L., E. Messer, and S. Millman. 1998. Who’s hungry and how do we know? Food shortage, poverty and deprivation. United Nations University Press, Tokyo.

DFID. 2001. Sustainable livelihoods guidance sheets. Section 8, Glossary. Department for International Development, London.

Dixon, J., A. Gulliver, and D. Gibbon. 2001. Farming systems and poverty: Improving farmers’ livelihoods in a changing world. Food and Agriculture Organization of the United Nations and World Bank, Rome and Washington DC.

Dolberg, F. 2001. A livestock development approach that contributes to poverty alleviation and widespread improvement of nutrition among the poor. LRRD 13(5).

Dörner, D. 1996. The logic of failure. Recognising and avoiding error in complex situations. A Merloyd Lawrence book. Metropolitan Books, New York.

Dove, M. R., and D.M. Kammen. 1997. The epistemology of sustainable resource use: Managing forest products, swiddens, and high-yielding variety crops. Human Organ. 56:91-101.

Eastwood, R., M. Lipton, and A. Newell. 2006 (forthcoming). Farm size. In Evenson, R. and P. Pingali (ed) Handbook of agricultural economics. Vol. III. North Holland, Amsterdam.

Edmeades, G.O., J. Bolanos, S.C. Chapman, H.R. Lafitte, and M. Bänziger. 1999. Selection improves drought tolerance in tropical maize populations. Crop Sci. 39(5):1306–1315.

Engel, P.G.H. 1997. The social organization of innovation: A focus on stakeholder interaction. Royal Tropical Institute KIT Press, Amsterdam.

Ericksen, P.J. 2006. Conceptualizing food systems for global environmental change (GEC) research. GECAFS Working Paper 2. Global Environmental Change and Food Systems, Environmental Change Institute, Oxford University Centre for the Environment, Oxford.

Ericksen, P.J. forthcoming. What is the vulnerability of a food system to global environmental change (GEC)? Submitted to Ecology and Society.

Evenson, R.E., and D. Gollin. 2003. Assessing the impact of the Green Revolution: 1990-2000. Science 300:758-762.

Falkenmark, M. 1995. Coping with water scarcity under rapid population growth. SADC Ministers Conf., Pretoria, 23-24 Nov 1995.

Fan, S., L. Zhang, and X. Zhang. 2002. Growth, inequality, and poverty in rural China: The role of public investments. Research Report No. 125. International Food Policy Research Institute, Washington DC.

Fan, S., P. Hazell, and S. Thorat. 1999. Linkages between government spending, growth, and poverty reduction in rural India. Research Report No. 110. International Food Policy Research Institute, Washington DC.

FAO. 1996a. Control of water pollution from agriculture - FAO irrigation and drainage paper 55. Rome: Food and Agriculture Organization of the United Nations.

FAO. 1996b. Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture. [Online]. Available at http://www.fao.org/ag/AGP/AGPS/GpaEN/gpatoc.htm (accessed 12 June 2006; verified 20 July 2006).Food and Agriculture Organization of the United Nations, Rome.

FAO. 2000. The State of Food and Agriculture: lessons from the past 50 years. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2003. Report of the Panel of Eminent Experts on Ethics in Food and Agriculture, Second Session, 18-20 March 2002. Rome: Food and Agriculture Organization of the United Nations.

FAO. 2004a. The State of Food and Agriculture 2003 – 2003. Agricultural Biotechnology. Meeting the needs of the poor?. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2004b. The state of world fisheries and aquaculture. Food and Agriculture Organization of the United Nations.

FAO. 2005. Global Forest Resource Assessment 2005. Progress towards sustainable forest management. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2006a. Global Forest Resources Assessment 2005. Progress towards sustainable forest management. FAO Forestry Paper 147. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2006b. Glossary of the Food and Agriculture Organization of the United Nations [Online]. http://www.fao.org/glossary/ (accessed 15 May 2006; verified 20 July 2006). Food and Agriculture Organization of the United Nations, Rome.

FAO. 2006c. State of world aquaculture 2006. FAO Fisheries Technical Paper 500. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2006d. Statistical Annex 2003. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2006e. The State of Food and Agriculture. Part II World and regional review: facts and figures. Food and Agriculture Organization of the United Nations, Rome.

FAO-CDP. 2007. FAO Corporate document repository. Fact sheet Egypt and Fact sheet Benin [online] Available at www.fao.org/docrep/V9648e/v9648e01.htm and www.fao.org/docrep/V7948e/v7948e.02.htm (accessed 25 Feb. 2007). Food and Agriculture Organization of the United Nations, Rome.

FAO-Gender. 2007. FAO Gender and food security in agriculture. [online] Available at www.fao.org/GENDER7en/agrib4-e.htm (accessed 25 Feb. 2007). Food and Agriculture Organization of the United Nations, Rome.

FAOSTAT. 2006. FAO Statistical Databases of the Food and Agriculture Organization of the United Nations [Online]. Available at http://faostat.fao.org/ (Accessed 10 June 2006, verified 20 July 2006). Food and Agriculture Organization of the United Nations, Rome.

Farrington, J., I. Christoplos, A.D. Kidd, and M. Beckman. 2002. Extension, poverty and vulnerability. The scope for policy reform. Final report of a study for the Neuchâtel Initiative. Overseas Development Institute, London.

GACGC. 1994. World in transition: The threat to soils. Annual report. German Advisory Council on Global Change, Bonn.

García, Z. 2005. Impact of Agricultural Trade on Gender Equity and Rural Women's Position in Developing Countries. Food and Agriculture Organization of the United Nations, Rome.

Gaventa, J. 1998. The scaling up and institutionalization of PRA: Lessons and challenges. p. 153-166. *In* Blackburn, P., and J. Holland (ed) Who changes? Institutionalising participation in development. Intermediate Technology, London.

Gibbons, M., C. Limoges, H. Nowotny, S. Schwartzman, P. Scott, and M. Trow. 1994. The new production of knowledge. Sage Publications, London.

Gigerenzer, G., P.M. Todd, and the ABC Research Group. 1999. Simple heuristics that make us smart. Oxford University Press, Oxford.

Gitay, H. 2005. Assessment process for Comprehensive Assessment of Water Management in Agriculture. Ecosystem chapter. Meeting of the working group on water pricing in agriculture, 3-4 June, Montpellier [Online]. Available at http://www.iwmi.cgiar.org/assessment/files/montpellier%20assessment%20process%203.1.ppt (accessed 20 April 2006; verified 20 July 2006). Comprehensive Assessment Secretariat, Colombo.

Global Monitoring Report. 2006. Millennium Development Goals: Strengthening Mutual Accountability, Aid, Trade, and Governance. The International Bank for Reconstruction and Development, The World Bank, Washington DC.

Glowka, L., F. Burhenne-Guilmin, and H. Synge in collaboration with J.A. McNeely, and L. Gündling. 1994. A guide to the Convention on Biological Diversity. Environmental Policy and Law Paper No. 30. The World Conservation Union, Gland and Cambridge.

Graham, T., E. van de Fliert, and D. Campilan. 2001. What happened to participatory research at the International Potato Center? Agric. Human Values 18:429-446.

Grainger, R.J.R., and S.M. Garcia. 1996. Chronicles of marine fishery landings (1950-94): Trend analysis and fisheries potential. FAO Fisheries Technical Paper No. 359. Food and Agriculture Organization of the United Nations, Rome.

Haggblade, S., P. Hazell, I. Kirsten, and R. Mkandawire. 2004. African agriculture: Past performance, future imperatives. *In* Haggblade S. (ed) Building on successes in African agriculture. 2020 Focus No 12. International Food Policy Research Institute, Washington DC.

Hardi, P., and T. Zdan (ed) 1997. Assessing sustainable development: Principles in practice. International Institute for Sustainable Development, Winnipeg.

Hazell, P. 1999. Agricultural growth, poverty alleviation, and environmental sustainability: havint it all. IFPRI 2020 Brief No. 59, March 1999. International Food Policy Research Institute, Washington DC.

Hemmati, M. and R. Gardiner. 2001. Gender Equity and Sustainable Development. Social Briefing No. 2. Towards Earth Summit 2002. United Nations Environment and Development Forum, Johannesburg.

Heymann, D.L. 2002. Food safety, an essential public health priority: Marrakesh, Morocco *In* FAO/WHO Global forum of Food Safety Regulators: 2002, Marrakesh, Morocco, FAO. cited *In* Hodges, J.R. and A.M. Kimball. 2005. The global diet: trade and novel infections. Glob. Health 1:4:1-7.

Hirsch Hadorn, G., D. Bradley, Ch. Pohl, S. Rist,. and U. Wiesmann. 2006. Implications of transdisciplinarity for sustainability research. Ecol. Econ. 60(1):119-128.

Horiuchi, S. 1999. Epidemiological transitions in developed countries: Past, present and future. p. 54-71. *In* Chamie, J., and R. Cliquet (ed) Health and mortality. issues of global concern. Proceedings of the Symposium on Health and Mortality, Brussels, Belgium. 19-22 November 1997. Population Division, Department of Economic and Social Affairs, United Nations Secretariat and Population and Family Study Centre (CBGS), Flemish Scientific Institute, New York and Leuven.

Hurni, H. and U. Wiesmann. 2004. Towards transdisciplinarity in sustainability-oriented research for development. p. 31-42. *In* Hurni, H., U. Wiesmann, and R. Schertenleib (ed). Research for mitigating syndromes of global change. Perspectives of the Swiss NCCR North-South, Vol.1, University of Berne, Geographica Bernensia, Berne.

Hurni, H. with the assistance of an international group of contributors. 1996. Precious earth. From soil and water conservation to sustainable land management. International Soil Conservation Organisation and Centre for Development and Environment, Wageningen and Berne.

Hurni, H., U. Christ, J.A. Lys, D. Maselli, and U. Wiesmann. 2001. The challenges in enhancing research capacity. p. 50-58. *In* KFPE. Enhancing research capacity in developing and transition countries. Experience, discussions, strategies and tools for building research capacity and strengthening institutions in view of promoting research for sustainable development. Geographica Bernensia, Berne.

IAC (InterAcademy Council). 2004. Realizing the promise and potential of African agriculture. Science and technology strategies for improving agricultural productivity and food security in Africa. InterAcademy Secretariat, Amsterdam.

ICRAF. 1997. Annual Report 1996. International Center for Research in Agroforestry, Nairobi.

ICSU. 2003. Optimizing knowledge in the information society. International Council for Science, Paris.

ICTSD. 2006. Fisheries, Inernational Trade and Sustainable Development. Policy Discussion Paper. International Centre for Trade and Sustainable Development, Geneva.

IFAD. 1998. Ghana – Women's contribution to household food security [Online]. Available at http://www.ifad.org/hfs/learning/46.htm (accessed 24 April 2006; verified 20 July 2006). International Fund for Agricultural Development, Rome.

ILO. 1962. Convention concerning Basic Aims and Standards of Social Policy. Convention No. 117. International Labour Organisation, Geneva.

ILO. 1999. Safety and health in agriculture, International Labour Conference, 88th Session, Geneva, 2000, Report VI (1), International Labour Organization, Geneva.

ILO. 2000. Occupational Safety and Health in Agriculture [Online]. Available at http://www.ilo.org/public/english/protection/safework/agriculture/intro.htm (accessed 15 Jan. 2007; verified 25 Feb. 2007). International Labour Organization, Geneva

ILO. 2005. HIV/AIDS and employment. ILOAIDS brief, September. International Labour Organization on HIV/AIDS and the World of Work, Geneva.

ILO. 2006. The End of Child Labour within Reach. International Labour Conference, 95th Session, 2006, Report 1(B). International Labour Organization, Geneva.

IUCN. 2005. Healthy corals fared best against tsunami. Press release [Online] Available at http://www.iucn.org/en/news/archive/2005/12/cordio_iucn_report_2005.pdf (accessed 5 June 2006, verified 20 July 2006). The World Conservation Union, Gland.

Johnson, I. 2005. Science in the service of poor farmers: The CGIAR-JIRCAS partnership. Tropical Agriculture Association Newsletter 25:25-27.

Kent, G. 2003. Principles for Food Trade. SCN News (26):43-44.

Klaey, A. 2000. The Kyoto Protocol and the carbon debate. A plea for an international policy on sustainable management of renewable natural resources. Centre for Development and Environment, Berne.

Krueger, A.O., Schiff, M. and A. Valdes (ed). 1991. The Political Economy of Agricultural Pricing Policy. A World Bank Comparative Study. Johns Hopkins University Press for the World Bank, Baltimore and London.

Kurien, J. 2006. Achieving a sustainable global fish trade. id21 insights 65:4.

Lambrou, Y. and G. Piana. 2006. Energy and Gender Issues in Rural Sustainable Development. Food and Agriculture Organization of the United Nations, Rome.

Leakey, R.R.B. 2001. Win:Win landuse strategies for Africa: 1. Building on experience elsewhere and capitalizing on the value of indigenous tree products, Int. For. Rev. 3:1-10.

Leakey, R.R.B., and P.A. Sanchez. 1997. How many people use agroforestry products? Agrofor. Today 9:4-5.

Lilja, N., J.A. Ashby, and L. Sperling (ed) 2000. Proceedings of the seminar on Assessing the Impact of Participatory Research and Gender Analysis, September 1998, Quito, Ecuador. Program on Participatory Research and Gender Analysis, Consultative Group on International Agricultural Research, Cali.

Liniger, H.P., and W. Critchley. 2007. Where the land is greener. Case studies and analysis of soil and water conservation initiatives worldwide. Centre for Development and Environment, Berne.

LivestockNet. 2006. Livestock Production and the Millennium Development Goals. The role of livestock for pro-poor growth. LivestockNet, InfoAgrar, Swiss College of Agriculture, Zollikofen.

Lund, H.G. and S. Iremonger. 1998. Omissions, commissions, and decisions – The need for integrated resource assessments. p. 182-189. *In* Environmental Research Institute of Michigan (ERIM) (ed) Proc. Int. Conf. Geospatial Information in Agriculture and Forestry. Decision Support, Technology and Applications,1st, Lake Buena Vista, Florida, 1-3 June. 1998. ERIM International Inc., Ann Arbor, Michigan.

MA (Millennium Ecosystem Assessment). 2003. Ecosystems and human well-being: A framework for assessment. Island Press, Washington DC.

MA (Millennium Ecosystem Assessment). 2005a. Ecosystems and human well-being: Synthesis. Island Press, Washington DC.

MA (Millennium Ecosystem Assessment). 2005b. Our human planet: Summary for decision-makers. Island Press, Washington DC

MA (Millennium Ecosystem Assessment). 2005c. Ecosystems and human well-being: Current states and trends. Volume 1. Island Press, Washington DC

Matthews, E., R. Payne, M. Rohweder, and S. Murray. 2000. Pilot analysis of global ecosystems: Forest ecosystems. World Resources Institute, Washington DC.

Maxwell, D., and K. Wiebe. 1999. Land tenure and food security: Exploring dynamic linkages. Development and Change 30:825-849.

Mazoyer, M., and L. Roudard. 1997. History of the world's agriculture. (In French). Editions du Seuil, Paris.

McC Netting, R. 1993. Smallholders, householders: Farm families and the ecology of intensive, sustainable agriculture. Stanford University Press, Stanford. Linares, 1985

McCalla, A. and C. de Haan. 1998. An international trade perspective on livestock and the environment. p. 13-20. *In* Proc. intl. conf. on livestock and the environment. 16-20 June 1997. Intl. Ag. Centre, Wageningen, the Netherlands. COAG, 2005

McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken, and K.S. White (ed) 2001. Climate change 2001 – Impacts, adaptation and vulnerability. Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

McNeely, J.A., H.A. Mooney, L.E. Neville, P.J. Schei, and J.K. Waage (ed) 2001. Global strategy on invasive alien species. The World Conservation Union in collaboration with the Global Invasive Species Programme, Cambridge, UK.

Meadows, D.H., D.L. Meadows, J. Randers, and W. Behrens. 1972. The limits to growth. Universe Books, New York.

Messer, E., and L.F DeRose. 1998. Food shortage. p. 53-91. *In* DeRose, L. E. Messer, and S. Millman (ed) Who's hungry and how do we know? Food shortage, poverty and deprivation. United Nations University Press, Tokyo.

Molden, D. 2003. Pathways to Improving the Productivity of Water. *In* Jinendradasa, S.S. (ed) Issues of Water Management in Agriculture: Compilation of Essays. Comprehensive Assessment of Water Management in Agriculture, Colombo:1-6.

Molden, D., and C. de Fraiture. 2004. Investing in water for food, ecosystems and livelihoods. Blue paper discussion draft. Comprehensive Assessment of Water Management in Agriculture, Colombo.

Molnar, A., S.J. Scherr, and A. Khare. 2005. Who conserves the world's forests? A new assessment of conservation and investment trends. Forest Trends and Ecoagriculture Partners, Washington DC.

Morisset J., 1997. Unfair Trade? Empirical Evidence in World Commodity Markets Over the Past 25 Years. Policy Working Paper 1815. The World Bank, Washington DC.

Moss, R.H., and S.H. Schneider. 2000. Uncertainties in the IPCC TAR: Recommendations to lead authors for more consistent assessment and reporting. p. 33-51. *In* Pachauri, R., T. Taniguchi, and K. Tanaka (ed) Guidance papers on the cross-cutting issues of the third assessment report of the IPCC. World Meteorological Organization, Geneva.

Müller, C. 2006. Synthesis and conclusion. p. 331-352. *In* Premchander, S., and C. Müller (ed) Gender and sustainable development: Case studies from NCCR North-South. Perspectives of the Swiss National Centre of Competence in Research (NCCR) North-South, University of Bern, Vol.2. Geographica Bernensia, Berne.

Nagayets, O. 2005. Small farms: Current status and key trends. Information brief. Prepared for the Future of Small Farms Research Workshop, Wye, UK. 26-29 June. International Food and Policy Research Institute, Washington DC.

Nazarea, V. D. (ed) 1999. Ethnoecology: Situated knowledge/located lives. The University of Arizona Press, Tucson.

Nowotny, H., P. Scott, and M.Gibbons. 2003. “Mode 2” revisited: The new production of knowledge. Minerva 41:179-194.

OECD. 1998. Reaching the goals in the S-21: Gender equality and the Environment. Working Party on Gender Equality, OECD-DAC. Organisation for Economic Co-operation and Development, Paris.

OECD. 2005. Multifunctionality in agriculture: What role for private initiatives? Organisation for Economic Co-operation and Development, Paris.

Oldeman, L.R. 1994. The global extent of soil degradation. p. 99-118. *In* Greenland, D.J. and I. Szabolcs (ed) Soil resilience and sustainable land use. CAB International, Wallingford.

Oldeman, L.R., R.T.A. Hakkeling, and W.G. Sombroek. 1990. World map of the status of human-induced soil degradation: An explanatory note. International Soil Reference and Information Centre and United Nations Environment Programme, Wageningen and Nairobi.

Olesen, I., A.F. Groen, and B. Gjerde. 2000. Definition of animal breeding goals for sustainable production systems. J. Anim. Sci. 78:570-582.

Olson, D.M., and E. Dinerstein. 1998. The global 200: A representation approach to conserving the earth’s most biologically valuable ecoregions. Conserv. Biol. 12(3):502–515.

Ostrom, E. 1990. Governing the commons: The evolution of institutions for collective action. Cambridge University Press, Cambridge.

Pahl-Wostl, C., and M. Hare. 2004. Processes of social learning in integrated resources management. J. Community Appl. Soc. Psychol. 14:193-206.

Pardey, P.G., and N. Beintema. 2001. Slow magic. Agricultural R&D a century after Mendel. International Food Policy Research Institute, Washington DC.

Penning de Vries, F.W.T., H. Acquay, D. Molden, S. J. Scherr, C. Valentin, and O. Cofie. 2003. Integrated land and water management for food and environmental security. Comprehensive Assessment of Water Management in Agriculture Research Report 1. Comprehensive Assessment Secretariat, Colombo.

Postel, S. 1999. Pillar of sand: Can the irrigation miracle last? Worldwatch and W.W. Norton, New York and London.

Prescott-Allen, R. 2001. The wellbeing of nations: A country by country index of quality of life and the environment. Island Press, Washington DC.

Raitzer, D. 2003. Benefit-cost meta-analysis of investment in the International Agricultural Research Centres of the CGIAR. Science Council Secretariat. Rome.

Reardon, T., Berdegué, J. and J. Farrington. 2002. Supermarkets and farming in Latin America: pointing directions for elsewhere?. Perspectives 81 (December). Department for International Development, London.

Reardon, T., Codron, J.-M., Busch, L., Bingen, J. and C. Harris. 2001. Global Change in Agrifood Grades and Standards: Agribusiness Strategic Responses in Developing Countries. Int. Food Agrib. Manage. Rev. 2(3).

Reardon, T., Timmer, C.P., Barrett, C.B. and J. Berdegué. 2003. The Rise of Supermarkets in Africa, Asia, and Latin America. Am. J. Agric. Econ. 85(5):1140-1146.

Revenga, C., J. Brunner, N. Henninger, K. Kassem, and R. Payne. 2000. Pilot analysis of global ecosystems: Freshwater systems. World Resources Institute, Washington DC.

Rice, A.L., L. Sacco, A. Hyder, and R.E. Black. 2000. Malnutrition as an underlying cause of childhood deaths associated with infectious diseases in developing countries. Bulletin of the World Health Organization 78(10):1207-1221.

Rist, S., and F. Dahdouh-Guebas. 2006. Ethnosciences - A step towards the integration of scientific and non-scientific forms of knowledge in the management of natural resources for the future. Environ. Dev. Sust. 8(4):467-493.

Rist, S., F. Delgado, and U. Wiesmann. 2003. The role of social learning processes in the emergence and development of Aymara land use systems. Mt. Res. Dev. 23:263-270.

Rist, S., M. Chiddambaranathan, C. Escobar, U. Wiesmann, and A. Zimmermann. 2006. Moving from sustainable management to sustainable governance of natural resources: The role of social learning processes in rural India, Bolivia and Mali. J. Rural Stud. 23(1):23-37.

Rockström, J. 1999. On-farm green water estimates as a tool for increased food production in water scarce regions. Phys. Chem. Earth (b), 24 (4):375-383.

Röling, N., and A. Wagemakers (ed) 2000. Facilitating sustainable agriculture. Participatory learning and adaptive management in times of environmental uncertainty. Cambridge University Press, New York.

Röling, N., and Van de Fliert, E. 1994. Transforming extension for sustainable agriculture: The case of integrated pest management in rice in Indonesia. Agric. Human Values 11 (2, 3):96-108.

Sanders, D.W., P.C. Huszar, S. Sombatpanit, and T. Enters. 1999. Incentives in soil conservation. Science Publishers, Inc., Enfield, New Hampshire.

Savenije, H.H.G. and P. van der Zaag. 2000. Conceptual framework fort he management of shared river basins; with special reference to the SADC and EU. Water Policy 2:9-45.

Scherr, S., A. White, and A. Khare, with contributions from M. Inbar, and A. Molnar. 2004. For services rendered: The current status and future potential of markets for the ecosystem services provided by forests. ITTO Technical Series No. 21. International Tropical Timber Organization, Yokohama.

Scherr, S., A. White, and A. Khare, with contributions from M. Inbar, and A. Molnar. 2004. For services rendered: The current status and future potential of markets for the ecosystem services provided by forests. ITTO Technical Series No. 21. International Tropical Timber Organization, Yokohama.

Scherr, S.J. 1999. Soil degradation: A threat to developing-country food security? 2020 Vision Food, Agriculture, and the Environment Discussion Paper No. 27. International Food Policy Research Institute, Washington DC.

Schroeder, D.G., and K.H. Brown. 1994. Nutritional status as a predictor of child survival: summarizing the association and quantifying its global impact. Bulletin of the World Health Organization. 72(4):569-79.

Scoones, I., and J. Thompson. 1994. Knowledge, power and agriculture - Towards a theoretical understanding. p. 16-31. *In* Scoones, I. and J. Thompson (ed) Beyond farmers first - Rural people's knowledge, Agricultural research and extension practice. Intermediate Technology Publications, International Institute for Environment and Development, London.

Seale, Jr., J., A. Regmi and J. Bernsteing: 2003. International evidence on food consumption patterns [Online]. Technical Bulletin no.1904. Available at www.ers.usda.gov/publications/tb1904. (accessed 10 February 2007; verified 26 February 2007). Economic Research Service, United States Department of Agriculture, Washington DC.

Sen, A. 1981. Poverty and famines: An essay on entitlement and deprivation. Clarendon Press, Oxford.

Sen, A. and J. Drèze (ed). 1990, 1991. The Political Economy of Hunger, in 3 volumes. Clarendon Press, Oxford.

Serageldin, I. 1996. Sustainability and the Wealth of Nations: First Steps in an Ongoing Journey. Environmentally Sustainable Development Studies and Monographs Series No. 5. The World Bank, Washington DC.

Shaxson, T.F., N.W. Hudson, D.W. Sanders, E. Roose, and W.C. Moldenhauer. 1989. Land husbandry: A framework for soil and water conservation. Soil and Water Conservation Society, Ankeny, Iowa.

Sheridan, C. 2005. EPO neem patent revocation revives biopiracy debate. Nature Biotechnol. 23:511 – 512.

Simons, A.J. and Leakey, R.R.B. 2004. Tree domestication in tropical agroforestry. Agrofor. Syst. 61(1):167-181.

Smakhtin, V., C. Revenga, and P. Döll. 2004. Taking into account environmental water requirements in global-scale water resources assessments. Comprehensive

Assessment Research Report 2. Comprehensive Assessment Secretariat, Colombo, Sri Lanka.

Smit, B. (ed) 1993. Adaptation to climatic variability and change: Report of the Task Force on Climate Adaptation. Canadian Climate Program, University of Guelph, Ontario.

Spencer, D. 2002. The future of agriculture in Sub-Saharan Africa and South Asia: W(h)ither the small farm? *In* Sustainable food security for all by 2020. Proceedings of an International Conference, September 4–6, 2001, Bonn, Germany. International Food Policy Research Institute, Washington DC.

Spencer, D.S.C., P.J. Matlon, and H. Löffler. 2003. African agricultural production and productivity in perspective. InterAcademy Council, Amsterdam.

Steinfeld, H., P. Gerber, T. Wassenaar, M. Rosales and C. de Haan. 2006. Livestock's long shadow: environmental issues and options. Livestock, Environment and Development, Virtual Research and Development Centre and Food and Agriculture Organization of the United Nations, Rome.

Steyl, I., Verfeld, D.B. and P.J. Nelson. 2000. Strategic Environmental Assessment for Water Use. Mhlatuze Catchment-Kwa-Zulu Natal. Department of Water Affairs, Pretoria.

Thirtle, C., L. Lin, and J. Piesse. 2003. The impact of research-led agricultural productivity growth on poverty reduction in Africa, Asia and Latin America. World Dev. 31 (12):1959-1975.

Thrupp, L.A. 1998. Cultivating diversity: Agrobiodiversity and food security. World Resources Institute, Washington DC.

Tilman, D. 1999. Global environmental impacts of agricultural expansion: The need for sustainable and efficient practices. Proceeding of the National Academy of Sciences of the United States of America 96:5995-6000.

Trawick P. 2003. Against the privatization of water: An indigenous model for improving existing laws and successfully governing the commons. World Dev. 31:977-996.

UN Millennium Project. 2005. Innovation: Applying knowledge in development. Task Force 10 on Science, Technology and Innovation. Earthscan Publications Ltd., London and Sterling VA.

UN. 1992. Convention on Biological Diversity. Concluded at Rio de Janeiro on 5 June 1992. Vol. 1760, I-30619. United Nations, New York.

UN. 1993a. Vienna Declaration and Programme of Action. World Conference on Human Rights, 14-15 June 1993, Vienna. United Nations, New York.

UN. 1993b. Agenda 21: Earth Summit – The United Nations Programme of Action from Rio. United Nations Publications, New York and Geneva.

UN. 1997. Coordination of the policies and activities of the specialized agencies and other bodies of the United Nations System. Mainstreaming the gender perspective into all policies and programmes in the United Nations System. E/1997/100. United Nations Economic and Social Council, Geneva.

UN. 2005a. World population prospects: The 2004 revision. Vol. 1. Comprehensive tables. Department of Economic and Social Affairs, Population Division ST/ESA/SER.A/244. United Nations, New York.

UN.2005b. World population prospects: The 2004 revision. Vol. III: Analytical report. Department of Economic and Social Affairs, Population Division ST//ESA/SER.A/246

UNAIDS, WHO. 2005. AIDS epidemic update. Special report on HIV prevention. United Nations Programme on HIV/AIDS and World Health Organization, Geneva and New York.

UNAIDS. 2005. Resource pack on gender and HIV/AIDS. Interagency Task Team on Gender and HIV/AIDS. Royal Tropical Institute (KIT) Publishers, Amsterdam.

UNDP. 2005. Women's empowerment – Biodiversity for development – The gender dimension [Online]. Available at http://www.undp.org/women/mainstream/index.shtml (accessed 15 May 2006, verified 20 July 2006). United Nations Development Programme, New York.

UNEP. 2002. Global Environment Outlook 3. Past, present and future perspectives. Earthscan Publications Ltd, London and Sterling VA.

UNEP. 2005. GEO Year Book 2004/5. An overview of our changing environment. United Nations Environment Programme, Nairobi.

UNEP. 2006. GEO Yearbook 2006. United Nations Environment Programme, Nairobi.

UNESCAP. 2001. Women in local government in Asia and Pacific: A comparative analysis of thirteen countries. United Nations Economic and Social Commission for Asia and the Pacific, Bangkok.

UNICCPR. 1966. International Covenant on Civil and Political Rights. United Nations, New York.

UNICESCR. 1966. International Covenant on Economic, Social and Cultural Rights. United Nations, New York.

UNSCN. 2004. 5th Report on the World Nutrition Situation: Nutrition for Improved Development Outcomes. United Nations Standing Committee on Nutrition, Geneva.

UNWWAP. 2003. Water for people: Water for life. United Nations World Water Action Programme, Paris.

USDA Economic Research Service, 2006 *from Molly Anderson's Draft, no further information.*

Uvin, P. 1995. The state of world hunger. p. 1-18. *In* Messer, E., and P. Uvin (ed) The hunger report: 1995. Gordon and Breach Science Publishers SA, Amsterdam.

Vali, J. 2000. Sustainable agriculture in a globalized economy. Report for discussion at the Tripartite Meeting on Moving to Sustainable Agricultural Development through the

Modernization of Agriculture and Employment in a Globalized Economy. International Labour Organization, Geneva.

Van de Fliert E. 2003. Recognising a climate for sustainability: extension beyond transfer of technology. Australian J. Exp. Agric. 43:29-36.

Van Koppen, B. 2003. Water Development for Poverty Eradication. *In* Jinendradasa, S.S. (ed) Issues of Water Management in Agriculture: Compilation of Essays. Comprehensive Assessment of Water Management in Agriculture, Colombo:39-42.

von Braun, J. 2005. Small scale farmers in a liberalised trade environment. In Small-scale farmers in liberalised trade environment [Online]. Available at http://honeybee.helsinki.fi/mmtal/abs/Pub38.pdf (accessed 23 February 2007). *In* Huvio, T., Kola, J. and T. Lundström (ed) Proceedings of the seminar, 18–19 Oct. 2004, Haikko, Finland. Agricultural Policy Publications No. 38. Department of Economics and Management, University of Helsinki, Helsinki.

Wack, P. 1985. Scenarios: Shooting the rapids. Harvard Business Rev. 64:135-150.

Wassmann, R., and P.L.G Vlek. 2004. Mitigating greenhouse gas emissions from tropical agriculture: scope and research priorities. Env. Dev. Sust. 6(1–20):1–9.

Watson, R. 2006. Presentation on the IAASTD. Presented during the First Global Authors Meeting in Istanbul, Turkey - November 14-17, 2005. With reference to FAO and World Bank.

Watson, R. and H. Gitay. 2007. Science – Policy Interface: The Role of Scientific Assessments. Draft. 9th Jan. 2007.

Watson, R.T. and H. Gitay. 2004. Mobilization, Diffusion and Use of Scientific Expertise. Institut du développement durable et des relations internationales, Paris.

Watson, R.T., J.A. Dixon, S.P. Hamburg, A.C. Janetos, and R.H. Moss. 1998. Protecting our planet, securing our future. Linkages among global environmental issues and human needs. United Nations Environment Programme, U.S. National Aeronautics and Space Administration, and The World Bank, Washington DC.

WCD. 2000. Dams and development. World Commission on Dams, London.

WCED. 1987. Our common future. World Commission on Environment. Oxford University Press, New York.

WCFSD. 1999. Our Forests. Our Future. Summary Report. World Commission on Forests and Sustainable Development, Winnipeg.

WCSFD. 1999. Our forests, our future. World Commission on Forests and Sustainable Development. Cambridge University Press, Cambridge, New York, and Melbourne.

WDR. 2007. World development report 2007. Development and the Next Generation. The World Bank and Oxford University Press, Washington DC and Oxford.

White, R., S. Murray, and M. Rohweder. 2000. Pilot analysis of global ecosystems: Grassland ecosystems. World Resources Institute, Washington DC.

WHO, 1999. Development of food-based dietary guidelines for the Western Pacific Region, WHO, Regional Office for the Western Pacific, Manila, pp. 6-12

WHO, 2003a. Diet, nutrition and the prevention of chronic diseases, WHO Technical Report Series No. 916, Report of a joint WHO/FAO Expert Consultation, Geneva, 2003, pp. 1-3

WHO. 1946. Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19-22 June, 1946; signed on 22 July 1946 by the representatives of 61 States (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948. The definition of health has not been amended since 1948. World Health Organization, New York.

WHO. 2003b. The world health report 2003 – Shaping the future. World Health Organization, New York.

WHO. 2005. The world health report 2005 – Make every mother and child count. World Health Organization, New York.

WHO-VPH. 2007.. Veterinary public health (VPH) webpage [Online]. Available at www.who.int.zoonoses/vph/en (accessed 25 Feb 2007). World Health Organization, Geneva.

Wiebe, K. (ed) 2003. Land Quality, Agricultural Productivity, and Food Security: Biophysical Processes and Economic Choices at Local, Regional, and Global Scales. Edward Elgar Publishing Co, Cheltenham and Northampton.

Wiesmann, U. 1998. Sustainable regional development in rural Africa: Conceptual framework and case studies from Kenya. Geographica Bernensia, Berne.

Winklerprins, A.W.G.A. 1999. Insights and applications local soil knowledge: A tool for sustainable land management. Soc. Nat. Resour. 12(2):151-161.

WOCAT. 2006. World Overview of Conservation Approaches and Technologies [Online]. http://www.wocat.net/ (accessed 12 June 2006, verified 20 July 2006). World Overview of Conservation Approaches and Technologies, Centre for Development and Environment, Berne.

Wollenberg, E., D. Edmunds, L. Buck, J. Fox, and S. Brodt. 2001. Social learning in community forests. CIFOR and the East-West Centre, Bogar Barat.

Wood, S., Sebastian, K. and S.J. Scherr. 2000. Pilot Analysis of Global Ecosystems. Agroecosystems. International Food Policy Research Institute and World Resources Institute, Washington DC.

World Bank. 1997. Expanding the measure of wealth: indicators of environmentally sustainable development. Environmentally Sustainable Development Studies and Monographs Series No. 17. The World Bank, Washington DC.

World Bank. 2006a. World Development Report 2006: Equity and development. Oxford University Press, New York.

World Bank. 2006b. Enhancing agricultural innovation: How to go beyond the strengthening of research systems? (DRAFT). The World Bank, Washington DC.

World Bank. 2006c. 2006 World development indicators. The World Bank, Washington DC.

WorldFish Center. 2006. The threat to fisheries and aquaculture from climate change. Policy Brief. WorldFish Center, Penang.

Worldwatch Institute. 2003. State of the world 2003. W.W. Norton & Company, New York and London.

WRI, 2006. Agriculture-food database available at http://earthtrends.wri.org)

WRI. 2005. World resources 2005: The wealth of the poor – Managing ecosystems to fight poverty. World Resources Institute, Washington DC.

WTO's Agreement on Agriculture (1995)

WWAP. 2003. Water for People. Water for Life. World Water Development Report. World Water Assessment Programme, United Nations Educational, Scientific and Cultural Organization and Berghahn Books, Paris, Oxford and New York.

Yapa, L. 1993. What are improved seeds? An epistemology of the Green Revolution. Econ. Geogr.69:254-273.

Ziegler, J. 2004. Economic, Social and Cultural Rights. The right to food. Report submitted by the Special Rapporteur on the right to food in accordance with Commission on Human Rights resolution 2003/25. Advance Edited Verion E/CN.4/2004/10. United Nations High Commissioner for Refugees, Geneva.

Zurek, M.B. 2006. A Short Review of Global Scenarios for Food Systems Analysis. GECAFS Working Paper 1. Global Environmental Change and Food Systems, Environmental Change Institute, Oxford Univ. Centre for the Environment, Oxford.