IAASTD

International Assessment of Agricultural Knowledge, Science and Technology for Development

Summary for Decision Makers of the Global Report

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This summary was approved in detail by Governments attending the IAASTD Intergovernmental Plenary in Johannesburg, South Africa (7-11 April 2008).

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Foreword

The objective of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) was to assess the impacts of past, present and future agricultural knowledge, science and technology on the:

- reduction of hunger and poverty,
- improvement of rural livelihoods and human health, and
- equitable, socially, environmentally and economically sustainable development.

The IAASTD was initiated in 2002 by the World Bank and the Food and Agriculture Organization of the United Nations (FAO) as a global consultative process to determine whether an international assessment of agricultural knowledge, science and technology was needed. Mr. Klaus Töepfer, Executive Director of the United Nations Environment Programme (UNEP) opened the first Intergovernmental Plenary (30 August-3 September 2004) in Nairobi, Kenya, during which participants initiated a detailed scoping, preparation, drafting and peer review process.

The outputs from this assessment are a Global and five Sub-Global reports; a Global and five Sub-Global Summaries for Decision Makers; and a cross-cutting Synthesis Report with an Executive Summary. The Summaries for Decision Makers and the Synthesis Report specifically provide options for action to governments, international agencies, academia, research organizations and other decision makers around the world.

The reports draw on the work of hundreds of experts from all regions of the world who have participated in the preparation and peer review process. As has been customary in many such global assessments, success depended first and foremost on the dedication, enthusiasm and cooperation of these experts in many different but related disciplines. It is the synergy of these interrelated disciplines that permitted IAASTD to create a unique, interdisciplinary regional and global process.

We take this opportunity to express our deep gratitude to the authors and reviewers of all of the reports—their dedication and tireless efforts made the process a success. We thank the Steering Committee for distilling the outputs of the consultative process into recommendations to the Plenary, the IAASTD Bureau for their advisory role during the assessment and the work of those in the extended Secretariat. We would specifically like to thank the cosponsoring organizations of the Global Environment Facility (GEF) and the World Bank for their financial contributions as well as the FAO, UNEP, and the United Nations Educational, Scientific and Cultural Organization (UNESCO) for their continued support of this process through allocation of staff resources.

We acknowledge with gratitude the governments and organizations that contributed to the Multidonor Trust Fund (Australia, Canada, the European Commission, France, Ireland, Sweden, Switzerland, and the United Kingdom) and the United States Trust Fund. We also thank the governments who provided support to Bureau members, authors and reviewers in other ways. In addition, Finland provided direct support to the Secretariat. The IAASTD was especially successful in engaging a large number of experts from developing countries and countries with economies in transition in its work; the Trust Funds enabled financial assistance for their travel to the IAASTD meetings.

We would also like to make special mention of the Regional Organizations who hosted the regional coordinators and staff and provided assistance in management and time to ensure success of this enterprise: the African Center for Technology Studies (ACTS) in Kenya, the Inter-American Institute for Cooperation on Agriculture (IICA) in Costa Rica, the International Center for Agricultural Research in the Dry Areas (ICARDA) in Syria, and the WorldFish Center in Malaysia.

The final Intergovernmental Plenary in Johannesburg, South Africa was opened on 7 April 2008 by Achim Steiner, Executive Director of UNEP. This Plenary saw the acceptance of the Reports and the approval of the Summaries for Decision Makers and the Executive Summary of the Synthesis Report by an overwhelming majority of governments.

Signed:

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Global Summary for Decision Makers

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Statement by Governments

All countries present at the final intergovernmental plenary session held in Johannesburg, South Africa in April 2008 welcome the work of the IAASTD and the uniqueness of this independent multistakeholder and multidisciplinary process, and the scale of the challenge of covering a broad range of complex issues. The Governments present recognize that the Global and Sub-Global Reports are the conclusions of studies by a wide range of scientific authors, experts and development specialists and while presenting an overall consensus on the importance of agricultural knowledge, science and technology for development they also provide a diversity of views on some issues.

All countries see these reports as a valuable and important contribution to our understanding on agricultural knowledge, science and technology for development recognizing the need to further deepen our understanding of the challenges ahead. This Assessment is a constructive initiative and important contribution that all governments need to take forward to ensure that agricultural knowledge, science and technology fulfills its potential to meet the development and sustainability goals of the reduction of hunger and poverty, the improvement of rural livelihoods and human health, and facilitating equitable, socially, environmentally and economically sustainable development.

In accordance with the above statement, the following governments approve the Global Summary for Decision Makers.

Armenia, Azerbaijan, Bahrain, Bangladesh, Belize, Benin, Bhutan, Botswana, Brazil, Cameroon, China (People's Republic of), Costa Rica, Cuba, Democratic Republic of Congo, Dominican Republic, El Salvador, Ethiopia, Finland, France, Gambia, Ghana, Honduras, India, Iran, Ireland, Kenya, Kyrgyzstan, Lao People's Democratic Republic, Lebanon, Libyan Arab Jamahiriya, Maldives, Republic of Moldova, Mozambique, Namibia, Nigeria, Pakistan, Panama, Paraguay, Philippines, Poland, Republic of Palau, Romania, Saudi Arabia, Senegal, Solomon Islands, Swaziland, Sweden, Switzerland, United Republic of Tanzania, Timor-Leste, Togo, Tunisia, Turkey, Uganda, United Kingdom of Great Britain, Uruguay, Viet Nam, Zambia (58 countries).

While approving the above statement the following governments did not fully approve the Global Summary for Decision Makers and their reservations are entered in Annex A.

Australia, Canada, and United States of America (3 countries).

Background

In August 2002, the World Bank and the Food and Agriculture Organization (FAO) of the United Nations initiated a global consultative process to determine whether an international assessment of agricultural knowledge, science and technology (AKST) was needed. This was stimulated by discussions at the World Bank with the private sector and nongovernmental organizations (NGOs) on the state of scientific understanding of biotechnology and more specifically transgenics. During 2003, eleven consultations were held, overseen by an international multistakeholder steering committee and involving over 800 participants from all relevant stakeholder groups, e.g., governments, the private sector and civil society. Based on these consultations the steering committee recommended to an Intergovernmental Plenary meeting in Nairobi in September 2004 that an international assessment of the role of AKST in reducing hunger and poverty; improving rural livelihoods and facilitating environmentally, socially and economically sustainable development was needed. The concept of an International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) was endorsed as a multi-thematic, multi-spatial, multi-temporal intergovernmental process with a multistakeholder Bureau cosponsored by the Food and Agriculture Organization of the United Nations (FAO), the Global Environment Facility (GEF), United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Bank and World Health Organization (WHO).

The IAASTD's governance structure is a unique hybrid of the Intergovernmental Panel on Climate Change (IPCC) and the nongovernmental Millennium Ecosystem Assessment (MA). The stakeholder composition of the Bureau was agreed at the Intergovernmental Plenary meeting in Nairobi; it is geographically balanced and multistakeholder with 30 government and 30 civil society representatives (NGOs, producer and consumer groups, private sector entities and international organizations) in order to ensure ownership of the process and findings by a range of stakeholders.

About 400 of the world's experts were selected by the Bureau, following nominations by stakeholder groups, to prepare the IAASTD Report (comprised of a Global and five Sub-Global assessments). These experts worked in their own capacity and did not represent any particular stakeholder group. Additional individuals, organizations and governments were involved in the peer review process.

The IAASTD development and sustainability goals were endorsed at the first Intergovernmental Plenary and are consistent with a subset of the UN Millennium Development Goals (MDGs): the reduction of hunger and poverty, the improvement of rural livelihoods and human health, and facilitating equitable, socially, environmentally and economically sustainable development. Realizing these goals requires acknowledging the multifunctionality of agriculture: the challenge is to simultaneously meet development and sustainability goals while increasing agricultural production.

Meeting these goals has to be placed in the context of a rapidly changing world of urbanization, growing inequities, human migration, globalization, changing dietary preferences, climate change, environmental degradation, a trend toward biofuels and an increasing population. These conditions are affecting local and global food security and putting pressure on productive capacity and ecosystems. Hence there are unprecedented challenges ahead in providing food within a global trading system where there are other competing uses for agricultural and other natural resources. AKST alone cannot solve these problems, which are caused by complex political and social dynamics, but it can make a major contribution to meeting development and sustainability goals. Never before has it been more important for the world to generate and use AKST.

Given the focus on hunger, poverty and livelihoods, the IAASTD pays special attention to the current situation, issues and potential opportunities to redirect the current AKST system to improve the situation for poor rural people, especially small-scale farmers, rural laborers and others with limited resources. It addresses issues critical to formulating policy and provides information for decision makers confronting conflicting views on contentious issues such as the environmental consequences of productivity increases, environmental and human health impacts of transgenic crops, the consequences of bioenergy development on the environment and on the long-term availability and price of food, and the implications of climate change on agricultural production. The Bureau agreed that the scope of the assessment needed to go beyond the narrow confines of science and technology (S&T) and should encompass other types of relevant knowledge (e.g., knowledge held by agricultural producers, consumers and end users) and that it should also assess the role of institutions, organizations, governance, markets and trade.

The IAASTD is a multidisciplinary and multistakeholder enterprise requiring the use and integration of information, tools and models from different knowledge paradigms including local and traditional knowledge. The IAASTD does not advocate specific policies or practices; it assesses the major issues facing AKST and points towards a range of AKST options for action that meet development and sustainability goals. It is policy relevant, but not policy prescriptive. It integrates scientific information on a range of topics that are critically interlinked, but often addressed independently, i.e., agriculture, poverty, hunger, human health, natural resources, environment, development and innovation. It will enable decision makers to bring a richer base of knowledge to bear on policy and management decisions on issues previously viewed in isolation. Knowledge gained from historical analysis (typically the past 50 years) and an analysis of some future development alternatives to 2050 form the basis for assessing options for action on science and technology, capacity development, institutions and policies, and investments.

The IAASTD is conducted according to an open, transparent, representative and legitimate process; is evidence-based; presents options rather than recommendations; assesses different local, regional and global perspectives; presents different views, acknowledging that there can be more than one interpretation of the same evidence based on different worldviews; and identifies the key scientific uncertainties and areas on which research could be focused to advance development and sustainability goals.

The IAASTD is composed of a Global assessment and five Sub-Global assessments: Central and West Asia and North Africa – CWANA; East and South Asia and the Pacific – ESAP; Latin America and the Caribbean – LAC; North America and Europe – NAE; Sub-Saharan Africa – SSA. It (1) assesses the generation, access, dissemination and use of public and private sector AKST in relation to the goals, using local, traditional and formal knowledge; (2) analyzes existing and emerging technologies, practices, policies and institutions and their impact on the goals; (3) provides information for decision makers in different civil society, private and public organizations on options for improving policies, practices, institutional and organizational arrangements to enable AKST to meet the goals; (4) brings together a range of stakeholders (consumers, governments, international agencies and research organizations, NGOs, private sector, producers, the scientific community) involved in the agricultural sector and rural development to share their experiences, views, understanding and vision for the future; and (5) identifies options for future public and private investments in AKST. In addition, the IAASTD will enhance local and regional capacity to design, implement and utilize similar assessments.

In this assessment agriculture is used to include production of food, feed, fuel, fiber and other products and to include all sectors from production of inputs (e.g., seeds and fertilizer) to consumption of products. However, as in all assessments, some topics were covered less extensively than others (e.g., livestock, forestry, fisheries and the agricultural sector of small island countries, and agricultural engineering), largely due to the expertise of the selected authors. Originally the Bureau approved a chapter on plausible futures (a visioning exercise), but later there was agreement to delete this chapter in favor of a more simple set of model projections. Similarly the Bureau approved a chapter on capacity development, but this chapter was dropped and key messages integrated into other chapters.

The IAASTD draft report was subjected to two rounds of peer review by governments, organizations and individuals. These drafts were placed on an open access Web site and open to comments by anyone. The authors revised the drafts based on numerous peer review comments, with the assistance of review editors who were responsible for ensuring the comments were appropriately taken into account. One of the most difficult issues authors had to address was criticisms that the report was too negative. In a scientific review based on empirical evidence, this is always a difficult comment to handle, as criteria are needed in order to say whether something is negative or positive. Another difficulty was responding to the conflicting views expressed by reviewers. The difference in views was not surprising given the range of stakeholder interests and perspectives. Thus one of the key findings of the IAASTD is that there are diverse and conflicting interpretations of past and current events, which need to be acknowledged and respected.

The Global and Sub-Global Summaries for Decision Makers and the Executive Summary of the Synthesis Report were approved at an Intergovernmental Plenary in April 2008. The Synthesis Report integrates the key findings from the Global and Sub-Global assessments, and focuses on eight Bureau-approved topics: bioenergy; biotechnology; climate change; human health; natural resource management; traditional knowledge and community based innovation; trade and markets; and women in agriculture.

The IAASTD builds on and adds value to a number of recent assessments and reports that have provided valuable information relevant to the agricultural sector, but have not specifically focused on the future role of AKST, the institutional dimensions and the multifunctionality of agriculture. These include: FAO State of Food Insecurity in the World (yearly); InterAcademy Council Report: Realizing the Promise and Potential of African Agriculture (2004); UN Millennium Project Task Force on Hunger (2005); Millennium Ecosystem Assessment (2005); CGIAR Science Council Strategy and Priority Setting Exercise (2006); Comprehensive Assessment of Water Management in Agriculture: Guiding Policy Investments in Water, Food, Livelihoods and Environment (2007); Intergovernmental Panel on Climate Change Reports (2001 and 2007); UNEP Fourth Global Environmental Outlook (2007); World Bank World Development Report: Agriculture for Development (2008); IFPRI Global Hunger Indices (yearly); and World Bank Internal Report of Investments in SSA (2007).

Financial support was provided to the IAASTD by the cosponsoring agencies, the governments of Australia, Canada, Finland, France, Ireland, Sweden, Switzerland, US and UK, and the European Commission. In addition, many organizations have provided in-kind support. The authors and review editors have given freely of their time, largely without compensation.

The Global and Sub-Global Summaries for Decision Makers and the Synthesis Report are written for a range of stakeholders, i.e., government policy makers, private sector, NGOs, producer and consumer groups, international organizations and the scientific community. There are no recommendations, only options for action. The options for action are not prioritized because different options are actionable by different stakeholders, each of whom have a different set of priorities and responsibilities and operate in different socioeconomic and political circumstances.

Key Findings

1. Agricultural Knowledge, Science and Technology (AKST) has contributed to substantial increases in agricultural production over time, contributing to food security. This has been achieved primarily through a strong focus on increasing yields with improved germplasm, and increased inputs (water, agrochemicals) and mechanization. These increases in productivity have contributed to a net increase in global food availability per person: from 2360 kcal in the 1960s to 2803 kcal per person per day in the 1990s, at a time when world population significantly increased.

2. People have benefited unevenly from these yield increases across regions, in part because of different organizational capacities, sociocultural factors, and institutional and policy environments. While in South Asia the percentage of people living in poverty (<US$2 per day) has decreased from 45 to 30%, in sub-Saharan Africa (SSA), for example, this percentage (around 50%) has remained the same over the last 20 years. Value added per agricultural worker in 2003 (in 2000 US$) in OECD countries was $23,081 with a rate of growth of 4.4% for 1992-2003. For SSA, the figures are respectively $327 and 1.4%.

3. Emphasis on increasing yields and productivity has in some cases had negative consequences on environmental sustainability. These consequences were often not foreseen as they occurred over time and some occurred outside of traditional farm boundaries. For instance, 1.9 billion ha (and 2.6 billion people) today are affected by significant levels of land degradation. Fifty years ago water withdrawal from rivers was one-third of what it is today: currently 70% of freshwater withdrawal globally (2700 km^3-2.45% of rainfall) is attributable to irrigated agriculture, which in some cases has caused salinization. Approximately 1.6 billion people live in water-scarce basins. Agriculture contributes about 60% of anthropogenic emissions of CH_4 and about 50% of N_20 emissions. Inappropriate fertilization has led to eutrophication and large dead zones in a number of coastal areas, e.g., Gulf of Mexico, and some lakes, and inappropriate use of pesticides has led to groundwater pollution, and other effects, for example loss of biodiversity.

4. The environmental shortcomings of agricultural practice associated with poor socioeconomic conditions create a vicious cycle in which poor smallholder farmers have to deforest and use new often marginal lands, thus increasing deforestation and overall degradation. Loss of soil fertility, soil erosion, breakdown in agroecological functions have resulted in poor crop yields, land abandonment, deforestation and ever-increasing movement into marginal land, including steep hillsides. Existing multifunctional systems that minimize these problems have not been sufficiently prioritized for research. There is little recognition of the ecosystem functions that mitigate the environmental impacts.

Multifunctionality

The term *multifunctionality* has sometimes been interpreted as having implications for trade and protectionism. This is *not* the definition used here. In IAASTD, multifunctionality is used solely to express the inescapable interconnectedness of agriculture's different roles and functions. The concept of multifunctionality recognizes agriculture as a multi-output activity producing not only commodities (food, feed, fibers, agrofuels, medicinal products and ornamentals), but also non-commodity outputs such as environmental services, landscape amenities and cultural heritages.

The working definition proposed by OECD, which is used by the IAASTD, associates multifunctionality with the particular characteristics of the agricultural production process and its outputs; (1) multiple commodity and non-commodity outputs are jointly produced by agriculture; and (2) some of the non-commodity outputs may exhibit the characteristics of externalities or public goods, such that markets for these goods function poorly or are non-existent.

The use of the term has been controversial and contested in global trade negotiations, and it has centered on whether "trade-distorting" agricultural subsidies are needed for agriculture to perform its many functions. Proponents argue that current patterns of agricultural subsidies, international trade and related policy frameworks do not stimulate transitions toward equitable agricultural and food trade relation or sustainable food and farming systems and have given rise to perverse impacts on natural resources and agroecologies as well as on human health and nutrition. Opponents argue that attempts to remedy these outcomes by means of trade-related instruments will weaken the efficiency of agricultural trade and lead to further undesirable market distortion; their preferred approach is to address the externalized costs and negative impacts on poverty, the environment, human health and nutrition by other means.

5. Projections based on a continuation of current policies and practices indicate that global demographic changes and changing patterns of income distribution over the next 50 years will lead to different patterns of food consumption and increased demand for food. In the reference run, global cereal demand is projected to increase by 75% between 2000 and 2050 and global meat demand is expected to double. More than three-fourths of growth in demand in both cereals and meat is projected to be in developing countries. Projections indicate a probable tightening of world food markets with increasing resource scarcity adversely affecting poor consumers and poor producers. Overall, current terms of trade and policies, and growing water and land scarcity, coupled with projected changes in climate is projected to constrain growth in food production.

6. Agriculture operates within complex systems and is multifunctional in its nature. A multifunctional approach to implementing AKST will enhance its impact on hunger and poverty, improving human nutrition and livelihoods in an equitable, environmentally, socially and economically sustainable manner.

7. An increase and strengthening of AKST towards[1] agroecological sciences will contribute to addressing environmental issues while maintaining and increasing productivity. Formal, traditional and community-based AKST need to respond to increasing pressures on natural resources, such as reduced availability and worsening quality of water, degraded soils and landscapes, loss of biodiversity and agroecosystem function, degradation and loss of forest cover and degraded marine and inshore fisheries. Agricultural strategies will also need to include limiting emission of greenhouse gases and adapting to human-induced climate change and increased variability.

8. Strengthening and redirecting the generation and delivery of AKST will contribute to addressing a range of persistent socioeconomic inequities. They include reducing the risk of conflicts resulting from competing claims on land and water resources; assisting individuals and communities in coping with endemic and epidemic human and animal diseases and their consequences; addressing problems and opportunities associated with local and international flows of migrant laborers; and increasing access to information, education and technology to poorer areas and peoples, especially to women. Such redirection and strengthening requires thorough, open and transparent engagement of all stakeholders.

9. Greater and more effective involvement of women and use of their knowledge, skills and experience will advance progress towards sustainability and development goals and a strengthening and redirection of AKST to address gender issues will help achieve this. Women farmers, processors and farm workers have benefited less from AKST than men overall and poor women least of all. Efforts to redress persistent biases in their access to production resources and assets, occupational education and training, information and extension services have met with limited success. Many of the societal, policy-related and operational impediments to more equitable progress, as well as the private and public costs of such an uneven pattern of development, are well understood as are the factors that discourage more determined action to empower women.

10. Many of the challenges facing agriculture currently and in the future will require more innovative and integrated applications of existing knowledge, science and technology (formal, traditional and community-based), as well as new approaches for agricultural and natural resource management. Agricultural soil and biodiversity, nutrient, pest and water management, and the capacity to respond to environmental stresses such as climate change can be enhanced by traditional and local knowledge systems and current technologies. Technological options-such as new genotypes of crops, livestock, fish and trees and advances in plant, livestock and fish breeding, biotechnology, remote sensing, agroecology, agroforestry, integrated pest and nutrient management and information and communication technologies (ICTs) will create opportunities for more resource-efficient and site-specific agriculture.[2]

11. Some challenges will be resolved primarily by development and appropriate application of new and emerging AKST. Such AKST can contribute to solutions provided appropriate institutions and capacities are in place. Examples include combating livestock diseases, e.g., vaccine development; mitigating greenhouse gas emissions from agriculture; reducing the vulnerability of agriculture to a changing climate; reducing the heavy reliance of agriculture and commodity chains on fossil fuels; and addressing complex socioeconomic issues regarding local, national and international public goods.[2,3]

12. Targeting small-scale agricultural systems by forging public and private partnerships, increased public research and extension investment helps realize *existing* opportunities. Strengthening participatory research and extension partnerships, development-oriented local governance and institutions such as cooperatives, farmer organizations and business associations, scientific institutions and unions support small-scale producers and entrepreneurs to capture and add value to existing opportunities on-farm, post-harvest and in non-farm rural enterprises. In some instances, opportunities lie in those small-scale farming systems that have high water, nutrient and energy use efficiencies and conserve natural resources and biodiversity without sacrificing yield, but high marketing costs do not allow them to harness these opportunities. The underlying principles, processes and knowledge may be relevant and capable of extrapolation to larger scale farming systems, particularly in the face of climate change effects.

13. Significant pro-poor progress requires creating opportunities for innovation and entrepreneurship, which explicitly target resource poor farmers and rural laborers. This will require simultaneous investments in infrastructure and facilitating access to markets and trade opportunities, occupational education and extension services, capital, credit, insurance and in natural resources such as land and water. The increasing market influence of large scale buyers and market standards are especially challenging for small producers necessitating further innovation in public and private training, education and extension services and suitable legal, regulatory and policy frameworks.

14. Decisions around small-scale farm sustainability pose difficult policy choices. Special and differential treatment for developing countries is an acknowledged principle in Doha agricultural negotiations and it is accepted that developing countries can have this special treatment especially on the grounds of food security, farmer's livelihoods and rural development. Suitable action is considered necessary at the international and national level to enable small farmers to benefit from these provisions. New payment mechanisms for environmental services by public and

[1] USA and Botswana.

[2] USA.

[3] Benin, Botswana, DRC, Ethiopia, Gambia, Kenya, Tanzania, Togo, Uganda.

Biotechnology

The IAASTD definition of biotechnology is based on that in the Convention on Biological Diversity and the Cartagena Protocol on Biosafety. It is a broad term embracing the manipulation of living organisms and spans the large range of activities from conventional techniques for fermentation and plant and animal breeding to recent innovations in tissue culture, irradiation, genomics and marker-assisted breeding (MAB) or marker assisted selection (MAS) to augment natural breeding. Some of the latest biotechnologies, called "modern biotechnology", include the use of *in vitro* modified DNA or RNA and the fusion of cells from different taxonomic families, techniques that overcome natural physiological reproductive or recombination barriers.

private utilities such as catchment protection and mitigation of climate change effects are of increasing importance and open new opportunities for the small-scale farm sector.

15. Public policy, regulatory frameworks and international agreements are critical to implementing more sustainable agricultural practices. Urgent challenges remain that call for additional effective agreements and biosecurity measures involving transboundary water, emerging human and animal diseases, agricultural pests, climate change, environmental pollution and the growing concerns about food safety and occupational health. Achieving development and sustainability goals calls for national and international regulations to address the multiple economic, environmental and social dimensions of these transboundary issues. These policies need to be informed by broad-based evidence from natural and social sciences with multistakeholder participation. Improved governance and strengthening engagement of stakeholders can redress some of the inadequacies where identified in AKST arrangements that often privilege short-term over long-term considerations and productivity over environmental and social sustainability and the multiple needs of the small-scale farm sector.

16. Innovative institutional arrangements are essential to the successful design and adoption of ecologically and socially sustainable agricultural systems. Sustainable agricultural production is more likely when legal frameworks and forms of association provide secure access to credit, markets, land and water for individuals and communities with modest resources. Creating market-based opportunities for processing and commercializing agricultural products that ensure a fair share of value addition for small-scale producers and rural laborers is critical to meeting development and sustainability goals.

17. Opening national agricultural markets to international competition can offer economic benefits, but can lead to long term negative effects on poverty alleviation, food security and the environment without basic national institutions and infrastructure being in place. Some developing countries with large export sectors have achieved aggregate gains in GDP, although their small-scale farm sectors have not necessarily benefited and in many cases have lost out. The small-scale farm sector in the poorest developing countries is a net loser under most trade liberalization scenarios that address this question. These distributional impacts call for differentiation in policy frameworks as embraced by the Doha work plan (special and differential treatment and non-reciprocal access). Developing countries could benefit from reduced barriers and elimination of escalating tariffs for processed commodities in developed and developing countries; and they could also benefit from reduced barriers among themselves; deeper generalized preferential access to developed country markets for commodities important for rural livelihoods; increased public investment in local value addition; improved access for small-scale farmers to credit; and strengthened regional markets.

18. Intensive export-oriented agriculture has increased under open market operations but has been accompanied by both benefits and adverse consequences depending on circumstances such as exportation of soil nutrients and water, unsustainable soil or water management or exploitative labor conditions in some cases. AKST innovations that address sustainability and development goals would be more effective with fundamental changes in price signals, for example, internalization of environmental externalities and payment or reward for environmental services.

19. The choice of relevant approaches to adoption and implementation of agricultural innovation is crucial for achieving development and sustainability goals. There is a wide range of such approaches in current use. In the past, most AKST policy and practice in many countries were undertaken using the "transfer of technology" approach. A critical decision for AKST stakeholders is the selection of approaches suited to the advancement of sustainability and development goals in different circumstances.

20. More and better targeted AKST investments, explicitly taking into account the multifunctionality of agriculture, by both public and private sectors can help advance development and sustainability goals. Increased investments in AKST, particularly if complemented by supporting investments in rural development (for example, infrastructure, telecommunications and processing facilities) can have high economic rates of return and reduce poverty. AKST investments also generate environmental, social, health, and cultural impacts. More evidence is needed on the actual levels and distributional effects of the economic and non-economic benefits and costs of these investments for better targeting of future AKST investments.

21. While public private partnerships are to be encouraged the establishment and enforcement of codes of conduct by universities and research institutes can help avoid conflicts of interest and maintain focus on sustainability and development in AKST when private funding complements public sector funds. Government capacity to understand, and where necessary mediate public–private partnerships, can be assisted for instance by means of monitoring systems.

22. Achieving sustainability and development goals will involve creating space for diverse voices and perspectives and a multiplicity of scientifically well-founded options, through, for example, the inclusion of social scientists in policy and practice of AKST helps direct and focus public and private research, extension and education on such goals. Diverse and conflicting interpretations of past and current events, coupled with the under-valuation of different types of AKST limit progress in the field. Understanding the underlying sources of competing interpretations of AKST is crucial to addressing goals. Some interpretations have been privileged over others and have helped push formal AKST along certain pathways, to the neglect of other scientifically sound options. Some of the by-passed options originate in traditional knowledge or civil society experience and may be better able to contribute to poverty reduction, social inclusion, equity and generate multifunctional outcomes.

Context

Agricultural knowledge, science and technology can play a key role in addressing development and sustainability goals—reducing hunger and poverty, improving rural livelihoods and facilitating equitable, environmentally, socially and economically sustainable development. This task requires that AKST address the multifunctionality of agriculture, not just as a site for food production, but also as a foundation for communities, economies and a host of ecological relationships. Hence effective management of physical and natural resources, the internalization of externalized costs and the continuing availability of, and access to, public goods, such as biodiversity, including germplasm, and ecosystem services are critical to meeting development and sustainability goals [Chapter 3].

Agriculture, for the purposes of the IAASTD, is a range of production systems, and is considered to be a linked, dynamic social-ecological system based on the maintenance, utilization and regeneration of ecosystem services managed by people. It includes cropping, animal husbandry, fishing, forestry, biofuel and bioproducts industries, and the production of pharmaceuticals or tissue for transplant in crops and livestock through genetic engineering. IAASTD looks at the entire system of goods and services from agriculture.

Agriculture provides a livelihood for 40% of the global population; 70% of the poor in developing countries live in rural areas and are directly or indirectly dependent on agriculture for their livelihood. Agriculture also has a major influence on essential ecosystem services such as water supply and purification, pollination, pest and disease control, and the uptake and release of carbon [Chapter 3].

Globally, AKST can contribute in important ways to addressing poverty alleviation for the 3 billion people who live on less than US $2 per day and must provide adequate and nutritious food for everyone, particularly for 854 million undernourished people. Other global development challenges include clean water for the 1.3 billion people who live without it and environmentally sustainable energy sources for 2 billion people; AKST can also play a role in addressing these challenges [Chapters 1, 3].

By focusing on development and sustainability goals at the global scale, this assessment naturally emphasizes the challenges facing developing countries and poor rural communities where the greatest numbers of people depend on agriculture for their livelihoods and where poverty and environmental degradation exist. However, challenges to meeting these goals exist in all countries and local and national solutions need to appreciate their interrelationships and the global context.

In order to realize development and sustainability goals, we must distinguish two areas for action. One area is technology development: continued crop, tree, fish and livestock improvement, and sustainable practices for using water and other natural resources and energy. However, goals can only be reached if we pay attention to a second area of action: organizational capacity and policy and institutional development. For example, the use of new technologies usually is predicated upon the existence of markets with remunerative prices, access to credit, inputs and a host of other services and supports that are often neglected.

Trends in investment in agricultural research and development are a critically important contextual component relevant to achieving development and sustainability goals because in general, public funding is more able to incorporate the interests of the underprivileged and the environment than private sources of funding. Investments in agricultural research and development (R&D) are still growing, but the growth rate declined during the 1990s. In addition, investment trends among countries have increasingly diverged. Investment in publicly funded agricultural R&D in many industrialized countries has stalled or declined and has become a small proportion of total spending on science and technology (S&T). Many developing countries have also stagnated or slipped in terms of publicly funded agricultural R&D investments, except for a few, often more industrialized, countries. Investments by the private sector have increased in industrialized countries, but have remained small in developing countries. Comprehensive data need to be compiled for a fuller assessment of the state of agricultural R&D including areas such as extension, traditional and local AKST, farming systems evolutions, social sciences, certain health sector research, mitigation and adaptation of climate change [Chapter 8].

Public investments in AKST can have economic rates of return in the order of 40-50% under favorable market conditions and contribute to meeting development and sustainability goals. But AKST investments also generate social, environmental, health and cultural costs and benefits, some of which are considered as externalities (positive and negative) and spillovers [Chapter 2]. These non-economic effects are also important to society, but are often not included in conventional rate of return (ROR) analyses because they present problems of attribution, quantification and valuation. Furthermore, ROR analysis fails to account for the distribution of costs and benefits among economic classes and stakeholder groups [Chapter 8].

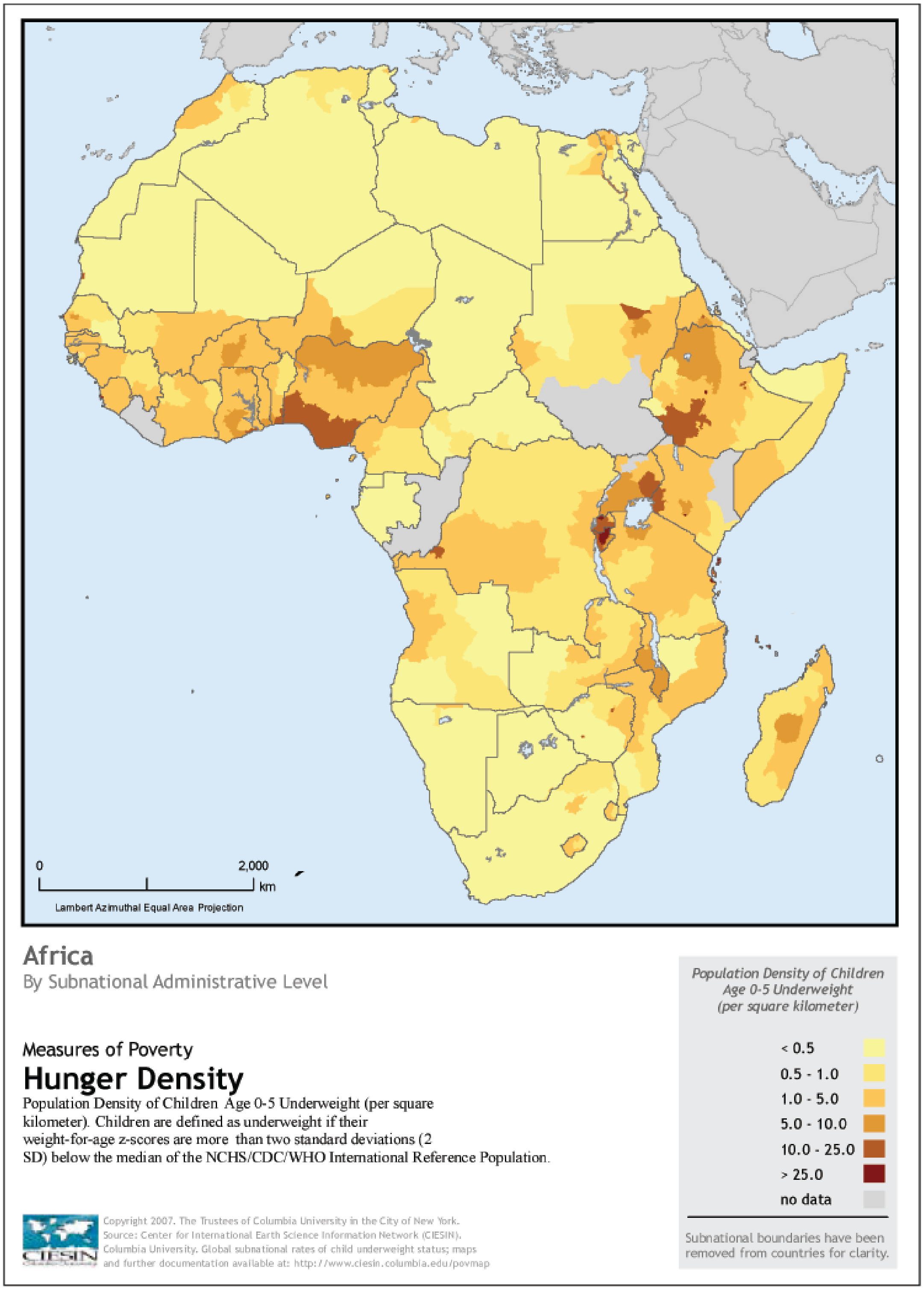


Figure GSDM-1. *Global Hunger (continued next page).*

Global challenges

Challenge: Decrease hunger and improve health and human nutrition

Food security. Formal, traditional and local AKST have made positive contributions to addressing hunger, food security, human health and nutrition [Chapter 2]. Substantial gains in agricultural productivity over the past 50 years have reduced rates of hunger and malnutrition, improved the health and livelihoods of many millions of people and

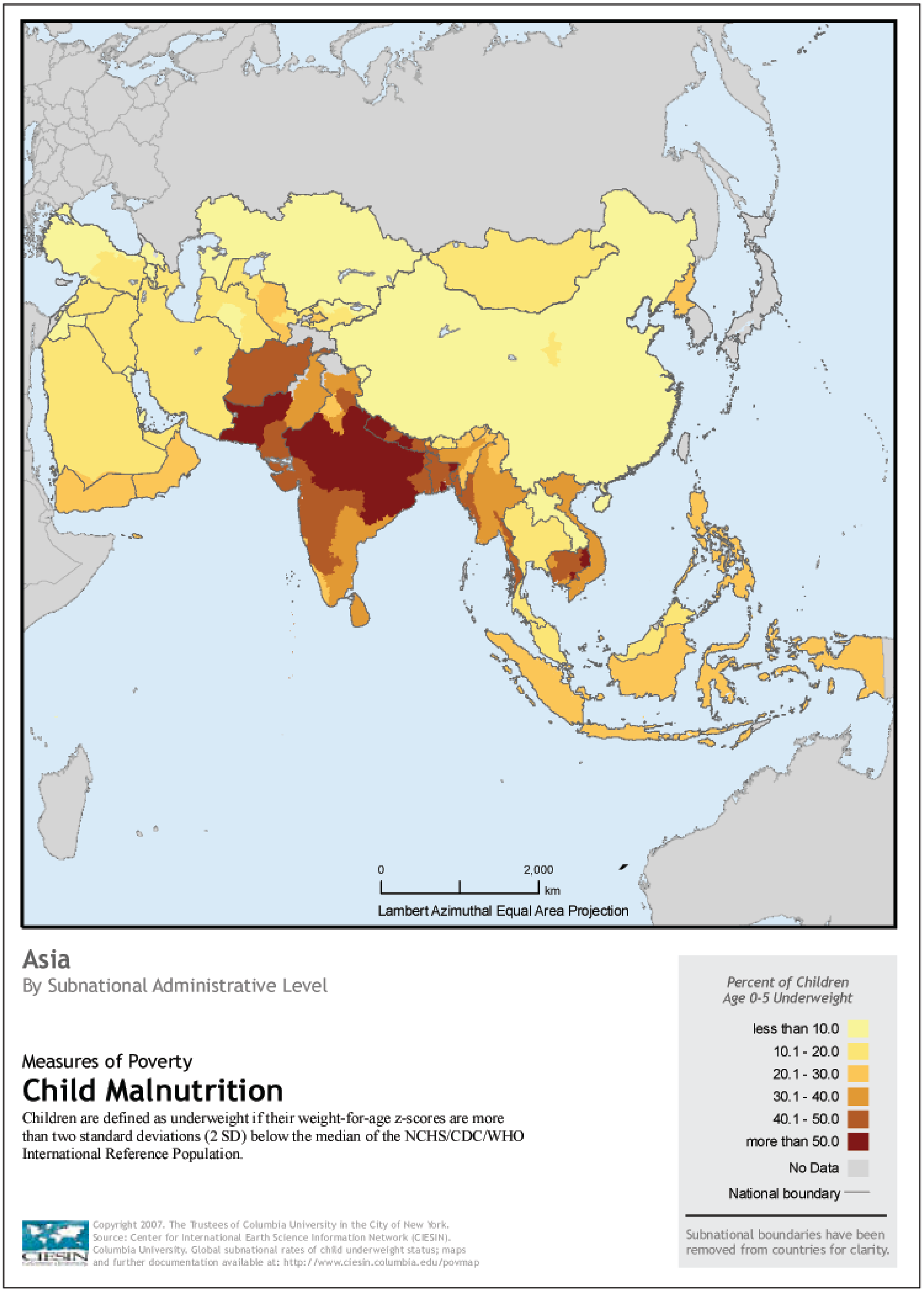


Figure GSDM-1. *Global Hunger.*

Latin America

By Subnational Administrative Level

Measures of Poverty

Child Malnutrition

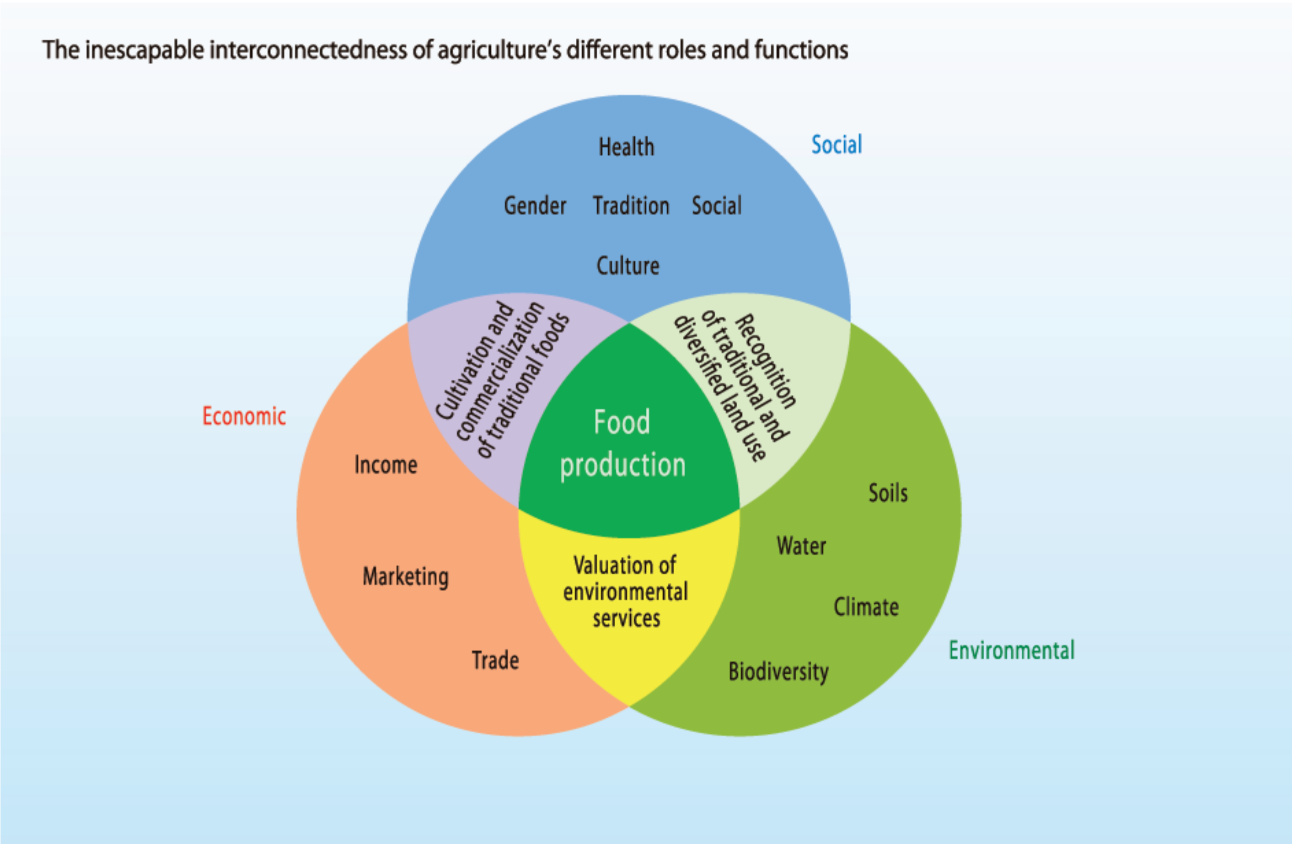
Children are defined as underweight if their weight-for-age z-scores are more than two standard deviations (2 SD) below the median of the NCHS/CDC/WHO International Reference Population.

Percent of Children Age 0-5 Underweight

- less than 10.0
- 10.1 - 20.0
- 20.1 - 30.0
- 30.1 - 40.0
- 40.1 - 50.0
- more than 50
- No Data
- National boundary

Subnational boundaries have been removed from countries for clarity.

Source: Center for International Earth Science Information Network (CIESIN), Columbia University. Global subnational rates of child underweight status; maps and further documentation available at: http://www.ciesin.columbia.edu/povmap



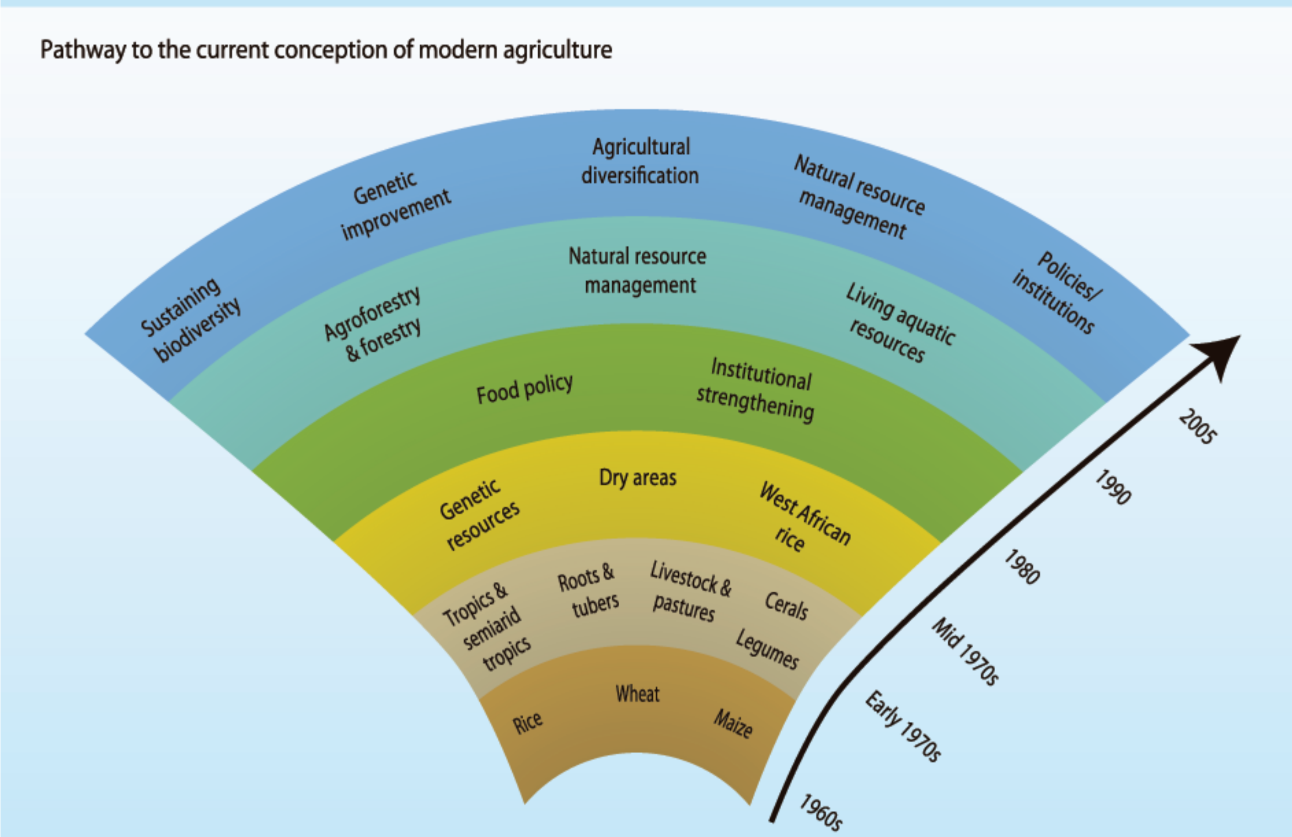


Figure GSDM-2. *A Multifunctional Perspective of Agriculture.*

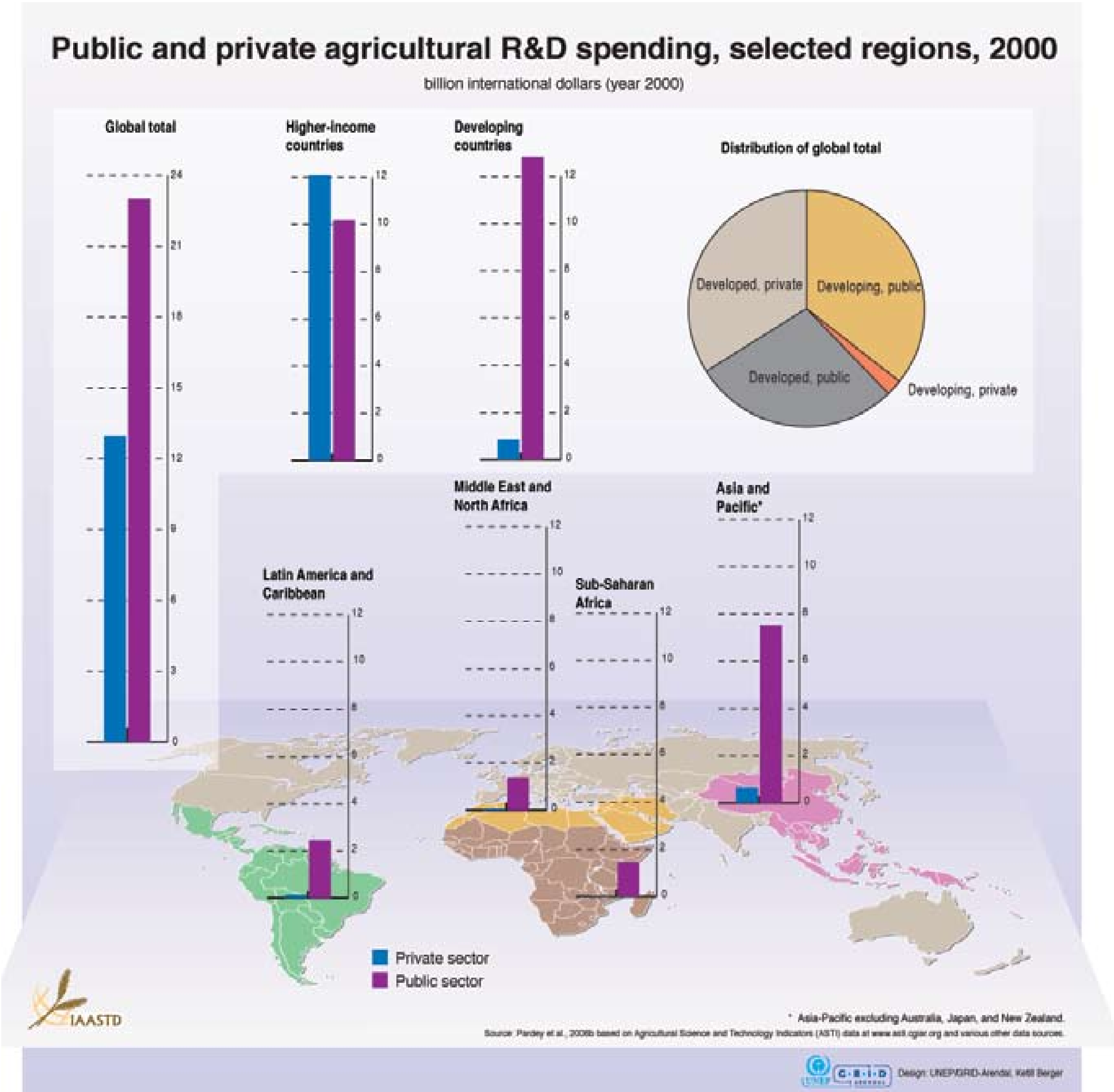


Figure GSDM-3. *Public And Private Agricultural R&D Spending by Region, 2000.*

stimulated economic growth in numerous countries. World cereal production has more than doubled since 1961 with average yields per hectare increasing around 150% in many high and low income countries, with the exception of most nations in sub-Saharan Africa. Production gains are attributed to improved crop varieties and livestock, soil management, improved access to resources (nutrients and water), infrastructure developments, policy initiatives, microfinance, education, better communication and advances in market and trade systems. Globally, until recently, food has become cheaper and average calorie availability has increased. In the mid-1960s, 57% of the world's population lived in countries where the average caloric availability was below 2200 kcal; now the proportion is 10%. Gains in China, India, Brazil and Indonesia were primarily responsible for this marked improvement in average nutrition [Chapter 3].

Despite much progress in agricultural technologies, persistent challenges remain that call for action in other domains such as governance. Substantial increases in agricultural production over time have had an uneven effect on food security. Hunger, malnutrition and food insecurity remain high, affecting millions of people, particularly in South Asia and sub-Saharan Africa [Chapters 1, 3, 4]. Furthermore, expected increases in global population and incomes over the next 50 years will lead to an increased demand for food. Demographic changes, including aging populations, urbanization, changing food consumption patterns and the distribution of income, are driving changes in dietary pat-

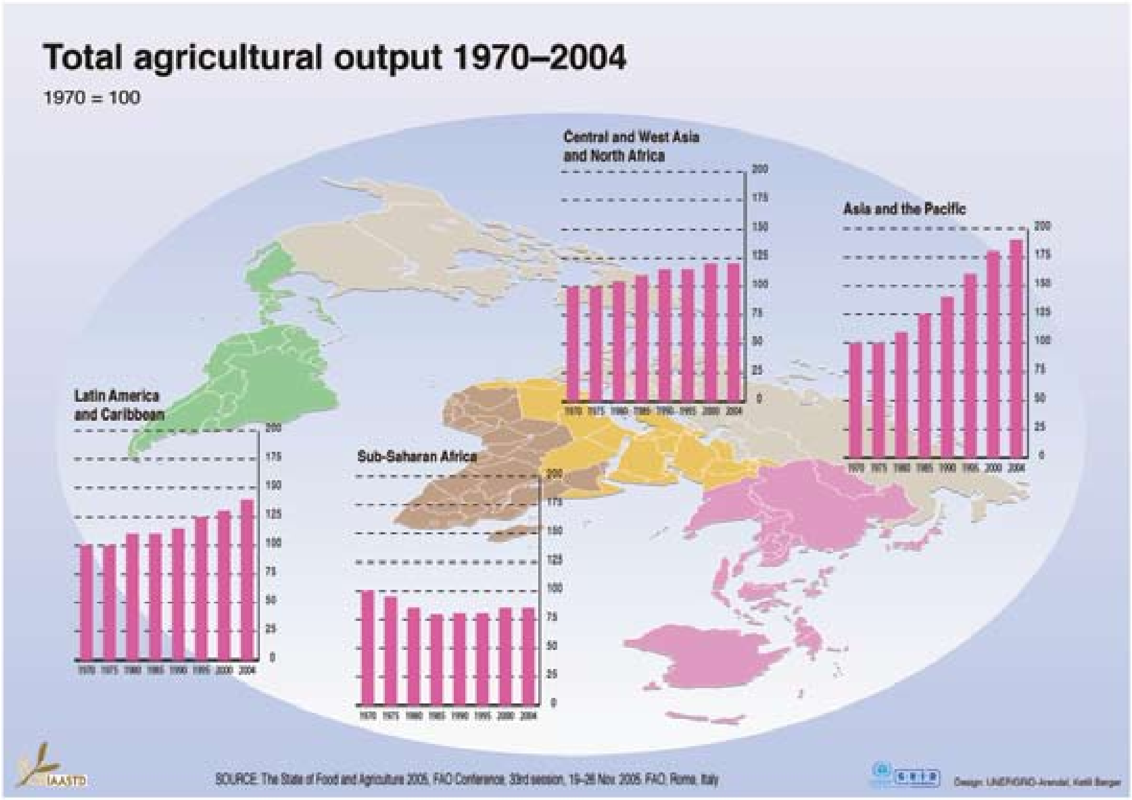


Figure GSDM-4a. *Total Agricultural Output.*

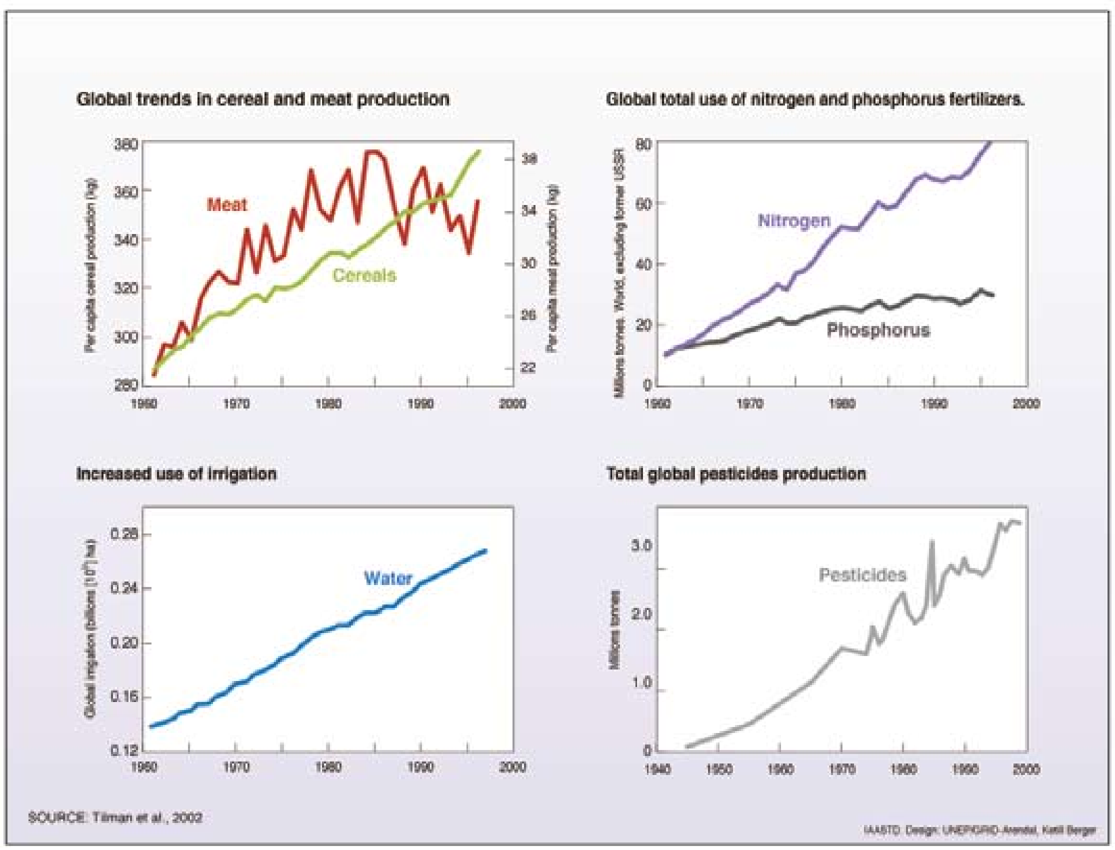


Figure GSDM-4b. *Global Trends In Output; N, P, Irrigation and Pesticide Use.*

terns with positive and negative effects on health [Chapters 5, 6]. Business-as-usual projections (i.e., broadly a continuation of current policies and practices) indicate a probable tightening of world food markets with increasing resource scarcity adversely affecting poor consumers and poor producers [Chapter 5].

Rapid growth in demand for meat and milk is projected to increase competition for land with crop production and to put pressure on the price for maize and other grains and meals. This is because it takes 4.5 plant-derived calories to produce one calorie of egg or milk and 9 plant-derived calories to produce one calorie of beef or lamb meat. Thus growing demand usually associated with growing income may trigger structural changes in the livestock sector that could have significant environmental implications but will not necessarily result in improved human nutrition for poor people or better opportunities for all small-scale producers.

Increases in livestock numbers projected to 2050 vary by region and species, but substantial growth in livestock production is projected under a business-as-usual approach to occur in nearly all the developing world. This projection calls for an increase in resources allocated to livestock related research; taking an integrated approach to grassland and crop-livestock systems to solve the multiple problems that beset intensive livestock production; and offering better prospects for achieving sustainable solutions [Chapters 3, 5].

Marine, coastal and freshwater ecosystems have been drastically altered over the past 50 years, reducing their productivity, resilience to stress, and potential to contribute to future food security. The total world production from capture fisheries has declined in recent years due to overfishing because of ineffective management, inappropriate fishing practices and poor understanding of ecosystem-based management approaches. Future projections indicate that capture fisheries will continue to decline and aquatic ecosystems will continue to degrade, seriously threatening food security. Fishing technology has outpaced the development and application of sound science and management. The development and unregulated use of fishing gears such as large-scale trawling, gill nets, long-lining and use of other destructive fishing practices, such as dynamite and cyanide, has damaged the productivity of ecosystems and habitats upon which fishing depends [Chapter 6].

Food production and the price of food may be affected by increased biofuel production due to competition for land and natural resources. The limited access to land by small-scale farmers is likely to limit their ability to supply and benefit from this new market. Equally critical, some crops used for liquid biofuel production will require large quantities of water, already a major constraint to agriculture in many parts of the world [Chapter 3].

The globalized food system affects local food systems that support the livelihoods of the poor [Chapter 2]. Low prices for commodity imports—in contrast to prices for processed food—can be favorable for poor consumers in net food-importing developing countries (given appropriate institutional arrangements), but imports at prices below the cost of local production undercut national farmers and rural development. Investment in AKST that builds resilience of local food systems to environmental and economic shocks can stabilize production and increase food security, provided that appropriate policy measures give temporary protection to local markets.

Improve health and human nutrition. Food safety hazards, which are biological, chemical or physical contaminants or agents that affect human health or nutrient bioavailability, may occur anywhere along the food chain. Pathogen produced toxins, such as mycotoxins, heavy metals and other contaminants, veterinary drug and pesticide residues can cause short- and longer-term adverse, even lethal, human health consequences when present in food systems. These hazards increase with the length of the food chain. Outbreaks of diseases transferred from food, such as Salmonella and Bovine Spongiform Encephalitis (mad cow disease), have heightened the demand for food safety standards [Chapter 2]. Concerns about GMOs in food and feed as well as consumer choice, have heightened demand for food safety standards and prompted countries to develop and implement regulations to address this issue [Chapter 2].[4]

Demand for products with high quality and safety standards is expected to continue to grow, creating a market that will be accessible only to producers and processors with sufficient AKST capacity and knowledge (e.g., postharvest handling). In developing countries, better national quality standards are likely to be a function of increased knowledge and public awareness about the health effects of nutritional choices and safer production practices and the expansion of public health regulations, liability laws and laboratory infrastructure [Chapters 5, 8].

Diet is one of the leading risk factors for chronic illness. Malnutrition remains a major cause of death, especially among children, but other illnesses, often correlated, such as obesity, heart disease, stroke, diabetes, HIV Aids and cancer have emerged. Cardiovascular disease is a leading cause of death in both industrialized and developing countries [Chapters 1, 3]. Changes in food availability and prices together with environmental, social and demographic factors (e.g., urbanization) have resulted in a worldwide dietary transition. This transition has affected social groups differently. Indeed, undernutrition and overconsumption coexist in a wide range of countries. Unbalanced diets are often related to low intake of fruits and vegetables and high intake of fats, meat, sugar and salt. Many traditional foods, however, are rich in micronutrients and expanding their role in production systems and diet could have health benefits.

Food security [is] a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, The State of Food Insecurity, 2001).

Food sovereignty is defined as the right of peoples and sovereign states to democratically determine their own agricultural and food policies.

[4] Australia and USA.

Infectious diseases, including pandemic HIV/AIDS and malaria, are among the leading causes of morbidity and mortality worldwide and are severely affecting food security in some developing countries. In addition to the major challenges that are raised by these illnesses, other diseases related to agricultural activity are expected to emerge or expand. The incidence and geographic range of many of these diseases are influenced by production systems (e.g., intensive crop and livestock), and economic (e.g., expansion of international trade), social (e.g., changing diets and living patterns), demographic (e.g., population growth and migration), environmental (e.g., land use and global climate change), and biological factors (e.g., microbial mutations). Most of these factors will continue to be relevant and may intensify during this century.

Serious socioeconomic consequences occur when diseases spread widely within human or animal populations (e.g., bluetongue disease), or when they spill over from animal reservoirs to human hosts (e.g., avian influenza); pathogens that infect more than one host species are of particular concern. In large part due to a globalized food system, the increase in disease emergence will affect both high- and low-income countries [Chapter 3]. Toxic agrochemicals applied in a wide range of agricultural systems result in exposure adversely affecting the health of producers, laborers and communities. Enforcement of rigorous regulations and implementation of effective risk management strategies can help reduce exposure but do not eliminate risk.

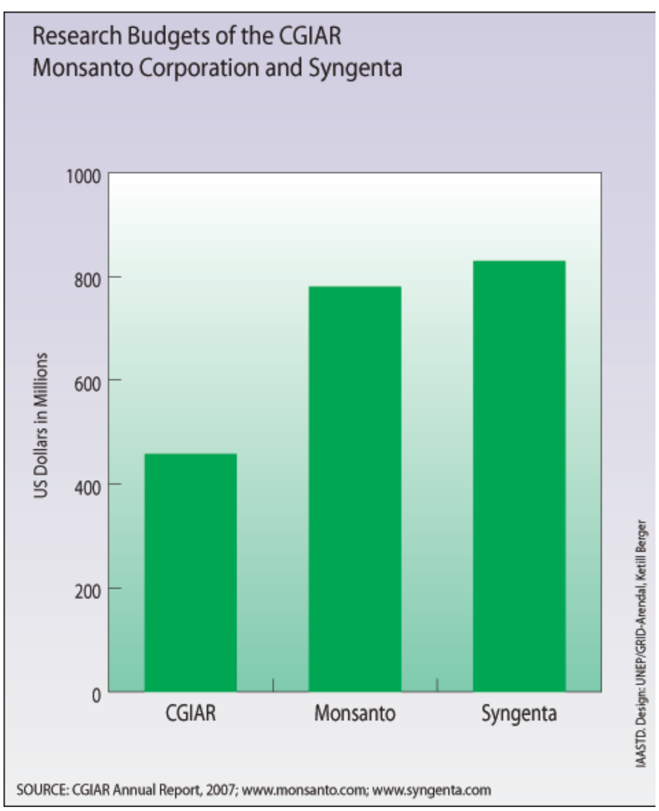


Figure GSDM-5. *Research Budgets of CGIAR, Monsanto and Syngenta*

The health and environmental risks and effects of agrochemicals have been extensively documented in the scientific and medical literature. On the other hand, the impacts of transgenic plants, animals and microorganisms are currently less understood. This situation calls for broad stakeholder participation in decision making as well as more public domain research on potential risks [Chapters 2, 3].

Challenge: Decrease poverty and improve rural livelihoods

AKST has the capacity to improve livelihoods, although effects have varied by region and social group. The ability to access and benefit from AKST is uneven, with industrialized countries gaining more than developing countries (especially those in Africa). The value added per agricultural worker in OECD countries in 2003 was US$23,081 with a growth between 1992 and 2003 of 4.4% per annum. For Africa, the figures were US$327 and 1.4%, respectively. These disparities are partly the result of historical, social, economic political trajectories and current policy. Developing countries are projected to increasingly rely on imported food [Chapter 5], often because local production is not remunerative or competitive because of lack of investment. The increase in off-farm employment will not necessarily keep pace with the loss of on-farm livelihoods, and although the proportion of people working in agriculture will decline with urbanization, the rural population is not expected to decline.

Many reasons exist for the expansion of agricultural trade: increasing interregional relationships, increasing demand for food, and commodity specialization facilitated by trade liberalization. Globalization and liberalization will affect countries and groups within countries in different ways. It is projected that agricultural trade among developing countries is likely to increase and their agricultural trade deficits with industrialized countries are likely to increase while industrialized countries will continue to run agricultural trade surpluses [Chapter 4]. In developing country urban markets with poor rural connectivity there could be increasing reliance on imports, which provide cheaper food but undermine rural employment and livelihoods and deter investment in mitigating land degradation. These trade imbalances also favor high-input, energy-intensive agriculture, which currently does not internalize environmental or social costs of production, an increasingly unsustainable approach.

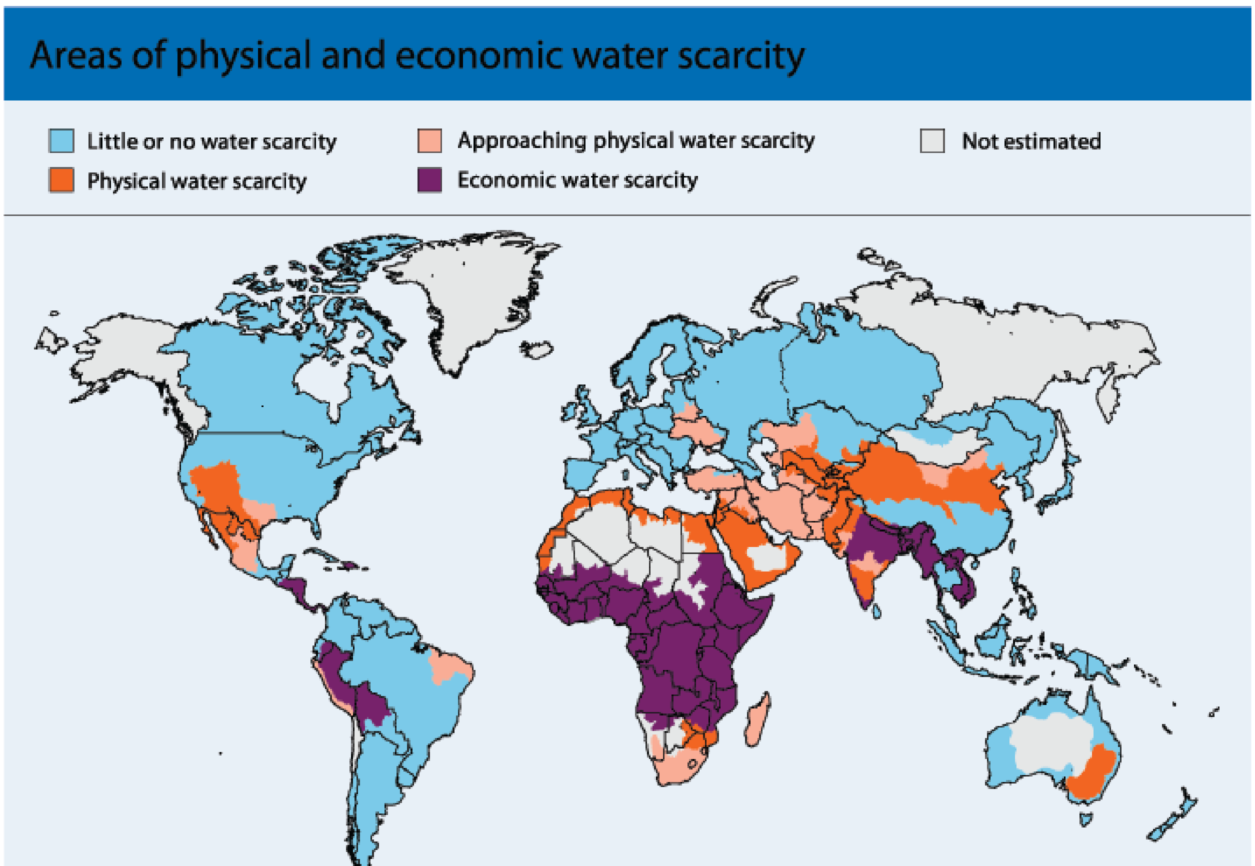
Challenge: Increase environmental sustainability

Over the last century, the agricultural sector has typically simplified production systems to maximize the harvest of a single component, generally ignoring other supporting, provisioning, and regulating ecological functions and services. When these practices have been associated with policies that provide resource price-distorting incentives, this has often led to degradation of environmental and natural resources (e.g., deforestation, introduction of invasive species, increased pollution and greenhouse gas emissions).

Agriculture currently contributes 60 and 50% of global anthropogenic emissions of CH_4 and N_2O, respectively. During the last 50 years, the natural resource base on which agriculture depends has declined faster than at any other time in history due to increased global demand and degradation; 75% of the crop genetic base of agricultural crops has been lost. Degradation of ecosystem functions (e.g., nutrient and water cycling), constrains production and may limit the ability of agricultural systems to adapt to climatic and other global changes in many regions. Sustainable agricultural practices are part of the solution to current environmental change. Examples include improved carbon storage in soil and biomass, reduced emissions of CH_4 and N_2O from rice paddies and livestock systems, and decreased use of inorganic fertilizers. Appropriate policies can promote mitigation of GHG emissions and increased carbon sequestration.

According to The Comprehensive Assessment of Water Management in Agriculture by 2050, agriculture in most regions will still be the largest user of freshwater resources, although its share is expected to decline relative to industrial and domestic uses [Chapter 3]. Under current water use practices, increases in population and changes in diet are projected to increase water consumption in food and fiber production by 70-90%. If demands for biomass energy increase, this may aggravate the problem. In addition, sectoral competition for water resources will intensify, further exacerbating the stress on developing country producers. Reliability of water supply for agriculture is projected to decline in many regions due to climate change and increasing climate variability although the potential for AKST to improve water management is substantial in both rainfed and irrigated agriculture.

Projected changes in the frequency and severity of extreme weather events in addition to increases in fire hazards, pests and diseases will have significant implications for agricultural production and food security. The effect of climate change on crop yields, fisheries, forestry and livestock is



Definitions and indicators

- Little or no water scarcity. Abundant water resources relative to use, with less than 25% of water from rivers withdrawn for human purposes.
- Physical water scarcity (water resources development is approaching or has exceeded sustainable limits). More than 75% of river flows are withdrawn for agriculture, industry, and domestic purposes (accounting for recycling of return flows). This definition—relating water availability to water demand—implies that dry areas are not necessarily water scarce.
- Approaching physical water scarcity. More than 60% of river flows are withdrawn. These basins will experience physical water scarcity in the near future.
- Economic water scarcity (human, institutional, and financial capital limit access to water even though water in nature is available locally to meet human demands). Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists.

Source: International Water Management Institute analysis done for the Comprehensive Assessment of Water Management in Agriculture using the Water sim model; chapter 2.

Figure GSDM-6. *Areas of Physical and Economic Water Scarcity.* Source: IWMI, 2007.

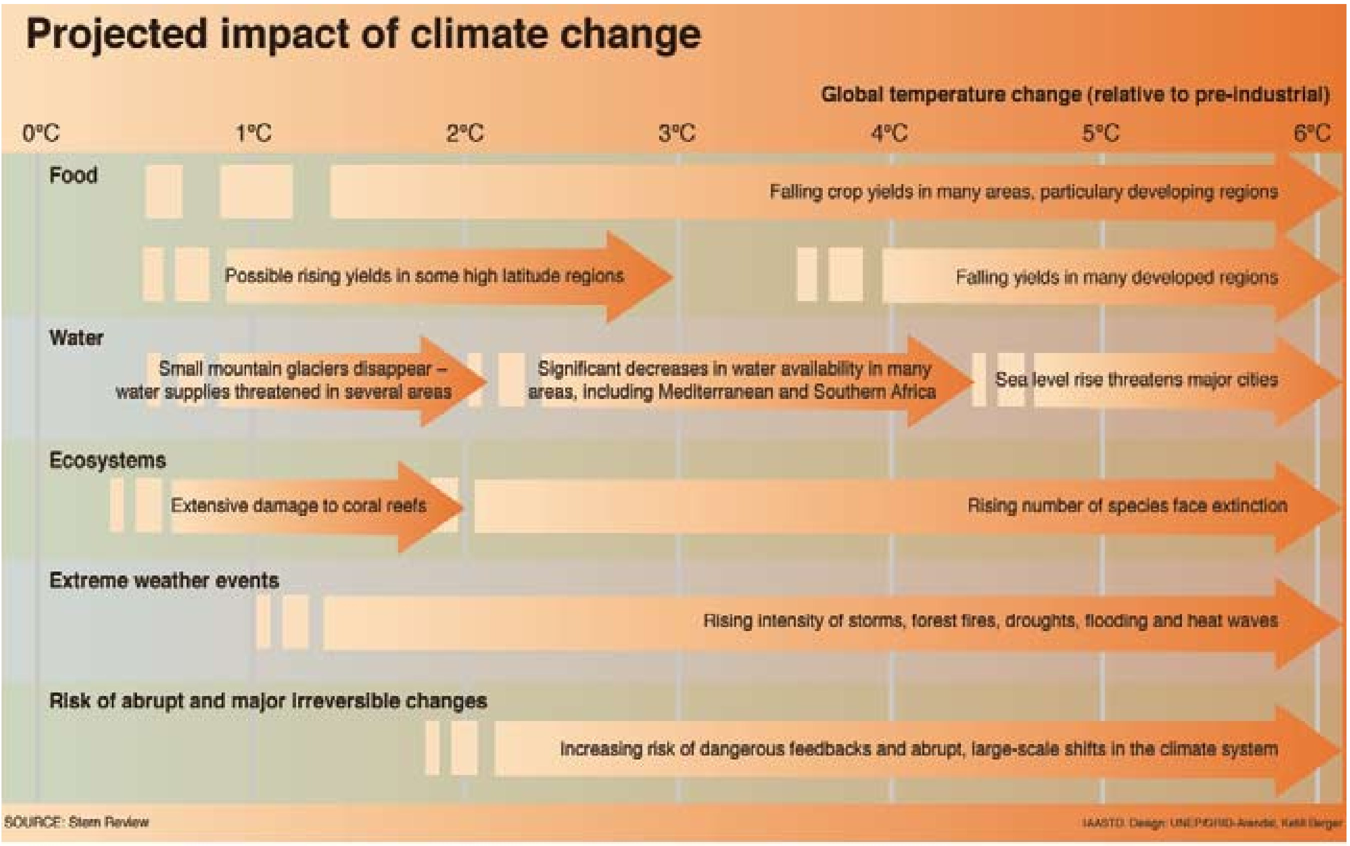


Figure GSDM-7. *Projected Impacts of Climate Change.* Source: Stern Review, 2007.

expected to vary from region to region; in general, the tropics and subtropics will experience negative effects, such as atypical floods and droughts, while temperate regions will have a longer growing season and hence more agricultural production under modest climate change (about 2-3°C rise in temperature) [Chapters 1, 5]. Some dry temperate areas may become drier, resulting in reduced agricultural production potential.

Challenge: Improve social sustainability, increase equity

Progress toward sustainability and development goals is not achievable without more determined involvement of women's knowledge, skills and experience and a redirection of AKST in order to provide opportunities for women. Women farmers, processors and farm workers have benefited less from AKST than men overall and poor women least of all. Efforts to redress persistent biases in their access to production resources, occupational education and training, information and extension services have met with limited success. The societal, policy-related and operational impediments to more equitable progress, as well as the private and public costs of such an uneven pattern of development, are well understood as are the factors that discourage more forceful action. Targeted support for women's participation in their management roles, for instance, in dairying, poultry, small stock breeding, as well as in new enterprises such as high value vegetable, fruit and flower production for export and a range of agroindustries has required innovative institutional arrangements and support to women's organizations, associations of women entrepreneurs and service providers' networks.

Gender equity is an important part of social equity. Women and men, who often have different roles and responsibilities in households and food production, often have different relationships to the various benefits derived from AKST and innovations. Gender-based patterns are context specific, but a persistent feature is that women have a key role in agricultural activities and yet, especially in developing countries, have limited access to and control over productive resources such as land, labor, technology, credit and capital including gender equitable land reform. Despite advances in gender awareness, access to AKST products and participation in AKST processes remain limited for women and for other marginalized groups. Limited attention has been paid to issues of vulnerability and social exclusion, or to the interaction of AKST-related opportunities with social protection policies [Chapter 3].

AKST alone cannot overcome gender and ethnic biases and inequities in agriculture, but insufficient attention to these issues by AKST actors can lead to unintentional increases in inequity. Significant investment in staffing and training for women and ethnic minorities within science and technology centers increases the probability of more equi-

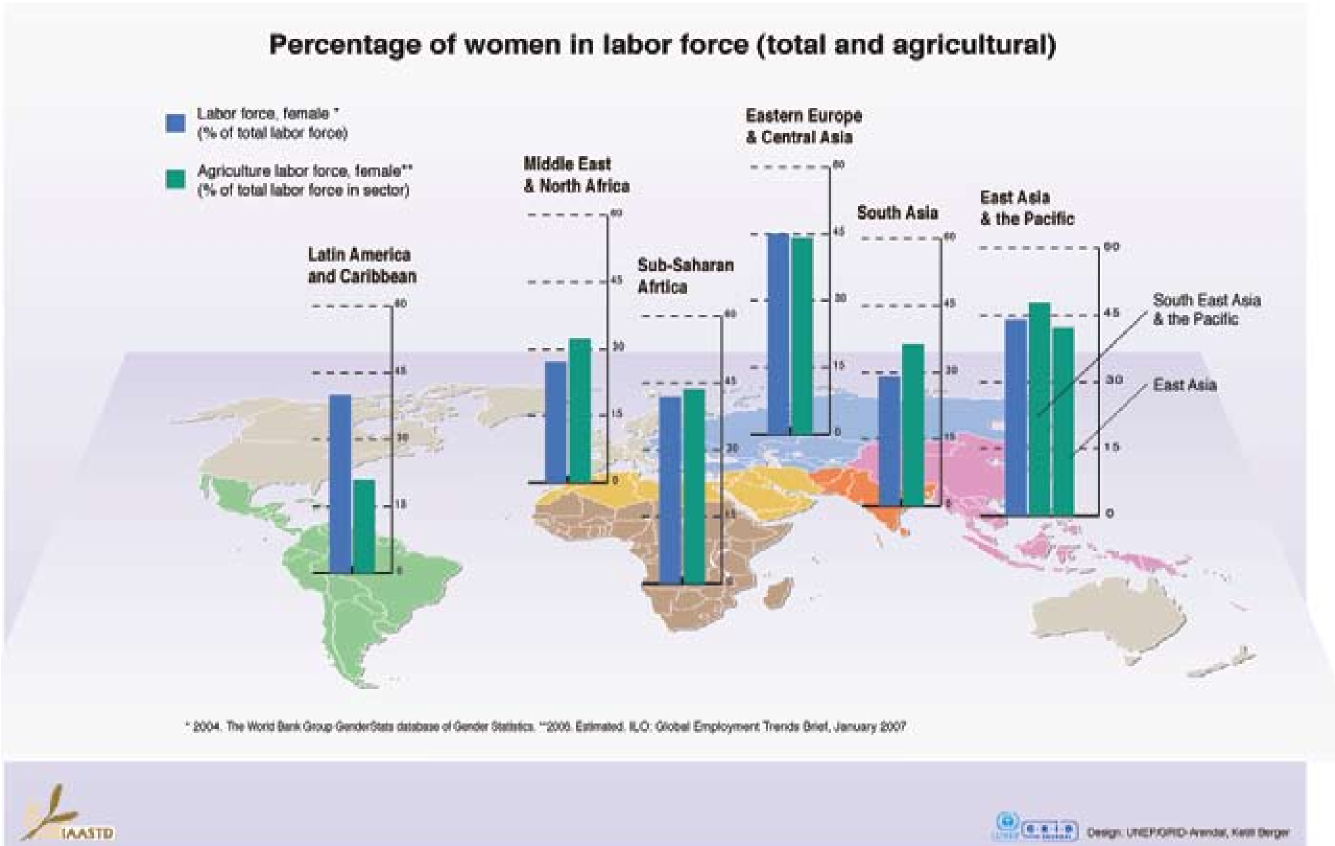


Figure GSDM-8. *Percentage of Women in Labor Force (Total and Agricultural).*

table outcomes for poor women. Unequal gender relations may be exacerbated by projected environmental and economic shocks. Investment in the resilience of local innovation systems should increase the equity of AKST outcomes [Chapter 2].

In general, regions with severe trade disadvantages, biophysical constraints and marginalized social groups have benefited least from innovations in AKST. Furthermore, the distribution of AKST benefits has accrued unequally to those who already hold agricultural assets—land, water, energy resources, markets, inputs and finance, training, information and communications. Policies and institutional arrangements that enable the less powerful to participate in AKST problem formulation and decision making can increase the equity of AKST outcomes, e.g., farmer and scientist research circles, farmer field schools. Regimes of intellectual property rights (IPR) that protect farmers and expand participatory plant breeding and local control over genetic resources and their related traditional knowledge can increase equity. Financial support to farmers' organizations can enable them to approach a range of knowledge and information providers for context-specific solutions.

Challenge: Governance mechanisms for improved institutional and organizational arrangements

AKST arrangements involve ethical choices and value judgments. In some cases they have excluded or marginalized key actors, such as small-scale farmers, with preference being given to short-term over longer term considerations. Some judgments have been privileged over others in AKST decision making. They have helped push formal AKST along certain pathways to the neglect of other well-evidenced options, some originating in traditional knowledge or civil society experience, that are more focused on the multiple roles of agriculture. Strengthening public support for empowering the organizations of farmers and other community-based groups can increase poor people's influence in collaborative AKST arrangements and decision making. Community-based approaches to natural resource management, such as watershed management, community forestry management, integrated pest and crop management and the strengthening of local seed systems, are helping support and integrate social and environmental sustainability although they are not a panacea [Chapters 2, 3; SR-NRM].

Many of the technologies potentially of use in sustainable farming are not adopted because small-scale producers lack access to the means and supporting services necessary to employ the technologies profitably. Those able to access information, credit, inputs, services and markets are better placed to take advantage of what formal AKST has to offer, thereby widening disparities within farming communities. Over time, a technology may diffuse to others, but since the same farmers tend to benefit from each technology release, the ensuing pressure on farm gate prices eventually leads to marginalization of those unable to keep up and to scale enlargement for those who remain. Comparative advantage demonstrates the theoretical efficiency of such a movement of labor to other sectors where it can be productively employed. Yet rural conditions may drive increasing numbers into civil disorder or insurrection and others into unregulated internal or trans-boundary migration, imposing costs that prove unmanageable in the short term. Stagnant national economies and urban areas may not offer a better livelihood or a pathway out of poverty.

These dilemmas pose difficult choices. The challenge of creating realistic farm-based opportunities for small-scale producers requires investments and institutional arrangements that create the conditions in which formal AKST reduces the risk of adoption and increases farm profitability. In the past this has been considered largely a public sector task; the challenge for the future lies in involving a wider range of actors beyond the public sector, including farmers' organizations and commercial enterprises [Chapter 3]. Strong government capacity to understand and where necessary regulate the private sector is needed; for instance through monitoring systems and enforcement of rules, which will help avoid conflicts of interest in AKST decision making. Universities and research institutes receiving substantial private funding may need to set in place oversight mechanisms and codes of conduct that preserve their independence.

The numerous institutional arrangements that connect AKST to practical applications are one of the most widely studied fields in the applied social sciences. Empirically based analysis robustly demonstrates that the transfer of technology approach to date has been the most widely used institutional model for science-driven technology supply in the public sector. This model has successfully driven productivity gains and scale enlargement when applied to properly managed technologies relevant to the target farmers and under the necessary conditions, such as access to markets and properly functioning services. The Chain-linked approach is the model most widely used in demand-led commercial development and is likely to become more dominant as modern markets penetrate deeper into rural areas. It is driven by regular feedback from market research on consumer profiles and preferences throughout the process of technology design and prototype testing.

In general neither model has been sufficiently effective in promoting combined sustainability and development goals. Approaches that foster development of innovation systems along value chains and wide stakeholder participation direct AKST to realizable opportunities. Sustainable management of agroecosystems by farmers requires approaches that develop by a shared understanding of principles and coordination of practices across multiple scales [Chapter 2].

Options for Action

Many of the challenges facing agriculture over the next 50 years will require more integrated application of existing science and technology development (formal, traditional and community-based) as well as new approaches for agricultural and natural resource management. Other challenges will only be resolved by development and application of new AKST [Chapter 6].

The question of which strategies will be best suited to advance development and sustainability goals is controversial and reflects different social and political assumptions, interests and values. In many areas of science and technology discourse, the tendency is for a single interpretation, which attributes cause and effect to some events or situations and not to others. This selectivity has important implications for projecting science in specific directions. Acknowledging competing well-supported narratives of science and technology approaches is crucial for designing effective policies. In many cases, AKST strategies that recognize the multiple functions required of sustainable agricultural systems (e.g., production, livelihoods, ecosystem services) already exist and some AKST recognizes the biophysical, socioeconomic and cultural diversity among agricultural systems that necessitate domain-specific solutions. For example, community-based innovation and local knowledge combined with formal AKST approaches, such as agroecology and agroforestry, can address issues relevant to rural poor people [Chapter 3].

By integrating expertise from other sectors there is more potential to develop solutions that increase productivity, protect natural resources and livelihoods and minimize agriculture's negative impact on the environment. Knowledge and technology from sectors such as communication, energy and health, as well as culture and arts can enhance the capacity of agriculture to contribute to reaching development and sustainability goals. Farmers need a choice of options to respond to challenges, given their diverse needs and resources, and to address the increasing complexity of stresses under which they operate [Chapters 2, 3].

Creating such opportunities requires more targeted changes, such as providing poor farmers in developing countries with infrastructural and institutional support (e.g., access to land and water, transport facilities, AKST, market information, entry into higher value markets, protection from unfair competition) food stockholding policies, and agreements between consumers in industrialized economies and producers in developing countries, as well as support to farmers organizations and for farmer to farmer arrangements within and between countries [Chapters 2, 3, 7].

The need is urgent to develop and retain knowledge in the agricultural sector. Local authorities, national governments and international organizations can facilitate and develop capacity by investing in education and by promoting new skills and technologies among all farming communities. Policy options include (1) reforming curricula at all levels to improve the attractiveness and societal relevance of agricultural studies; (2) increasing access to technology education and science—informed farm and agroecosystem management knowledge to all those working in the agricultural sector; (3) improving collaboration between ministries (agriculture, water, environment, education) and universities; (4) developing infrastructure to facilitate the use of information and communications technology (ICT) in informal and formal education systems; (5) mobilizing funds from a variety of sources to support agricultural education reform; and (6) encouraging university participation in recovering and recognizing traditional and local knowledge and including the participation of traditional knowledge actors in curricula design [Chapters 2, 3, 7].

Decrease hunger and improve health and human nutrition

Decrease hunger and increase food security. Many of the challenges facing agriculture over the next 50 years will be able to be resolved by more targeted application of existing AKST, institutional reform, approaches for modern and traditional agricultural and natural resource management, and breakthroughs in science and technology. Examples involving better resource management include improved soil and water management to increase water retention and decrease erosion; strengthened organizational capacities to address emerging water scarcity by increasing water productivity and providing increased value per unit of water used; wider deployment of soil conservation measures; use of microbiological techniques to suppress diseases in soils; and the use of phosphorus-solubilizing bacteria. Other examples of using existing AKST include integrated pest management (IPM) supported by farmer experimentation and learning; molecular techniques; and modeling of pest and alien species dynamics to reduce reliance on chemicals to maintain human and ecosystem health while addressing emerging pest threats posed by climate change. Integrated crop, tree, livestock and fish systems can be intensified and managed as multifunctional agricultural systems with less negative consequences to ecosystems [Chapter 6].

Future options include new cultivation techniques and improved varieties of crops, livestock, fish and trees developed through accelerated processes, such as traditional and participatory breeding combined with marker assisted selection, genomics and transgenic approaches. These options could facilitate adaptation to a wider range of habitats and biotic and abiotic conditions, increase yields, enhance nutritional quality of food, produce nontraditional products and complement new production systems, provided environmental and social risks are properly addressed. Integrated advances in nanotechnology, remote sensing, geographic information systems, global positioning systems and information communication technology could provide opportunities for more resource-efficient and site-specific agriculture.[5] [Chapter 6].

AKST can be harnessed to mitigate greenhouse gas (GHG) emissions from agriculture and to increase carbon sinks and enhance adaptation of agricultural systems to climate change impacts. New technologies could reduce the reliance of agriculture and the food chain on fossil fuels for agrochemicals, machinery, transport and distribution. Existing AKST could also help reduce fossil fuel dependency given changes in institutional arrangements and incentives. Emerging research on energy efficiency and alternative energy sources for agriculture will have multiple benefits for sustainability. There is considerable potential for expanding the use of digesters (e.g., from livestock manure), gasifiers and direct combustion devices to generate electricity. More research and development is needed to reduce costs and improve operational reliability [Chapter 6].

Some existing approaches to food production have the potential to address inequities created by industrial agricultural practices and to internalize many of the environmental and social costs that modern practices have externalized. Such approaches can become effective if alliances exist among producers and consumers. One technique for land rehabilitation is agroforestry, which has developed community-based techniques in land rehabilitation that offer opportunities to (1) increase yields of staple food crops; and (2) create productive mixed cropping systems for small-scale producers in which perennial cash crops and indigenous food species replace the need for unproductive forest fallows in shifting cultivation and support food sovereignty [Chapters 2, 3, 7].

Internet access and the spread of mobile phones already facilitate the exchange of scientific, technological and market information among farmers, scientists, commercial enterprises, advisory and extension workers and other stakeholders. However, private and public organizations will need to provide more access to information, such as climate forecasts, market prices and pest dynamics, for a diversity of user groups. The ready availability of affordable ICT will provide new opportunities for improving natural resource management, food security and livelihood strategies of rural communities [Chapters 3, 5, 6].

The potential for precision agriculture, ICTs, ecological production, nanotechnology and other emerging technologies to help advance development requires institutional development to create the conditions in which such technologies can generate opportunities for resource-poor producers in diverse local conditions. Technological, policy and institutional development go hand in hand and reinforce each other. Global food security and national food sovereignty call for ending the marginalization of producers in developing countries [Chapter 3].

Improve human health and nutrition. Promotion of health and good nutrition levels cannot be divorced from political and social conditions that are grounded in environmentally sustainable approaches, and that include an educated and informed public, a regulatory and implementation framework, and government accountability that ensures food stock management, control over food production, marketing, pricing and distribution, disaster preparedness and other aspects embedded in food sovereignty.

Developing and implementing good agricultural practices (GAPs), including integration of ecological processes across production systems, will help ensure animal and plant health as well as promote food safety. In countries with limited facilities for implementation and monitoring of occupational health and food safety standards, the best option to limit risks from exposure to agrochemicals is to eliminate the use of category 1a/1b chemicals (WHO Highly Hazardous Chemicals) and promote alternative pest management including IPM, agroecological approaches, biocontrols, organic farming, and farmer field schools.

Where they can be effectively monitored and enforced, GAPs can help manage risks associated with pathogen contamination of such foods as fruits and vegetables. Implementing GAPs may help developing countries cope with globalization without compromising sustainable development objectives. Analysis of hazards can target issues of biosecurity, disease monitoring and reporting, input safety (including agricultural and veterinary chemicals), control

[5] Kyrgyzstan.

of potential foodborne pathogens and traceability. Public education on improved food handling and nutrition and improved sanitation systems throughout the food production chain are integral to managing the risks associated with pathogens. With new research on the effects of agricultural practices on environmental and human health, and the development of environmentally safe alternative practices, safety standards will need to evolve that are capable of responding to the effects of climate change, new technologies and human mobility [Chapters 3, 6]. One of the problems with GAPs, standards, sanitation systems, hazard analysis, etc., (particularly in the poorest countries) is that they require often unaffordable resources, and assume standards of implementation that are as yet beyond reach.

Integrating policies and programs across the food chain can help reduce the spread of infectious diseases. Focusing on interventions at a single point along the food chain may not provide the most efficient and effective control. Control of zoonotic diseases requires rapid identification and communication of disease outbreaks; financial compensation; and training and strengthening of coordination between veterinary and public health infrastructure. Identifying emerging infectious diseases and responding effectively to them requires enhancing epidemiologic and laboratory capacity and providing training opportunities. Grounding agricultural systems and advances in AKST in ecological and epidemiological principles would help avoid emerging outbreaks of pests and diseases.

Strategies for improving nutritional health include nutrition education at all levels, regulation of product formulation through legislation (e.g., banning the use of transfats in processed foods in Sweden, reducing quantities of salt in the UK); increasing the marketing incentives for fresh produce such as fruits and vegetables; and adopting fiscal policies (taxation, trade regimes) that take into account population health effects. New efforts to use indigenous species and produce locally important foods may help to improve micronutrient intake [Chapters 3, 6, 7].

Many constraints (e.g., political, market, trade, economic, institutional) prevent the full deployment of current technologies to improve food safety and public health. Effective national regulatory standards and liability laws that are consistent with international best practice and the infrastructure to ensure compliance will be necessary to meet development and sustainability goals. Infrastructure needs include sanitary and phytosanitary surveillance programs for animal and human health, laboratory analysis and research capabilities (e.g., skilled staff for research) and training and auditing programs [Chapter 2]. However, given the limited resources and lack of effective control of public agencies in many countries, the most effective options are to remove hazards to the extent possible, and promote coherent policies that support safer pest and disease management. National and regional trust funds and expanding current aid for trade commitments are innovative ways to finance this capacity development [Chapter 7].

Decrease poverty and improve rural livelihoods

Developing countries are vulnerable to rapid fluctuations in world food prices and their agricultural and food systems are unlikely to be resilient to environmental, political and economic shocks. Policy options to enable these countries to respond to crises and achieve food security and sovereignty include greater democratic control (local, national, regional) and public sector involvement in agricultural policy, specifically through empowering farmer organizations, national governments and regional trading blocs. Other policy options include improving (1) security of tenure and access to land, germplasm and other resources; (2) diversification with locally important crop species; (3) access to resources (e.g., credit, nutrients); (4) supporting rural livelihoods by transparent price formation and functioning markets with the objectives of improving small farm profitability and helping ensure that farm-gate prices are above marginal costs of local production; and (5) strengthen social safety nets. These options imply a fundamental transformation of AKST and economy wide approach to agricultural policy [Chapters 3, 7].[6]

Increased agricultural trade can offer opportunities for the poor. At the same time, growing evidence indicates agricultural trade liberalization to date has not significantly benefited small scale farmers or rural communities in many countries. Approaches to give small-scale farmers greater opportunity to invest, innovate and to make AKST effective as a tool for improving rural livelihoods include a suite of policy options to stabilize and increase farm-gate prices.[7] These options include developing rational subsidy strategies wherever possible and renewed efforts to reduce trade distorting subsidies in developed countries to establish fair competition in the global market; streamline and improve provision of legitimate anti-dumping measures and provide temporary protection; and improve international market access for developing countries, and establish new contractual arrangements[8,9] [Chapters 3, 7].

Increase equity

Opening national agricultural markets to international competition can offer economic benefits, but can lead to long-term negative effects on poverty alleviation, food security and the environment without basic national institutions and infrastructure being in place. Some developing countries with large export sectors have achieved aggregate gains in GDP, although their small-scale farm sectors have not necessarily benefited and in many cases have lost out. The small scale farm sector in the poorest developing countries is a net loser under most trade liberalization scenarios that address this question. These distributional impacts call for differentiation in policy frameworks as embraced by the Doha work plan (special and differential treatment and non-reciprocal access). Developing countries could benefit from reduced barriers and elimination of escalating tariffs for processed commodities in developed and developing countries; and they could also benefit from reduced barriers among themselves; deeper generalized preferential access to developed country markets for commodities important for rural livelihoods; increased public investment in local value

[6] Australia and USA.

[7] Cameroon.

[8] Australia.

[9] Australia, Brazil, Canada, Costa Rica, Cuba, El Salvador, Honduras, Panama, Paraguay, USA and Uruguay.

addition; improved access for small-scale farmers to credit; and strengthened regional markets.[10, 11]

Intensive export-oriented agriculture has increased under open market operations that has been accompanied by both benefits and adverse consequences depending on circumstances such as exportation of soil nutrients and water, unsustainable soil or water management, or exploitative labor conditions in some cases. AKST innovations that address sustainability and development goals would be more effective with fundamental changes in price signals, for example, internalization of environmental externalities and payment or reward for environmental services.[11] In addition, the quality and transparency of governance, including increased participation of stakeholders in AKST decision making is fundamental to improved sustainability and development outcomes [Chapter 7].

Brokered long-term contractual arrangements (market alliances, commodity chains, public and private outgrower schemes, etc.) have proved effective in improving the livelihoods of small-scale farmers. These approaches can promote value-chain activities and generate employment, provided there is transparency and equitable power relations among actors. They can allow small-scale producers to respond to opportunities through institutional arrangements that provide market access and credit for inputs and planting materials. In a number of cases these schemes have fostered misuse and corruption, compromising their effectiveness. The contribution of these arrangements needs further testing to determine if they generate sufficient opportunity in resource-poor agricultural systems [Chapter 7]. Other proven policy approaches include expanding access to microfinance, financing value chains and local markets, streamlining food chains, supporting fair trade and organic agriculture as diversification and value addition strategies, and encouraging large-scale sustainable trading initiatives by the private sector. The trade policy environment, including reducing or eliminating escalating tariffs on agricultural products in developed and developing importing countries, along with the strengthened national institutions and infrastructure, including improved local and regional market linkages, are key determinants of whether these policy approaches will produce pro-poor results on the ground [Chapter 7].

In the absence of strong local and national institutions that are supportive of development and sustainability goals, the transfer of productivity-enhancing technologies does not significantly benefit resource-poor, risk-exposed producers. The global linear transfer of research and technology results in imbalanced competition between farming systems that have been supported by public economic investments for decades and systems that have never received comparable public investments. Policy options to promote innovation systems for pro-poor development (as opposed to technology transfer per se) and to strengthen poor people's participation in AKST governance are essential if development and sustainability goals are to be reached [Chapter 7].

Technologies such as high-yielding crop varieties, agrochemicals and mechanization have primarily benefited the better resourced groups in society and transnational corporations, rather than the most vulnerable ones. To ensure that technology supports development and sustainability goals, strong policy and institutional arrangements are needed to balance private, communal and national rights systems regarding knowledge and resources. Policy options to redress the weaknesses and inequities[12] in the current rights systems on intellectual property and genetic resources may include (1) a closer connection between protection levels and development goals; (2) explicit policies regarding the management of intellectual property in public organizations; (3) the preservation, maintenance, promotion and legal protection of traditional knowledge and community-based innovation; and (4) options for benefit-sharing of genetic resources and derived products.[13] Natural resource management policies are needed to explicitly address how access and ownership is shared among the communities from which these resources originate [Chapters 3, 7].

Society benefits when women are engaged in decision making, and when they have access to AKST and resources such as land, water and agricultural inputs and seeds. Health services, childcare and education support women's participation in agriculture. Preferential targeting of AKST and additional public support are needed to prepare resource poor women to become effective market participants [Chapter 5].

Environmental Sustainability and Natural Resource Management

Advances in AKST can help create synergy among agricultural growth, social equity and environmental sustainability [Chapters 3, 5]. Integrated approaches to AKST can help agriculture adapt to water scarcity, provide global food security, maintain ecosystems and provide sustainable livelihoods for the rural poor. Integration of food production with other ecosystem services in multifunctional systems can advance multiple goals (e.g., integrated rice and aquaculture systems, integrated crop and livestock systems). AKST can help increase water productivity by reducing field losses of water (e.g., precision and micro-irrigation) and through breeding and soil and crop management. The greatest potential increases in water productivity are in rain fed areas in developing countries; contour farming, ridging, no-till, increased soil organic matter and water harvesting can increase soil water retention and reduce runoff in these areas [Chapter 3]. Improved design and management of large dams and irrigation systems can maintain aquatic and riparian ecosystems, avoid siltation and salinization, and create greater equity between upstream and downstream users. Improvements in water quality can be achieved through policies which combine enforceable regulations to reduce and prevent contamination of ground and surface water by agricultural inputs with investment in AKST [Chapter 6].

The ecological footprint of industrial agriculture is already too large to be ignored and projected increases in future global environmental changes could make the footprint even larger. Policies that promote more rapid uptake of proven AKST-based mitigation and adaptation solutions can contribute to checking or reversing this trend while maintaining sufficient food production. Policies that

[10] Australia.
[11] Brazil, Cuba, Ethiopia and Uganda.
[12] Canada and Uganda.
[13] Canada.

promote sustainable agricultural practices (e.g., using market and other types of incentives to reward environmental services) stimulate more technology innovation, such as agroecological approaches and organic farming to alleviate poverty and improve food security. Growing pressure on natural resources requires new investment policies for AKST. Innovative and better targeted AKST investment policies are essential to build natural, human, financial, social and physical capital for social and environmental sustainability [Chapter 8].

Sustainable fisheries require practical and efficient application of an ecosystem approach, which might include improved monitoring, control and enforcement, and be underpinned by a certification system. Marine protected areas could be expanded and prices of fishing concessions increased. A range of AKST policy responses is needed to ensure appropriate choices on how best to utilize and share resources, and reduce negative environmental and social effects of aquaculture. Appropriate policies would include ending subsidies for unsustainable technologies [Chapter 3].

Payment or reward for performance-based ecological services (PES) recognizes the importance of the multiple functions of agriculture and creates mechanisms to value and pay for the benefits of resource-conserving ecosystem services provided by sustainable agricultural practices, such as low-input and low-emission production, conservation tillage, watershed management, agroforestry practices, carbon sequestration, biological control and pollination, and conservation of agricultural biodiversity. Other policy approaches that are already in use in various countries, which would reduce the negative footprint of agriculture include taxes on carbon, agrochemical use and water pollution. Such taxes provide incentives to reach internationally or nationally agreed use-reduction targets and support resource-conserving and low-emission technologies. They provide incentives for multifunctionality in using agricultural land, broadening revenue options for land managers and allowing carbon-impact food labeling. Another option includes prohibiting particularly damaging practices in highly vulnerable areas (e.g., deforestation in tropical forest margins, use of toxic chemicals in watershed headways and near streams). To meet development goals, incentive and regulatory systems can be designed to ensure stable revenues for small-scale farmers and local communities, such as product certification for geographical origin and organic agriculture. The long-term sustainability and equity of the benefits generated by these systems is an area for further research [Chapters 3, 7].

AKST can play a proactive role in responding to the challenge of climate change and in mitigating and adapting to climate-related production risks. Climate change both influences and is influenced by agricultural systems. The direct negative effects of climate variability and projected climate change will predominately be felt in the tropics and subtropics. AKST can be harnessed to mitigate greenhouse gas (GHG) emissions from agriculture, to increase carbon sinks and biodiversity (e.g., tree planting and conservation tillage), and to enhance adaptation of agricultural systems to biotic and abiotic results of climate change. However, some of these policies could increase competition for resources, e.g., agriculture for food vs. bioenergy and forestry for carbon sequestration. Some models that simulate very low stabilization levels (450 ppmv CO_2-equivalents) indicate a need for measures, such as carbon sequestration and bioenergy plantations, that would compete with land for food. Advances in AKST and a focus on local knowledge could reduce the reliance of agriculture and the food chain on fossil fuels for agrochemicals, machinery, transport and distribution. Emerging research on energy efficiency and alternative energy sources for agriculture will have multiple benefits for sustainability [Chapters 3, 5, 6].

A negotiated global long-term (30-50 years), comprehensive and equitable regulatory framework with differentiated responsibilities and intermediate targets to reduce GHG emission could limit the magnitude of human-induced climate change, which is projected to undermine agricultural productivity throughout the tropics and sub-tropics. An expanded Clean Development Mechanism could be used, with a comprehensive set of eligible agricultural mitigation activities and within a national sectoral approach, including a wide range of practices (e.g., tree planting, no-till, livestock and rice paddy management). The advantage of these approaches is that they are applicable to the conditions of small scale agriculture in developing countries, but require transparent and accountable processes and frameworks to function effectively. Other approaches could include reduced agricultural subsidies to cropping systems that promote GHG emissions [Chapter 7].

To address expected climate change challenges and impacts, a major role for AKST is needed to increase adaptive capacity and enhance resilience through purposeful biodiversity management. Options include irrigation management, water harvesting and conservation technologies, diversification of agriculture systems, the protection of agrobiodiversity and screening germplasm for tolerance to climate change. These measures would need to be supported by appropriate policy options, integrated spatial planning, and early warning and communication infrastructure that support the generation and dissemination of adaptation knowledge, technologies and practices.

Research is needed to better understand the potential benefits and harms of producing bioenergy, which are strongly dependent on local circumstances. Some countries are currently promoting or developing domestic biofuel policies with the aim of furthering rural job creation and economic development as well as mitigating climate change. But negative effects on poverty (e.g., rising food prices, marginalization of small-scale farmers) and the environment (e.g., water depletion, deforestation) may outweigh these benefits and need to be carefully assessed.

Given that first-generation biofuels are often not economically competitive with petroleum fuels, most biofuel policies rely on a complex set of subsidies and regulations to promote production. Small-scale biofuels could offer livelihood opportunities, especially in remote regions and countries where high transport costs impede agricultural trade and energy imports. The next generation of liquid biofuels (cellulosic ethanol and biomass-to-liquids technologies) could possibly mitigate some of the concerns about first-generation biofuels. It is not clear when these technologies might become commercially available. Considerable capital costs, large economies of scale, a high degree of technological sophistication and intellectual property rights issues

Table GSDM-1. *Examples of policy approaches to advance development and sustainability goals.*[1]

Policy approaches	Poverty and livelihoods	Hunger and nutrition	Human health	Environmental sustainability	Social equity and inclusion (including gender)	Economically sustainable development
Payment for ecosystem services	• Security of tenure • Fair local justice systems • Administrative capacity for fair distribution • National frame-works to protect poor people's rights effectively			• Carbon sinks • Sustainable management of wetlands and ground-water • Flood control	• Recognition of discrimination and exclusion and enforce-able means to redress these	• Long-term markets for eco-nomic viability • National eco-nomic policy to maintain commitment to goals of ecosys-tems services payment mech-anism
Germplasm management	• Farmers' seed rights recognized and protected • Sui generis poli-cies recognized in IPR patents & legally protected	• Effective complemen-tarity between advanced techniques for germplasm management & participatory plant breeding • Recognition of consumer preferences with respect to GM products	• Capacity for effective regu-lation, testing • Effective government capacity to negotiate international agreements (with private sector and international agencies)	• National policy on biodiversity • Effective na-tional policy practice for maintaining adequate bio-diversity (in-cluding capac-ity to monitor and act) • Ensure no cross-contam-ination	• Policy for identifying and working with women and ex-cluded groups • Effective local mechanisms for implemen-tation	• Sufficient in-volvement of technology users in sci-ence policy and practice • Sufficient capi-tal and technical infrastructure to sustain a relevant national germplasm research policy
Water management	• Legally recog-nized rights for poor people to access water resources	• Access rights to water for agricultural purposes	• National and international regulations to reduce the use of toxics • Investment in reliable do-mestic water & sanitation facilities • Scientific capacity to assess current & potential water-induced health prob-lems	• Transitions from manage-ment of water use functions to manage-ment of hydro-logical cycles • Capital in-vestments in landscape & engineering works • Payment mechanisms for ecosystem services • Incentives for sustainable management of ground-water	• Legally recog-nized entitle-ments for all residents which are technically & legally en-forced	• National plans for water management (including flood management, ground water extraction, eco-logical status of surface water, irrigation sys-tems, etc.) • Fair trans-boundary water management agreements • National & international mechanisms for adjudicat-ing competing water claims

[1] USA.

make it unlikely that these technologies will be adopted widely in small developing countries in the next decades. Research and investments are needed to explore risks and potentials of these technologies [Chapter 6].

There is also considerable potential for expanding the use of digesters (e.g., livestock manure), gasifiers and direct combustion devices to generate electricity, especially in off-grid areas and in cogeneration mode on the sites of biomass waste-generating industries (e.g., rice, sugar, paper mills). Research and investments are needed to explore their costs and benefits, particularly in developing countries [Chapter 6].

Improved Governance: Institutional and Organizational Arrangements

Most participants in intergovernmental processes recognize the importance of political commitment and ensuring full and meaningful participation of stakeholders across scales in forming and implementing policy regarding agriculture. In some countries diverse groups including civil society and the private sector collaborate in the development of policy; they are informed by scientific and empirical evidence and represent public interests. In these cases policies have focused on the multifunctionality of agriculture and have aimed to meet a broad range of goals, which include crop productivity, sustainable economic development, environmental sustainability, health and social well-being [Chapters 2, 3].

The wider application of AKST institutional models capable of addressing the combined development and sustainability goals requires resources to support the transaction costs of interaction among the partners as an integral part of the innovation process. In some cases, as in multi-organizational arrangements involving supermarkets or commercial actors in market-oriented value chains, these costs can be recovered from the commercial returns. In other cases, public subsidies (e.g., arrangements between farmers' organizations, advisory service providers, and global science networks), or private funding (e.g., arrangements between farmers' organizations, technology providers and intermediary organizations such as development foundations or NGOs) may be required, drawing on the lessons of past successes and failures.

Institutional arrangements with proven potential for advancing sustainability and development goals include farmers' participation in plant breeding as well as adaptive research; the provision of R&D funds to research users for contracting services from AKST suppliers; and staffing catchment management agencies to facilitate multi-organizational collaboration in the AKST needed to support agroecosystem management. Other modalities with proven potential to progress toward sustainability and development goals include multi-organizational arrangements to support the AKST needed by Farmer Field Schools and farmer-scientist research circles; AKST networks between NGOs, farmers' organizations and research institutes; collaboration among public sector AKST providers, within and between developing countries; and various farmer-to-farmer arrangements [Chapters 2, 3].

A growing number of actors is participating in creating and improving the conditions in which AKST can have a high payoff for small-scale producers. These conditions include roads, market facilities, irrigation schemes and services relevant to small scale producers' and laborers' needs. In some circumstances public actors particularly at local government levels can play an enabling role to facilitate the participation of, for instance, NGOs, farmers' organizations, professional associations, private sector and scientific organizations and unions in providing infrastructure and services; in others public actors necessarily will remain the main provider.

Publicly funded research and education institutes in some countries, especially in sub-Saharan Africa, have weakened considerably. Innovative forms of collaboration are emerging such as regional networks, public-private consortia, more effective division of labor and capacity between research institutes and universities, and recognition of the research roles that NGOs and farmers themselves play. Persistent problems include competence in some scientific fields, movement of capacity to industrialized countries and the private sector, and weak incentives for science in both public and private sectors to address pro-poor issues. Global and transboundary issues call for new arrangements for co-operation and capacity development that will need adequate resourcing.

Investments

More and better targeted public and private investments in AKST can make major contributions to meeting development and sustainability goals. Included are investments in developing technology and management systems that more efficiently use scarce resources such as land, forests, water, and, in the future, fossil fuels; in helping protect ecosystem services by reducing GHG emissions, reducing water pollution, and slowing or reversing the loss of biodiversity; and in controlling plant and animal pests and diseases. Additional investments are also needed in areas for which evidence suggests that knowledge gaps exist [Chapter 8].

Governments will continue to play an important role in providing public goods, assuring equitable access to AKST and creating an enabling policy and institutional environment. The political economy and good governance are important determinants in mobilizing resources for AKST; they also play a major role in allocating resources between different AKST components. Increased demand for responsiveness to the needs of the vulnerable, coupled with accountability and transparency are needed to drive changes in AKST investment decisions [Chapter 7].

More government funding and better targeted government investments in AKST in developing countries can contribute in a major way to meeting development and sustainability goals. This increase would involve more investment by the public sector in order to deliver a wide range of global public goods. This increased funding is justified given (1) the potential for high economic ROR in technologies that are applied by farmers in the field; and (2) evidence that AKST investments can help reduce poverty. Public investments must be targeted using evidence other than simply overall ROR to include social, environmental, health and cultural aspects, positive and negative, and the distribution of costs and benefits among different groups. Higher investment in human resource development would facilitate acquiring knowledge and skills in frontier sciences. Funding is also needed for processes that ensure that resource-poor farmers, natural resource managers and other intended ben-

Table GSDM-2. *Examples of enabling conditions for S&T to advance development goals.*

Activity area	Approaches	Institutional arrangements, laws, regulations
Capacity development	• Internet-mediated distance learning & education • Public-private R&D partnerships in e.g., water management • Competitive grant funding to cover costs of field study in tertiary & post-doctoral training	• Occupational education for farmers (including where appropriate farmer field schools) • Research networks & multi-organizational consortia (national, regional, international) • Decentralized R&D facilities in collaboration with village development centers, NGOs, farmer organizations
Generation of knowledge & technology	• Farmer participation in adaptive research • Farmer participation in plant breeding, combining advanced and local knowledge, techniques & skills • Participation of actors along entire value chains in market research	• Evolution of varietal release procedures & criteria to accept & certify farmer-generated seed • Multi-organizational collaboration with local communities in the commercial development of wild and semi-domestic forest species
Access to, use & exchange of information & technology	• Support to farmer-to-farmer networking and extension • Research, extension, farmer collaboration in development & spread of short videos (CDs, etc) and radio programs • Mobile Plant Health Clinics, linked to service laboratories • Trade & market information services based on mobile telephony	• Community and rural school-based service centers with internet access
Science & technology planning	• Inclusion of research & technology users in problem identification and planning decisions • Application of processes and methods for public deliberation concerning new or contentious S&T	• Further development of regional and international forums to drive S&T planning addressing global issues
Science & technology policy	• Participation of civil society, private sector and governments in policy processes and the evolution of framework legislation	• Evolution of seed law to accept sale of certified farmer-produced seed and recognize local seed systems • Strong government regulation of private sector where necessary to prevent conflicts of interest • Implementation of Convention on the Elimination of All Forms of Discrimination (CEDAW) in signatory countries

eficiaries of the research participate in research decision-making [Chapter 8].

Private firms both large and small have been and will in the future continue to be major suppliers of inputs and innovations to commercial and subsistence farmers and can therefore make major contributions toward meeting development and sustainability goals. They will rarely provide public goods or supply goods and services for which there is no market but evidence shows that there are considerable spillovers from private suppliers of technology to farmers and consumers. To make the best use of private investments in AKST, government regulations are needed to address negative externalities and monopolistic behavior and to support good environmental practices, while at the same time providing firms with incentives to invest in pro-poor AKST [Chapter 8].

The ability to allocate human and financial resources effectively will depend on a significant improvement in the capacity of those in both public and private sectors to forecast and respond to environmental, social and economic changes, locally and globally. This will include the capacity to make strategic technological choices, create effective public policy and regulatory frameworks, and pursue educational and research initiatives and extension. The involvement of farmers, the lay public, school children and others in monitoring and risk assessment, improving GIS capability and creating databases and other management information systems can upgrade AKST forecasting capacities, allocate resources appropriately, and provide the data required for making strategic technological choices.

Annex A

Reservations by Governments

Reservations on SDM

Australia: Australia recognizes the IAASTD initiative and reports as a timely and important multistakeholder and multidisciplinary exercise designed to assess and enhance the role of AKST in meeting the global development challenges. The wide range of observations and views presented however, are such that Australia cannot agree with all assertions and options in the report. The report is therefore noted as a useful contribution which will be used for considering the future priorities and scope of AKST in securing economic growth and the alleviation of hunger and poverty.

Canada: The Canadian Government recognizes the significant work undertaken by IAASTD authors, Secretariat and stakeholders and notes the Global Summary for Decision Makers as a valuable and important contribution to policy debate which needs to continue in national and international processes. While acknowledging considerable improvement has been achieved through a process of compromise, there remain a number of assertions and observations that require more substantial, balanced and objective analysis. However, the Canadian Government advocates the Global SDM be drawn to the attention of governments for consideration in addressing the importance of AKST and its large potential to contribute to economic growth and the reduction of hunger and poverty.

United States of America: The United States joins consensus with other governments in the critical importance of AKST to meet the goals of the IAASTD. We commend the tireless efforts of the authors, editors, Co-Chairs and the Secretariat. We welcome the IAASTD for bringing together the widest array of stakeholders for the first time in an initiative of this magnitude. We respect the wide diversity of views and healthy debate that took place.

As we have specific and substantive concerns in each of the reports, the United States is unable to provide unqualified endorsement of the reports, and we have noted them.

The United States believes the Assessment has potential for stimulating further deliberation and research. Further, we acknowledge the reports are a useful contribution for consideration by governments of the role of AKST in raising sustainable economic growth and alleviating hunger and poverty.

Reservations on Individual Passages

1. USA and Botswana prefer to use the word “incorporate” rather than “towards”.
2. USA does not believe that there is sufficient balance in reflecting the use/range of new technologies, including modern biotechnology in Key Findings 10 and 11.
3. Benin, Botswana, DRC, Ethiopia, Gambia, Kenya, Tanzania, Togo, Uganda: the paragraph does not adequately address the need to invest in financial, human, political and physical capital and time in the development and application of new and emerging AKST in developing countries in order to develop capacity to cope with existing and emerging challenges.
4. Australia and USA noted that they would have included the words “the safety in” before the word “GMOs”.
5. Kyrgystan objects to the mention of transgenics in this paragraph.
6. Australia and USA reserve on this sentence.
7. Cameroon does not support strategies leading to increased farm gate prices because these will be reflected in local markets and then weaken the purchasing power of the population. Rather, AKST policy options should act to reduce the costs of production at the farm level in order to lower farm gate prices, while ensuring profitable returns to the farmers.
8. Australia suggests that a number of trade and domestic policy assertions and observations require more substantial, balanced and objective analysis to be meaningful for decision makers.
9. Australia, Brazil, Canada, Costa Rica, Cuba, Dominican Republic, El Salvador, Honduras, Panama, Paraguay, USA and Uruguay state that the above paragraphs must be without implication for any governments’ position in relevant international negotiating fora.
10. Australia suggests that a number of trade and domestic policy assertions and observations require more substantial, balanced and objective analysis to be meaningful for decision makers.
11. Brazil, Costa Rica, Cuba, Ethiopia and Uganda requested that Figure 7.2: Projected gains (losses) for developed and developing countries under Doha scenarios for agriculture; and Figure 7.3: Poorest countries lose income under all Doha scenarios, from Chapter 7 of the Global Report should have been included in this document.
12. Canada and Uganda prefer the following language “to better take into account national policy priorities and characteristics” instead of “to redress the weaknesses and inequities”.
13. Canada does not agree with the last three words “ . . . and derived products.” on point 4.
14. USA suggests deletion of this table since it does not add additional clarity for policy makers.

Annex B

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Annex D

Steering Committee for Consultative Process and Advisory Bureau for Assessment

Steering Committee

The Steering Committee was established to oversee the consultative process and recommend whether an international assessment was needed, and if so, what was the goal, the scope, the expected outputs and outcomes, governance and management structure, location of the Secretariat and funding strategy.

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