Global Report of IAASTD
Summary for Decision Makers

Key Findings

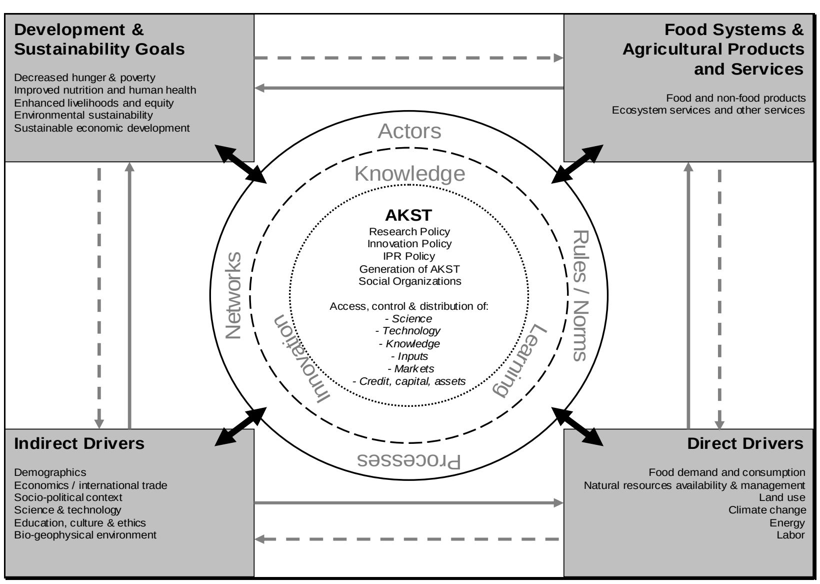
- Agricultural Knowledge Science and Technology (AKST) has contributed to some major developmental achievements, for example reduction of hunger in many parts of the world, however, the drawbacks, e.g., environmental degradation, declining human health and mortality associated with agricultural practices, and social exclusion, are increasingly outweighing the benefits;
- The poorest and most marginalized continue to not benefit by advances in AKST;
- Agriculture policies can no longer externalize the costs of agricultural and food production without great economic, environmental and social risks;
- Successfully meeting the IAASTD sustainability and development goals of reduction of hunger and poverty, the improvement of rural livelihoods and human health, and equitable, socially, environmentally and economically sustainable development, requires placing increased importance on the multiple functions of agriculture, i.e.,
  - production of food and fiber;
  - provision of ecosystem services, and conservation of natural resources and biodiversity; and
  - provision of livelihoods (income, health, nutrition, etc) and supporting the quality of rural life;
- A multifunctional approach to agriculture involves:
  - implementing and developing tools that diversify farming systems;
  - building natural capital and social sustainability by developing agricultural policy and practices in the context of social and environmental sustainability, resources and constraints;
  - contributing to the mitigation of climate change; and
  - investing in AKST on the basis of multifunctional parameters;
- Promising new technologies and approaches exist, based on working with nature and harnessing global knowledge with local and traditional knowledge, coupled with participatory approaches that can help poor people;
- New institutional and public and private organizational arrangements are required to support this locally-important, more integrated approach to the development and dissemination of AKST;
- Achieving the IAASTD sustainability and development goals will require a more holistic and long-term perspective of agriculture by all stakeholders.

Introduction

Agricultural systems are characterized by a high degree of complexity embracing economic, biophysical, socio-cultural and environmental dimensions, with AKST increasingly addressing human behaviors and the institutions (rules and norms) that determine achievement of the sustainability and development goals. The multiple roles of agriculture, which include food security, environmental, social, economic and cultural services vary by geographic scale from local to global and by social context, and are based on often fragile but always interdependent natural systems and social constructions. When the focus of research and extension or other knowledge and information systems is one dimensional, multifunctionality becomes elusive. The value of agricultural public goods, e.g., environmental benefits or the vitality of community life, are under-estimated when the purpose and design of AKST application is primarily production. Achieving multifunctionality is never simple; management for one service or perceived environmental benefit may have negative impacts on other environmental and/or social goals. Key concepts include maintaining ecological and social resilience in a rapidly changing world.

The conceptual framework (Fig. 1) illustrates the inter-relationships among and between the indirect and direct drivers of change, food systems and agricultural products and services, the development and sustainability goals, and how each of these influence and are influenced by AKST. It also recognizes that the political, economic, and social context will vary geographically, as will the ecosystems, agricultural and production systems, which is in part the underlying rationale for the IAASTD sub-global assessments.

Figure 1. IAASTD Conceptual Framework



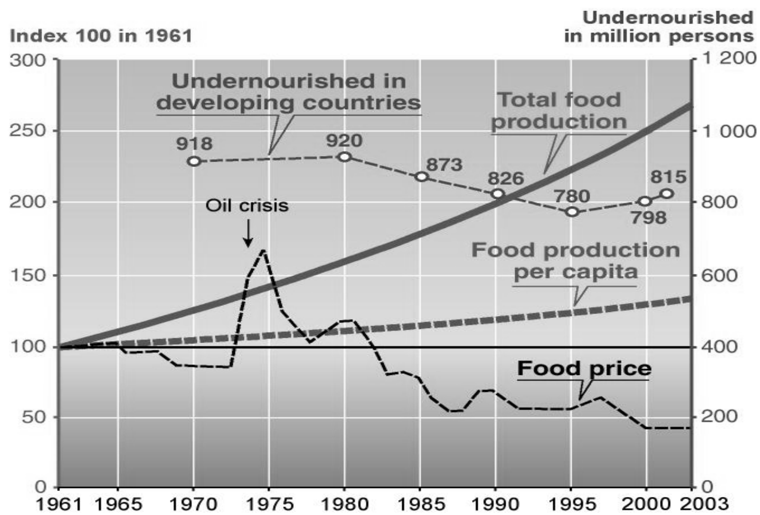
Part I: Present and Past Consequences of AKST on Development and Sustainability Goals

Key messages

- Despite advances in AKST that have enabled substantial gains in agricultural production, there is persistent poverty, impoverished livelihoods, uneven distribution of benefits, declining human health and increasing environmental degradation;
- A range of multifunctional AKST initiatives have addressed the needs of the poor and the degraded environment at the local level, by proactively promoting the pursuit of environmental and social goals in addition to improved total production;
- The outcome of AKST depends on contextual, historical and political conditions and increasingly involves organizational partnerships and institutional reforms, driven by a need to realize synergies among different disciplines, sectors, and actors within and between local, national and global institutions.
- Achieving the sustainability and development goals through AKST requires: (i) recognizing the limitations of technology supply push to initiate market driven diffusion and treadmill processes at the expense of more participatory approaches; (ii) inter- and multi-disciplinarity; (iii) commercial, ethical and environmental considerations; (iv) involvement of all stakeholders; (v) targeting of populations and regions at risk; and (vi) a long-term perspective.
- While on average investments in AKST are still growing, but at a decreasing rate for the public sector during the 1990s, there is evidence of under-investment in AKST. AKST in the more-developed world is increasingly undertaken by the private sector.
- Public investments in AKST have significantly contributed to overall economic growth, but this has not always resulted in poverty reduction or resource sustainability. Economic rates of return alone are insufficient to guide AKST investment decisions, which have economic, social, environmental, health and cultural costs and benefits to society.
- The level, effectiveness and efficiency of AKST investments and their contribution to broader sustainability and development goals vary with governance, which is in general improved with the participation of non-governmental stakeholders.

Advances in AKST have enabled substantial gains in agricultural production. World cereal production has more than doubled since 1961, with average productivity increasing 250% in both high- and low-income countries. These increases in productivity have been accompanied by decreases in post-harvest loss and a persistent downward trend in the real price of food staples, including cereals. Where policy and market conditions have allowed, this has resulted in major benefits to people’s nutrition and health, as well as to farmers’ livelihoods and the economic growth of some countries. In developing countries the proportion of people consuming less than 2200 kcal per day dropped from 57% in 1964-66 to just 10% in 1997-99. In Asia the proportion suffering from chronic hunger halved from 40% to 20%. With a focus on calorie production, levels of hunger have declined sharply, but hunger and malnutrition have not been eliminated - there are currently an estimated 800 million hungry or 1.2 billion income-poor, with women and children being the worst affected. Micronutrient deficiencies have fallen in some areas due to recent expansion of AKST to crops such as vegetables, pulses and fruits, which also diversify the diet. Recent developments in biotechnology, and especially the development of new transgenic cultivars, may offer opportunities for a new generation of technological KST, although it has yet to be demonstrated that they deliver the multifunctional outcomes needed. Currently, this new technology is being favored by a few multinational companies and the advances are being implemented in a small number of countries where concerns[1] about the ecological, social and health impacts have not led to the government placing a ban on field trials and wider cultivation.

Figure 2. Trends in food production and price



Sources: FAOSTATS, SOFI, Millennium Ecosystem Assessment

Despite much progress in crop and livestock breeding and in agricultural technologies, persistent problems of uneven distribution of benefits, declining health and increasing environmental degradation exist. Additionally, poverty and impoverished livelihoods still affect hundreds of millions of people.

[1] Some of these concerns relate to the process of evaluation and the inherent asymmetry in evidence gathering, i.e., almost exclusively under the purview of the developer.

a. ***Unevenly distributed productivity benefits.*** Poor countries (especially in sub-Saharan Africa) have gained proportionately less than some richer countries (USA and Europe).[2] Similarly, major benefits have escaped marginal agroecological regions (rain-fed dryland areas) and marginalized people (small-scale farmers, rural and urban laborers, landless people, women and the poorest. Fifty years of public support to research, extension, subsidization of inputs, protection, etc., has led to a situation where the added value per worker in industrial agricultures (high input, highly capitalized, relatively large scale, embedded in networks of institutional support) is now so much higher than in resource-poor (rain fed, diverse, high risk, low input) agricultures, that the latter have no hope to compete, even in their own markets. Reasons vary and are complex. Household purchasing power parity and not crop yield is the single greatest determinant of household food security. Capacities to make use of formal AKST and thus the benefits differ between countries, regions and social groups, including access to formal knowledge, resources,[3] commercial and other infrastructure and agricultural services/inputs. In addition, through policy instruments and commercial pressures (e.g., trade rules and regulations and property rights), AKST has often been inappropriately applied – especially in relation to the needs of poor producers and women.[4]

b. ***Negative health impacts have arisen from land use change, increasingly extended food chains, urbanization, dietary changes, and misuse of chemicals.*** Totally inadequate coordination between human health and agricultural knowledge systems has undermined the potential to manage and control major diseases, e.g., water-borne diseases in irrigation systems, animal diseases infecting humans, e.g., Avian bird flu and Mad Cow Disease, possibly causing large-scale epidemics, as well as the potential to realize the goal of food for all and further reduction of hunger. Certain AKST systems and practices have negative impacts on human health, notably the risks of chemical misuse and wider pollution, which in turn affect agricultural production itself through reductions in labor productivity and increased costs of household care. Socio-economic trends have resulted in unprecedented dietary and health transitions.[5] Worldwide there are now more overweight people who are suffering from obesity, than there are underweight and suffering from undernutrition[6] and micronutrient deficiencies. This results from more people eating foods (often highly processed) high in calories, fat and sugar, sodium and

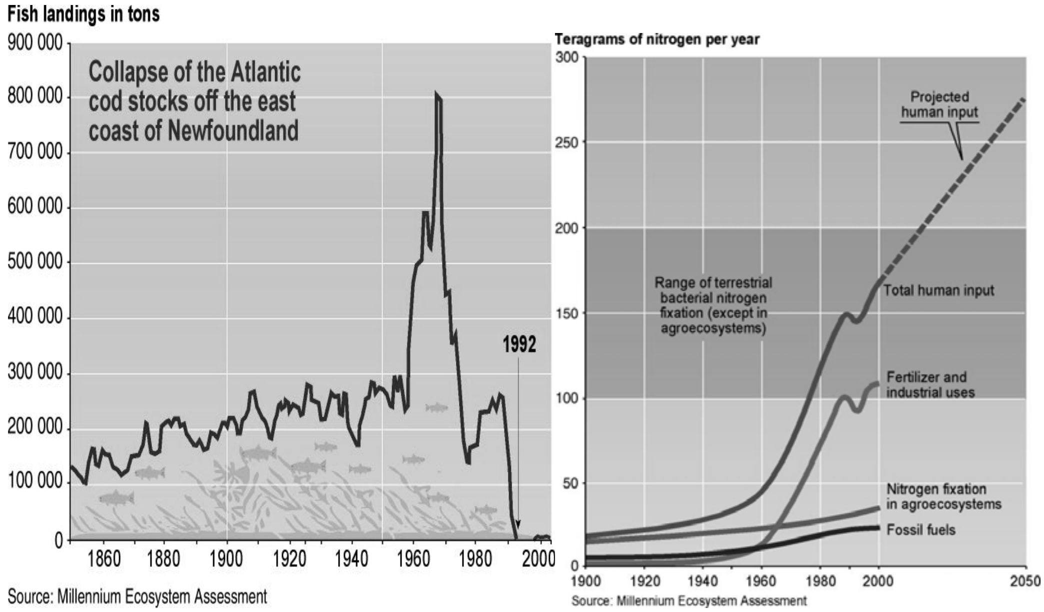
[2] Advances, e.g., adoption of yield enhancing technologies, coupled with the organization of markets and prevailing power structures, have resulted in millions of people leaving farming in North America and Europe.
[3] Tractors profoundly increase productivity yet access to tractors is very limited (about 2% of farmers).
[4] While AKST can generate productivity and prosperity, it can also contribute to inequity and poverty.
[5] Strongly influenced by factors such as marketing and use of AKST
[6] Despite the increase in global food production there are still about 800 million undernourished people.

low in micronutrients. Consequently, less developed countries are now suffering from the double burden of diet-related disease due to both micronutrient deficiencies and obesity, with its related problems of diabetes and heart disease.

c. ***The exploitation of natural capital has resulted in substantial environmental degradation of land, lakes, rivers, oceans and the atmosphere.*** Agricultural demands on land (extensification) and water have often exerted significant pressures on natural resources (e.g., soils, biodiversity, extent of ecosystems (e.g., mangroves and forests), freshwater, and carbon-derived energy), frequently exacerbated by urban demands. Additionally, problems arising from the intensive use of external inputs (fertilizer, pesticides, fossil fuels, etc.) are on the increase, especially in industrialized countries and in modernized production systems in developing countries. The ecological thresholds beyond which natural processes collapse are increasingly being breached – notably by the accumulation of agricultural contaminants in water bodies, negative impacts of agricultural run-off and over-fishing on fisheries, the drying up of wetlands and freshwater bodies by over-extraction for farming use, degradation or 'mining' of soils by inappropriate or unsustainable cultivation and fertilization practices. Increased emissions of greenhouse gases are an additional factor, i.e., CO_2, CH_4 and N_2O, notably from increased production of rice and livestock numbers, use of fertilizers, conversion of tropical forests to farmland and increasing mechanization, all of which contribute to global and local climate change. Figure 3 illustrates the collapse of Atlantic cod stocks off of Newfoundland, Canada due to over-fishing, and the increased release of nitrogen from human activities, with adverse consequences on aquatic ecosystems. Environmental degradation feeds back negatively to agriculture itself – eroding the natural foundations upon which it depends.[7]

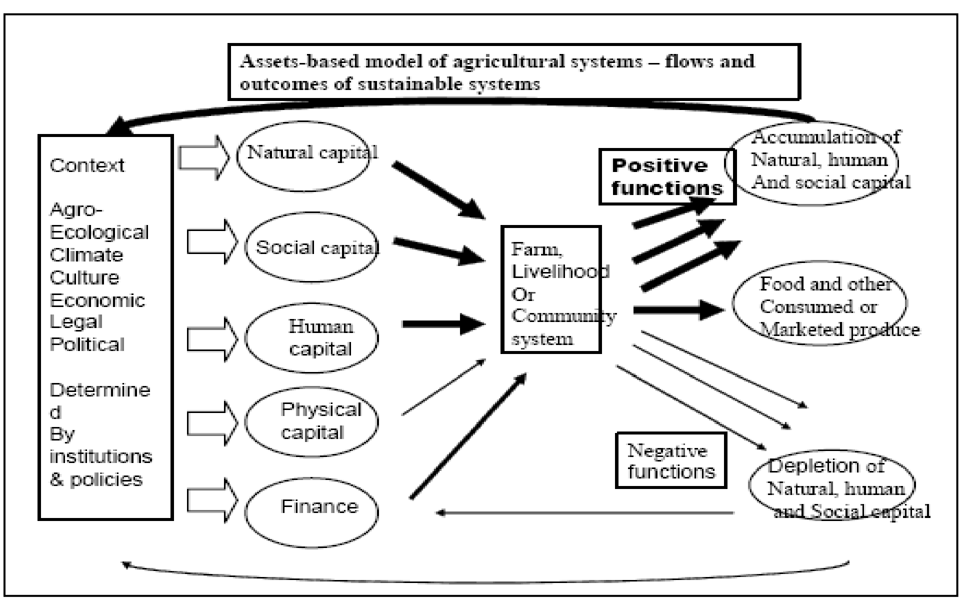
[7] All human life, not just those that live in rural areas, depends on a healthy, vibrant and sustainable agriculture (crops, livestock, forests and fisheries) and food systems.

Figure 3. Impact of over-fishing on cod stocks and human activities on nitrogen release.



Over the last 15 years, a range of multifunctional KST initiatives, involving an Integrated Natural Resources Management approach to agricultural diversification, have been shown to be effective at the local level in addressing the needs of the poor and the degraded environment, by proactively promoting the pursuit of environmental and social goals in addition to improved total productivity. Innovative integrated agricultural systems producing ecosystem services – Integrated Pest Management, Integrated Natural Resource Management (4), Integrated Water Management, agroforestry, ecoagriculture - have emerged, enabling agriculture to work 'with', rather than 'against', nature. Many of these multi-goal initiatives have emphasized participatory engagement with stakeholder groups.

Figure 4. The concept of integrated natural resource management.



Sustainable agriculture is more knowledge intensive than ever before, covering social, ecological and economic dimensions that, in changing circumstances, require stakeholders to be better informed. Given the increasing limitations on land and water availability, plus the continued evolution of pests and diseases, environmental change and markets, AKST has to keep evolving. All stakeholders (from farmers to international policy makers) therefore require access to, and some understanding of, a range of different types of knowledge and information, including: (i) local and traditional technical and socio-cultural; (ii) biological and genetic; (iii) environmental and technological; (iv) post-harvest processing; (v) consumer demands; (vi) market chain; and (vii) environmental and social impacts of AKST itself. As yet, few formal information systems effectively integrate this wide range of knowledge, and poor linkages with formal AKST systems impose limits to how local knowledge is effectively and responsibly integrated into global knowledge.

Expanded knowledge of biotechnology has begun to influence agriculture worldwide. Since the development of cell culture and recombinant DNA techniques, new discoveries at the molecular level have led to scientific advances[8] in genomics, transgenics, and the use of molecular markers. Public and private research organizations in both high- and low-income countries are using advanced biotechnology to introduce new traits into traditional crops for various purposes[9]. 102 million hectares of GM crops were planted in 22 different countries in 2006, representing a 60-fold increase in adoption since 1996. However, only four kinds of transgenic crops (soybean, maize, cotton and oilseed rape) and two different traits (tolerance to herbicides and resistance to specific insect pests) are in wide scale production. Moreover, approximately 96% of transgenic crops are grown in just six countries[10], with over half of all production in the United States alone, and well over two-thirds in only two countries despite over ten years of availability. Transgenics do not offer a magic bullet, and rely on a case-by-case basis on research, development and evaluation to determine performance and sustainability in any given context of use. A number of social, environmental and human health concerns persist, in particular those relating to gene flow and allergens. National biosafety regulatory systems are emerging among developing countries to monitor, evaluate and provide guidance on

[8] The extent to which and for whom the advances in scientific understanding of molecular level dynamics translates into sustainable development is both highly complex and debated.
[9] Transgenics tend to be planted on large tracts of land as monocrops, facilitated by highly concentrated land ownership patterns.
[10] USA, Argentina, Brazil, Canada, India, and China

biotechnology applications.[11] Non-transgenic biotechnologies have far fewer regulatory, social and political concerns and costs**.**

Present and Past Organizational Arrangements and Actors in AKST

The outcome of AKST depends on the contextual, historical and political conditions, institutional arrangements and mix of actors engaged in specific situations. Arrangements that work in one setting cannot be transferred to other settings in the expectation they will work in the same way. Capacity, understanding and knowledge cannot be separated from the actors involved and the contexts in which knowledge is generated and used. Analysis of institutional and organizational feasibility in a specific context is essential for fostering the innovations that support move toward the attainment of combined development, equity and sustainability goals. New regulatory frameworks, educational curricula, institutional arrangements etc., need to be developed and implemented in consultation with the actors in each context.

Since the mid 20th Century, there have been two relatively independent pathways to agricultural development: Globalization and Localization: 'Globalization', which has dominated formal AKST, was initiated in developed countries and has involved an unprecedented degree of consolidation in public-sector agricultural research, international trade and marketing and international policy, and as well as the increasing dominance of AKST funded by the agro-chemical, processing and food industries. 'Localization' has come from the grassroots of civil society and has involved locally-based innovations meeting the everyday needs of local people and communities and of local enterprises. Globalization has dominated localization, which often addresses the integration of social and environmental issues with agricultural production but has lacked a range of market and policy linkages to enable new products and opportunities to grow. However, this trend is changing and there are already a few examples of successful public/private partnerships (e.g., fair-trade tea/coffee) involving global companies (e.g., Unilever) and local communities.

Formal AKST practice has, in the past, too easily assumed technology supply push to initiate market driven diffusion and treadmill processes as the only and most appropriate path for AKST impact. In general, control has been given to those with powerful voices over those who are unorganized and/or voice-less. However, civil society groups have recently become more effective in changing the nature of AKST arrangements. Civil society and other policy analysts point to the importance of listening to and working with men and women as

[11] The regulatory requirements of transgenics are hard to staff and enforce in the poorest countries, with the weakest public administrations and fragile scientific base. The development of effective "independent" regulatory regimes for transgenics implies large investments in capacity development and education.

citizens, consumers, small-scale farmers and food processors, rural and urban migrant laborers, as they can contribute to knowledge production and technical development through their agricultural, environmental and dietary management practices. Formally organized AKST actors need to collaborate more with these groups to ensure inclusion of societal needs and concerns.

Effective AKST increasingly involves organizational partnerships and institutional reform. There is a need to realize synergies between different forms of agriculture (i.e., linkages between farming, forestry and fisheries); between agriculture and the non-farm sectors; between different disciplines and knowledge traditions (i.e., linkages between natural and social sciences), and between local, national and global institutions.

Achievement of the development and sustainability goals requires existing and emerging AKST to target populations and regions most at risk. Individuals and communities must be empowered and resourced to engage in AKST development and deployment, to build greater local resilience and the opportunity for endogenous development. A major limitation is the reluctance of formal AKST actors to work with the tools of civil society engagement and empowerment in order work effectively with those who have been overlooked.

Innovations are shaped by trade-offs within the AKST system itself, are a consequence of power relationships among stakeholders, and can be driven not only by commercial interests but also by ethical values, such as solidarity, equity, etc, and culture, and identity. Fair trade and community-supported agriculture are examples of this type of innovation.[12] Governments benefit from providing the framework in which such human values and collective processes can become effective drivers of AKST. In a highly competitive economic environment, end-users and consumers have increased their participation in the design and the sourcing of goods and services.

Achieving the development and sustainability goals requires taking a long-term perspective on AKST and encouraging inter- and multi-disciplinarity among social and natural sciences. Historically there has been a preference for taking a short term rather than a long term perspective on AKST. The characteristics of agriculture require that the questions raised by the producer or end-user or concerned stakeholder inform the scientific questions framed by disciplinary research, social sciences as well as natural sciences. The design of knowledge, methods and tools that enable a more effective dialogue among scientists of different traditions is an important challenge for the development of the capacity of the scientific community to address multi-functionality. The predominance of natural sciences to date has left

[12] The globalization of organic agriculture is being driven by socially and environmentally responsible consumers, which is a major positive global social force.

relatively little room for social sciences in development programs. Promotion of inter- and multi-disciplinarity is now, as it has been for decades, a strategic issue, but must be combined with a strong disciplinary underpinning, including the disciplines of economics, political science and anthropology.

Present and Past Investments in AKST

On average investments in AKST is still growing but at a decreasing rate for the public sector during the 1990s (Table 1). Moreover, there has been an increasing diversity in investment trends among countries. Investment in agricultural public AKST in many developed countries has stalled or declined and has become a small proportion in total S&T spending. Many developing countries are also stagnating or slipping in terms of public AKST investments. However, a selected few, often the more industrialized countries, e.g., Brazil, China and India, have substantially increased their investments. The slowing growth in AKST investments in the public sector is likely to have implications for attaining equity, sustainability and the development goals. Increasing the amount spent on public AKST in developing countries that are heavily reliant on agriculture would constitute a wise investment but difficult because it competes with non-agricultural sectors such as health and education.

Table 1. Total public agricultural research expenditures by region, 1981, 1991, and 2000

	Agricultural R&D spending			Shares in global total		
	1981	1991	2000	1981	1991	2000
	(*million 2000 international dollars*)			(*percentage*)		
Asia & Pacific (28)	3,047	4,847	7,523	20.0	24.2	32.7
China	1,049	1,733	3,150	6.9	8.7	13.7
India	533	1,004	1,858	3.5	5.0	8.1
Latin America & Caribbean (27)	1,897	2,107	2,454	12.5	10.5	10.7
Brazil	690	1,000	1,020	4.5	5.0	4.4
Sub-Saharan Africa (44)	1,196	1,365	1,461	7.9	6.8	6.3
West Asia & North Africa (18)	764	1,139	1,382	5.0	5.7	6.0
Developing countries, subtotal (117)	*6,904*	*9,459*	*12,819*	*45.4*	*47.3*	*55.7*
Japan	1,832	2,182	1,658	12.1	10.9	7.2
USA	2,533	3,216	3,828	16.7	16.1	16.6
Subtotal, higher income countries (22)	*8,293*	*10,534*	*10,191*	*54.6*	*52.7*	*44.3*
Total (139)	**15,197**	**19,992**	**23,010**	**100.0**	**100.0**	**100.0**

Source: Pardey et al. (2006a) based on Agricultural Science and Technology Indicators (ASTI) data at www.asti.cgiar.org.

Funding for public AKST in developing countries is heavily reliant on government and donor contributions, but these sources have declined. Donor support for AKST has substantially declined since the mid-1980s with the majority of this smaller amount supporting global research rather than research at the country level. However, after a period of stagnation, funding for the Consultative Group of International Agricultural Research (CGIAR) has increased significantly during the past few years, now reaching over US$450 million per year. While this is a considerable amount, it is far too small to effect major changes across all developing countries, and is insignificant in comparison to private commercial investments in AKST. International support of AKST can sometimes distort the incentives, research priorities and resource allocations in national or local research systems. Thus donors need to be sensitive to the possible distortions that they can create.

AKST in the more-developed world is increasingly undertaken by the private sector, with the outputs increasingly transferred to developing countries through commercial ties. Private-sector research is also growing in the developing world, but is concentrated in a few countries where the private sector thinks it can bring products to market quickest and with the most profit. In addition, higher education agencies, NGOs, foundations, and producer groups are also increasing their participation in AKST. Publicly funded research in developing countries is mostly conducted by government-sponsored agencies.

There is evidence of under-investment in research in agriculture. Rates of Return (RoR) in AKST across commodities, countries and regions on average are high and have not declined over time. They are much higher than the rate at which most governments can borrow money, which suggests under-investment in AKST. Although limited, evidence indicates that the investments in agriculture R&D perform equally well or better than the other public-sector investments in the agricultural sector. However, RoR alone are insufficient to guide AKST investment decisions. AKST investment generates economic, social, environmental, health and cultural costs and benefits to society, some of which are considered as externalities (positive or negative) and spillovers. Non-economic positive and negative impacts may be highly valued by society, but often are not included in conventional RoR analysis due to quantification and valuation problems. The challenge is to factor these aspects into the macro-level decision-making process. RoR analysis needs to be complemented by other approaches to estimating impact of AKST investment on poverty reduction, ecosystem services and well-being.

Public investments in AKST have significantly contributed to overall economic growth, but this has not always resulted in an equitable distribution of benefits, poverty reduction or environmental sustainability. Public investments in AKST have in some countries significantly contributed to poverty reduction, but AKST's impact on poverty varies greatly depending on the policies, institutions, and ownership of resources of the country. Before AKST investments are made, planning for distributional efficacy should be integrated in investment design. Even when decisions are made expressly to meet the sustainability and development goals, the real benefits may accrue more to the influential groups within society unless countervailing measures are taken. Additional analysis of innovation processes is required to understand better who has benefited from this additional growth and why it did not always translate into commensurate improvement in poverty, equity, food security or environmental sustainability.

Increased demand for effectiveness, efficiency, responsiveness to stakeholder needs, accountability and transparency is a driving force leading to changes in AKST investment decisions. High transaction costs in knowledge generation, and in information or technology transfer, inefficiency in resource allocation and utilization, lack of transparency, exclusion of some stakeholders, unequal access, and fear of private monopoly over technologies developed through public AKST institutions have prompted changes in AKST systems.

The level, effectiveness and efficiency of AKST investments and their contribution to broader development goals vary according to governance, which is improved with the participation of non-governmental stakeholders. Governance is an important determinant of the mobilization of resources for AKST and plays a major role in allocation of resources between different components of AKST. Increased participation of farmers, women's organizations, producer associations, and private sector actors has shown signs of improving the performance of AKST, which in the past was often "captured" by elites, and forces AKST institutions to develop and disseminate technologies that meet the needs of a broader section of rural and urban society. Governments continue to play an important role in providing public goods, assuring equitable access to AKST, and creating an enabling policy and institutional environment.

The environmental impact or the ecological benefits of AKST investments depend also on environmental governance and the performance of related institutions (judiciary, regulators etc.). Though governance ideally should require and facilitate the internalization of environmental costs and benefits by all actors, this does not happen very often, especially in developing countries because of weak institutions and/or corruption. Experimentation with alternative policy instruments going on in different parts of the world (e.g., eco-system service payments, economic and market based instruments and information disclosure mechanisms). Lessons need to be learned or extracted for scaling up or replication of the use of these instruments.

Part II: Future Challenges

Key messages

- o The challenges of meeting the development and sustainability goals are becoming increasingly complex and will require the integration of AKST with place-based and context relevant factors.
- o Agriculture will need to adapt to changes in driving forces (demographic, economic, social, cultural and environmental) to address the multiple functions of agricultural production and will require comprehensive approaches that increase productivity to meet the projected increasing demand and diversification of products, while protecting natural resources and ensuring greater equity in the allocation of costs and benefits.
- o Growing demand for food, feed, fiber and bioenergy will lead to intensification, extensification or bringing marginal land into production unless smarter policies and incentives can be designed to guide the development of other options.
- o World food markets will become tighter, with increasing scarcity, as indicated by a projected increase in world food prices for key cereals and meat under the reference projections.
- o Exporting countries will be increasingly important in meeting food demand and reducing upward pressure on food prices in developing countries.
- o The need to increase production can be reduced in some regions through improved post-harvesting technologies contiguous to production sites and by improved agricultural transport infrastructure for both rural and urban markets.
- o Biotechnology developments could likely lead to productivity gains in agriculture, potentially with important benefits for small farmers in the developing world.
- o The protection and nurturing of local and traditional knowledge is needed to preserve agrobiodiversity and encourage and support technological innovation.
- o Reconfiguration of agricultural systems, including integration of ecological concepts, are needed to detect, prevent and mitigate emerging disease threats, coupled with effective implementation of international standards and surveillance systems for food safety, plant and animal health, and well financed animal and plant health.
- o Advances in agroecology offer the potential to increase productivity while providing critical ecosystem services, including improved soil and water quality and carbon sequestration.
- o Emissions of greenhouse gases from the agricultural sector and the vulnerability of the agricultural sector to current climate variability and projected changes, especially to extreme events, need to be reduced.

AKST is needed to reduce the carbon intensity of the agricultural sector and to assess the economic, environmental and social sustainability of second generation biofuels.

The challenges of meeting the equity, development and sustainability goals are becoming increasingly complex and will require agriculture to adapt to changes in driving forces and the integration of AKST with place-based and context relevant factors (i.e., economic, social, cultural and environmental) to address the multiple functions of agricultural production and will require comprehensive approaches that increase productivity, protect the natural resources on which agriculture depends, as well as minimize agriculture's negative impact on the environment. Furthermore, the diversity of farmer needs, and the increasing complexity of stresses under which they operate (e.g., increasing water scarcity and land degradation, increasing levels of local and regional air pollution, land policy conflicts, a changing and more variable climate, less labor due to HIV/AIDS and endemic diseases, and less genetic diversity), require the development of multiple options. AKST plays a key role in shaping the quality and quantity and access to resources as well as the efforts at different levels (households, national, and international) to reduce poverty and hunger in a sustainable manner.

Improved Food and Nutritional Security and Human Health

The projected increase in global population in the next 50 years (by about 2-3 billion people), on-going urbanization, and changing diets (carbohydrates to proteins) and lifestyles will lead to a strong increase in the demand for food, feed and fiber and pressure on the agricultural system. This increased demand has to be met while at the same time addressing the vital role agriculture and land use change play in global environmental problems. Growing demand will lead to intensification, extensification or bringing marginal land into production unless smarter policies and incentives can be designed to guide the development of other options.[13] Productivity needs to be increased world-wide in conditions of human-induced climate change, increasing competition for water and declining soil quality, while minimizing biodiversity losses. Policy innovation thus needs to take a broad cross-sectoral view of frameworks that result in productivity, equity and sustainability.

The need to increase production can be reduced in some regions through improved post-harvesting technologies close to production sites and by improved agricultural transport infrastructure for both rural and urban markets. AKST research and investment for post-harvesting technologies and agricultural transportation lags behind that for production technologies. Mapping of post production technology needs and resources should guide research and investment.

[13] Multifunctionality in agriculture can be enhanced by better use of residues, co-products, and wastes as well as by optimizing agricultural production techniques and crop rotation. Integrated systems and biorefinery options might provide more with less and with a smaller environmental footprint.

World food markets will become tighter, with increasing scarcity, as indicated by a projected increase in world food prices for key cereals and meat under the reference projections. Real world prices are projected to increase in the coming decades for most cereals (24-41 percent) and meat (9-11 percent), reversing trends from the past several decades, adversely impacting on food security and the development goals. In the reference run, childhood malnutrition (children of up to 5 years) will continue to decline, but cannot be eradicated by 2050: Childhood malnutrition is projected to decline from 146 million children in 2000 to 117 million children by 2025 and 80 million children by 2050,[14] with progress being slowest in Sub-Saharan Africa. Water scarcity will increasingly constrain production due the limited increase in supply and rapid shift of water from agriculture in key water-scarce agricultural regions in China, India, and CWANA, accompanied by climate change, which will increase heat and drought stress in some regions. With declining availability of water and land that can be profitably brought under cultivation, expansion in area will contribute very little to future production growth. Competition for land will be one of the key challenges in the coming decades, with more land being used for urbanization, infrastructure, food production and bioenergy. Growing food scarcity in global markets, growing variability and reduced availability of water resources, and increasing competition for land calls for enhanced investment and effectiveness in implementation of AKST.

Exporting countries will be increasingly important in meeting food demand and reducing upward pressure on food prices in developing countries. With rising food prices due to inability of most developing countries to increase food production rapidly enough to meet growing demand, the major exporting countries will provide an increasingly critical role in meeting food consumption needs. Heavy reliance on food imports in sub-Saharan Africa will continue in the reference projections despite faster agricultural production growth expected in the region due to accelerated AKST during the next 50 years. The USA, Brazil, and Argentina, as well as Canada, Australia and Europe are a critical safety valve in providing relatively affordable food to developing countries.

Continuing structural change in the livestock sector, driven mainly by rapid growth in demand for livestock products, will bring about profound changes in livestock production systems with significant implications for social equity, the environment, and public health. The increased production of livestock, which will vary by region and species, is expected to come from the same or a declining resource base, and without appropriate action there are prospects that this could lead to degradation of land, water, and animal genetic resources in both intensive

[14] Alternative policy experiments show that with higher investments in AKST the share of malnourished children in the group of developing countries are projected to decline to only 64 million from the baseline of 80 million. If these higher investments in AKST are combined with improvements in complementary service sectors, such as health and education, then a further reduction to 47 million is projected.

and extensive livestock systems. Trade-offs are inevitably going to be required between food security, poverty, equity, environmental sustainability, and economic development.

Biotechnology developments could likely lead to productivity gains in agriculture, potentially with important benefits for small farmers in the developing world. Since most of the world's poorest people live in rural areas of developing countries and depend on agriculture for their livelihoods, improving agricultural productivity remains the key to poverty reduction. Transgenic crops differ in the extent to which they are pro-poor, depending on the cultivation practices associated with them, the IPR and biosafety regimes that apply and the extent to which smallholders have the necessary resources (human, physical, financial and social capital) to enable them to adopt new technology. Economic impacts tend to be more pro-poor where significant market competition exists in the supply of transgenic seed.[15] With increasing scarcity in the reference run, advancement in productivity and profits from improved agricultural research and extension can contribute to substantial increases in rural income and poverty alleviation. Investments in conventional breeding and tools of biotechnology such as marker-assisted selection and cell and tissue culture techniques—and likely an increasing contribution from genetically modified crops—can in particular boost crop yield growth in rain fed environments. Resource-poor farmers will be excluded from the benefits of modern science, including biotechnology, if measures are not taken to avoid social exclusion in dissemination of new agricultural technologies. In addition, harmonization of regulatory standards, including biosafety standards, must be put in place.

Improvement in land tenure systems would enhance enforcement of agricultural land preservation and promote sustainability objectives. Rural populations under weak land preservation regulations have failed to invest in long-term land improvements on existing agricultural land and have also in many countries abandoned land in favor of migration to forest and other marginal lands. Policies related to land tenure and resources access are of great relevance for the sustainable management and use of natural resources in all countries of the world where the majority of the population rely heavily on land to provide income, employment and livelihoods. Many countries have already started revision, improvement and reformulation of land policy and tenure. However, inappropriate administrative and institutional practices are found on most reform agendas.

[15] For example, the insect-resistant cotton varieties developed independently by the Chinese Government have introduced enough competition in the Chinese seed market to keep market prices low, allowing small farmers to reap the majority of the economic value created by the crops. In contrast, the Argentine Bt cotton market is not competitive, and the seed supplier charges such high prices that the crop is not profitable for farmers and hence has not been widely adopted.

The protection and nurturing of local and traditional knowledge is needed to preserve agrobiodiversity and encourage and support technological innovation. The development of national programs to conserve indigenous agrobiodiversity and the implementation of the Global Plan of Action for Food and Agriculture (GPA) for the conservation and sustainable utilization of plant and genetic resources for food and agriculture (PGRFA) are needed. Conservation of the diverse genetic pool of landraces is needed for modern plant breeding for ecological fit and for genetic resistance.

Reconfiguration of agricultural systems, including integration of ecological concepts, is needed to improve food safety and reduce detect, prevent and mitigate emerging disease threats. Food-borne disease is estimated to affect 30% of the population in industrialized countries and to account for an estimated 2.1 million deaths in developing countries annually. The proportion of the population at high risk of illness or death from food-borne pathogens is rising in many countries due to factors such as age, chronic diseases, immunosuppressive conditions and pregnancy. In addition, the number of emerging plant, animal, fish and human diseases is projected to increase due to multiple factors including, climate change, intensification of crop, fish and livestock systems, and expansion of international trade. Well-publicized incidences of BSE, foot-and-mouth disease and avian flu has resulted have raised public concerns with regard to intensified food production, particularly of meat. Outbreaks of illness due to food-borne pathogens, such as salmonella, e. coli, and listeria, that may contaminate fruit, vegetables, poultry, beef or dairy products, have pointed to the need for strict food safety standards. Implementation of international standards for food safety, plant and animal health (e.g., Codex, OIE, IPPC, CPB**)** is often limited to export establishments and has limited effects on the domestic sector. The policy challenge, especially in developing countries, remains that of designing and enforcing effective incentives for the implementation of standards for domestic public health including nutrition, and animal and plant health. In addition, animal and plant health, and food safety surveillance and interventions, which are currently financed on ad hoc basis, often in response to an emergency, need permanent or longer-term financing as a global public good.

A significant reduction in the incidence of fatal accidents in agriculture is needed. The current accident rate is twice the average for other industries. Worldwide, agriculture accounts for some 170,000 occupational deaths each year. Machinery, such as tractors and harvesters, accounts for the highest rates of injury and death. Exposure to pesticides and other agrochemicals constitutes one of the principal occupational hazards, with poisoning leading to illness or death. Between two and five million cases of pesticide poisoning occur each year and result in approximately 40,000 fatalities. New technology has brought about a reduction in the physical drudgery of much agricultural work, but has also introduced new risks, notably associated with the use of machinery and the intensive use of chemicals without appropriate information, safety training or protective equipment.

Environmental Sustainability, Climate Change and Energy

Conflict over shared environments from local to global level will intensify as a result of population and economic growth, water scarcity, environmental degradation, climate change, refugee flows, coexistence of competitive production systems and increasing inequalities, impacting the ability to realize food needs. Participatory, multi-stakeholder processes and tools such as multi-criteria analysis are necessary in the prevention and resolution of problems in conflict areas, such as trans-boundary basins. Conflict could be reduced with more equitable agricultural trade relationships, protection of access rights to resources, efforts to limit climate change, and enabling policies that stimulate urban planners, water authorities, land use planners and private commercial actors to build and manage landscapes that give priority to agroecology.

Water availability for agriculture is one of the most critical factors for food security. In arid and semi-arid regions in the world, water scarcity has already become a severe constraint to food production and a direct threat to the livelihoods of the poor. Increasing rates of soil degradation in many regions may further limit the ability of agriculture systems to reduce food insecurity. The expansion of irrigation and associated agricultural water withdrawal for improved productivity will continue to depend on availability of water resources sufficient to produce food for the growing world population while at the same time meet increasing municipal, industrial and environmental requirements.

AKST is needed to address the emerging challenge of climate change. Climate change influences and is influenced by agricultural systems. The two challenges are: (i) to reduce the impact of the agricultural sector on the climate system by reducing the emissions of greenhouse gases (GHG) from the sector and associated agrofood systems; and (ii) to reduce the vulnerability of the agricultural sector, including the risks to regional and global food supplies, to current climate variability and projected changes in climate and associated extreme weather events, i.e., floods, droughts and heat waves. To date the emphasis has been on identifying approaches to reduce GHG emissions, whereas the major challenge for the future is to increase the resilience of the agricultural sector to projected changes in climate through the generation and use of AKST (i.e., through changes in agricultural practices and policies, and seed traits):

- *Mitigation of GHG emissions*: Greenhouse gas emissions can be reduced by sequestering carbon through activities such as afforestation, reforestation, agroforestry, conservation agriculture and improved management of pastoral systems; reducing deforestation; and reducing emissions from rice paddies and livestock[16]. The design and implementation of appropriate policies, incentives and institutional arrangements will be key elements of success given that past policies have amounted to externalizing the costs of climate change. Technological approaches need to be embedded in a long-term equitable global regulatory framework to limit greenhouse gas emissions that recognizes the potential contributions from the agricultural sector.

- *Impacts and adaptation:* AKST can be used to reduce the vulnerability of agricultural and food systems to projected changes in climate, through improved management practices and systems, including more efficient use of water and crop selection[17], and potentially by seeds developed to be more resilient to climate-induced biotic and abiotic stresses, i.e., drought-, temperature- pest- and salinity-tolerant crops, especially for the tropics and sub-tropics.

Agriculture needs to be less dependent on fossil fuel energy. Different forms of agriculture use different levels of energy; with transitions in agricultural production and food systems in general being accompanied by greater reliance on fossil fuel energy. Rising energy prices and changing subsidy regimes are likely to be important drivers of change in agricultural production and food systems. New AKST will be needed to reduce the reliance of agriculture and the food chain on fossil fuels for agrochemicals, machinery, transport, storage and distribution[18]. Emerging research on energy efficiency and alternative renewable energy sources for agriculture will have multiple benefits for sustainability.

Bioenergy is being promoted in many countries to enhance energy security, reduce GHG emissions, and stimulate rural development, but economic, social and environmental concerns limit the extent to which these goals can be met with currently available biofuels technologies. Bioelectricity and bioheat are more viable. First generation biofuels such as bioethanol and biodiesel are economically competitive with fossil fuels only in the most efficient feedstock producer markets and under particularly favorable market conditions of high oil and low feedstock prices. Therefore in general they depend on direct and indirect forms of subsidies practically everywhere in the world. While non-market benefits (e.g., reductions in GHG emissions and energy security) may justify these subsidies in theory, net benefits are highly

[16] If livestock intensification is used to reduce methane emissions, care must be taken to avoid adverse human health consequences

[17] Diets could change to more drought-resistant crops

[18] Agricultural systems differ in capacity to produce eco-efficiently. Output-input (O-I) ratios of 75 countries world-wide found O-I ratio variations from 156 to 0.41. The countries shown to have the most in-efficient agriculture (O-I ratios < 2) included mostly rich countries. The countries with efficient agriculture (ratios > 30) included Ghana, Niger and Uganda.

uncertain. Sugarcane ethanol and soybean biodiesel generally exhibit much larger GHG emission reductions and better balances between energy inputs and outputs than maize ethanol. Land and water intensity of 1st generation biofuels can lead to serious threats for the environment[19] and also for food security.[20] If there is a shift towards wood and grassy crops (cellulose-based 2nd generation biofuels), this option offers greater CO_2 reduction options and less land use per unit of energy, although technical breakthroughs would be required to achieve this. Current bioelectricity and bioheat technologies give rise to less negative externalities – largely because they not produced from agricultural crops but mostly from wastes and residues. Their application can contribute to reducing global GHG emissions and increasing energy access in developing countries.

Part III: Options for Action

Key Messages

- Meeting the IAASTD equity, development and sustainability goals will require:
  - smarter application of current technologies and the development of new technologies with the full involvement of the user community; a policy framework that recognizes synergies and trade-offs among environmental issues, trade policies and agricultural policies; investment strategies that are pro-poor and recognize the multi-functionality of agriculture, as well as innovative combinations of technologies, policies, capacity development and investment strategies.
- Advances in AKST, such as through genomics, nanotechnology, remote sensing, precision agriculture, information and communication technologies, may transform our approaches in addressing the development and sustainability goals.
- The potential of second-generation biofuels to be economically, environmentally and socially sustainable needs to be explored:
- Options for improved resource management in the agricultural sector include full cost accounting; market mechanisms to internalize environmental externalities of agricultural production and pay for agroenvironmental services; and improved land tenure systems.
- A global long term equitable regulatory framework for climate change, with intermediate targets, is needed to limit the adverse impacts of climate change.
- Mechanisms to democratize global trade regimes and market relations are fundamental to achieving development and sustainability goals.

[19] Loss of biodiversity, soil and water degradation

[20] The large-scale cultivation of biomass for energy applications can mean a considerable change in land use, and compete with the use of this land for food production. At the time of writing, riots were taking place in Mexico as a result of rising maize prices in part due to US use of maize for bio-ethanol.

- Multiple, complementary approaches, including abolishing tariff escalation to encourage investment to add value locally, micro-finance, fair trade and organic production, and private sector sustainable trading initiatives are needed to stabilize and increase farm-gate prices and enable farmers and rural communities to capture value in commodity chains, improve livelihoods and transition to sustainable agricultural practices.
- Technical innovation at the farm level to increase productivity and incomes in resource-poor agricultures can only be effective if farmers have opportunities to market their produce.
- Internationally, policies and regulations related to food safety, plant and animal health could be better integrated.

More investment in public and private research is necessary to: (i) increase productivity while providing ecosystem services such as reduced greenhouse gas emissions, reduced water pollution, and slowing or reversing the loss of biodiversity; (ii) focus on the problems of the poor; (iii) develop technology and management systems that save on the use of scarce resources such as land, water, and in the future, fossil fuels; (iv) understand, monitor and control plant and animal pests and diseases; and (v) better understand the role of governance in improving the AKST system.

Technology Options

Smarter and more targeted application of existing best practice AKST continues to be critical to achieving the IAASTD development and sustainability goals. It is essential to draw on competences from and build on developments in a wide range of sectors to have the maximum impact on achieving the goals and to prevent the present situation worsening under both foreseen and unpredictable shocks. The greatest scope at present for improving livelihoods and equity for the majority of the poor and hungry exists in small-scale diversified production systems, greater attention to development of value-added market chains, and more just regional and global commodity and food trading arrangements. Emerging AKST will need to be inclusive of a wide variety of approaches in order to meet the development and sustainability goals. If the world experiences the worst case climate change scenarios – which the continued absence of hard, concerted action at national, regional, and global scales makes yearly more certain – then AKST for sustaining food security for many more of the world’s people will once again become a central policy concern.

Advances in AKST, such as through genomics, nanotechnology, remote sensing, precision agriculture, information and communication technologies, may transform our approaches in addressing the IAASTD development and sustainability goals. There is the potential for new genotypes of crops, livestock, fish, and trees to facilitate adaptation to adverse biotic and abiotic conditions, bring new yield levels, produce non-traditional products, and complement new production systems. The widespread application and impact of these breakthroughs will depend on resolving concerns of access, affordability, relevance, biosafety, human health, and the policies (investment and incentive systems) adopted by individual countries. More effective collaboration between local, traditional and formal knowledge of agroecological processes and synergies, and in the application of resultant technologies, will play a crucial role in future AKST response to the challenges of hunger, productivity, and environmental protection. Current and future advances in agroecology offer the potential to capture productivity benefits while simultaneously providing critical ecosystem services, including optimal soil and water quality, carbon sequestration, and biodiversity. Ecological approaches to food production and food systems also have the potential to address inequities created by industrial agriculture.

Further development of bioelectricity and bioheat technologies as well as small-scale biofuels and bio-oils applications offers large potential benefits for development, and the potential of second-generation biofuels to be economically, environmentally and socially sustainable needs to be explored:

- More research is needed on the production and application of small-scale biofuels and bio-oils that could offer livelihood opportunities, especially in remote regions and countries where high transport costs impede agricultural trade and energy imports. There is also considerable potential for expanding the use of digesters, gasifiers and direct combustion devices, especially in off—grid areas and in cogeneration mode on site of biomass wastes generating industries (e.g. rice, sugar and paper mills). More investments are needed in R&D and the development of technical standards to improve operational reliability of digesters and gasifiers. To be successful, these efforts need to be accompanied with local capacity building, knowledge dissemination and better access to finance; and
- Expansion of production of 1st generation biofuels can lead to rising food prices, deplete water resources and induce the conversion of pristine ecosystems into agricultural land. New or yet to emerge cellulosic ethanol and biomass-to-liquids technologies hold the best promise to mitigate many of these concerns but it is not clear when these technologies may become commercially available. Moreover, considerable capital costs, large economies of scale, a high degree of technological sophistication and intellectual property rights issues make it unlikely that these technologies will be adopted widely in many developing countries in the next decades. Research and investments are needed to accelerate the development of these technologies and explore their potential and application in developing countries.

  Sustainability standards for biofuels need to be developed that balance economic, environmental and social sustainability goals with market access and development opportunities for developing countries.

Policy Options

A policy framework is needed that recognizes synergies and trade-offs among environmental issues, trade policies and agricultural policies. There are many disconnects between national policy processes and among multi-lateral environmental agreements and with the World Trade Organization.

Policy options exist to provide enabling environments for participatory approaches, farmer field schools, farming systems research and development, at the farm and community level, to release their potential in generating innovation, empowerment, women's emancipation, not only in IPM, but in health, soil fertility and water management. However, at the macro-levels (national and international) these approaches have, on the whole, scarcely been incorporated into national policies or poverty reduction strategies. The rural poor have no political clout and, in the short term, hardly any visible contribution to make at the macro level. Unless concrete (market) opportunities are created for resource-poor farmers, these approaches will not lead to sustainable results.

Options for improved resource management in the agricultural sector have roots in the same fundamental paradigm shift that is required for all aspects of sustainable development – full cost accounting and recognition of the multifunctionality and interdependence of landscapes: market mechanisms to internalize environmental externalities of agricultural production and pay for agroenvironmental services would stimulate the adoption of sustainable agricultural practices and improve natural resources management. Some options include the establishment and strengthening of agencies administrating large water systems that cross traditional administrative boundaries; systems for monitoring forest conditions and forest dwellers' welfare, more transparent land and forest allocations and regulations; and more support for monitoring regulatory compliance by government, landholders, and forest concessionaires. Policy approaches to address the globalization of market failure include taxes on pesticide use as incentives to reach use reduction targets, support for organic agriculture, and a policy mechanism to internalize the environmental costs of agricultural production, e.g., related to carbon emissions. Payment for environmental services (PES) is an approach that recognizes the multifunctionality of agriculture, and creates mechanisms to value and pay for the benefits of ecosystem services provided by sustainable agricultural practices such as organic production, watershed management, and agroforestry practices and carbon sequestration among other resource conservation measures as a public good. To support development goals PES schemes should be structured to generate stable revenue flows to help ensure long-term sustainability of the ecosystem that provides the services, and to ensure that small farmers and communities, not just large landowners, may participate and benefit.

Policy options exist for devising Natural Resources Management policies better taking into account how ownership and accountability are shared among communities through common rights and not only in the legal form of individual property. Laws, incentives, contracts, taxes, quotas and permits have to take in account this diversity of NRM knowledge. The design of NRM policies should not be derived from or conform to a concept of individual ownership and rights that is not universal.

A global long term regulatory framework for climate change, with differentiated responsibilities and intermediate targets, is needed to limit the impact of climate change on the agricultural sector and development and sustainability goals. A modified Clean Development Mechanism in a future regulatory system should consider appropriate windows for agriculture dealing with avoided deforestation, afforestation, re-forestation, and other agricultural practices, e.g., no-till agriculture.

Agricultural trade liberalization has not benefited poor farmers and rural communities, has not mitigated the steep decline in agricultural commodity prices, and tends to exacerbate the environmental impacts of agricultural production throughout the production chain:

- Projected welfare gains from further liberalization are small, derive mostly from the liberalization of manufacturing sector not agriculture, and accrue largely to developed countries. The poorest countries are among the net losers under all trade liberalization scenarios. The environmental impacts of increased global agricultural trade include increased long distance transport contributing to greenhouse gas emissions, increased use of synthetic inputs, and increased specialization and monoculture production which tends to decrease agrobiodiversity. Climate change and worsening water shortages may require policies to move away from traditional agricultural trade liberalization.
- New policy approaches are needed to stabilize and increase farm-gate prices, a key factor in determining farmers' capacity to invest, innovate and make AKST an effective tool for improving rural livelihoods. Current proposals for the elimination of industrialized country subsidies are projected to increase prices only slightly (e.g. about 12% for cotton) and benefit just a few developing countries; additionally subsidy elimination carries significant potential environmental trade-offs, including increased deforestation resulting from shifting production

to the developing South. A combination of anti-dumping disciplines (to prevent predatory pricing), expanded special products provisions, supply management approaches, and agricultural diversification to reduce commodity export dependency and enhance national productive capacity are also needed. Additional policy options to reverse the decline in commodity prices include instituting price bands, a renewed effort to negotiate international commodity agreements, and the reestablishment of state trade enterprises to serve as a competitive counterweight to multinational agribusiness companies.

Mechanisms to democratize global trade regimes and market relations are fundamental to achieving development and sustainability goals. The principles of good governance, including transparency, representation, accountability and access to information, should be applied to international trade negotiations, so that social and environmental concerns are better represented in the resulting agreements. Strategic Impact Assessments of proposed trade agreements would help educate policy makers and stakeholders, increase transparency, and promote decision-making that would support development goals; similarly international comparative technology assessments of emerging technologies such as nanotechnology and biofuels would assist in making investment and policy decisions on these and other emerging technologies that would support the achievement of development and sustainability goals. Democratizing market relations is also necessary to support development goals. A major anti-competitive effect of globalization has been a rapid concentration of market power in a limited number of transnational agribusiness companies which has driven down negotiating power and prices for agricultural producers, especially resource poor farmers in developing countries. International competition policy and anti-trust mechanisms are needed to govern corporate power over commodity markets and promote more equitable distribution of agricultural rents that could help improve rural livelihoods and drive development.

Multiple, complementary approaches, including abolishing tariff escalation to encourage investment to add value locally, micro-finance, fair trade and organic production, and private sector sustainable trading initiatives are needed to enable farmers and rural communities to capture value in commodity chains, improve livelihoods and transition to sustainable agricultural practices. Local processing and value addition to primary goods offers a major income opportunity for developing countries, yet in many cases this is not being achieved because many OECD markets apply escalating tariffs that prevent market entry of value added goods. Tariff escalation policies act as a barrier to adding value locally, and should be ended to enable local value added agricultural processing that could diversify and significantly improve rural livelihoods and economies. Additional approaches including targeted micro-finance credit and insurance schemes; fair trade initiatives which provide greater equity in international trading, higher commodity prices and incentives to adopt sustainable agricultural practices including organic production; and new business and procurement models that may be adopted by supply chain partners to increase market access for small-scale farmers, are all important policy options to pursue. Agricultural market analysis services, market education, and market information services aimed at small farmers, as well as strengthening agricultural research and extension to provide market information and marketing assistance, are necessary to enable farmers to take advantage of new market opportunities.

Internationally, policies and regulations related to food safety, plant and animal health could be better integrated to more effectively utilize the limited resources that are applied to SPS issues. Food safety standards are largely implemented in developing countries for the purpose of trade facilitation, with little benefit to domestic consumers who are affected by a wide array of food-borne illnesses. Confining Codex, OIE and IPPC to work within their constitutional mandates may be of less relevance today given the globalization of agriculture and trade. The efficacy of working within the traditional international mandates is challenged by the emergence of alternative regulatory mechanisms that integrate food safety, animal and plant health related standards and production practices in on-farm HACCP plans. Revising SPS-related policy and regulatory measures within a biosecurity framework may be one option for promoting cross-sectoral interventions.

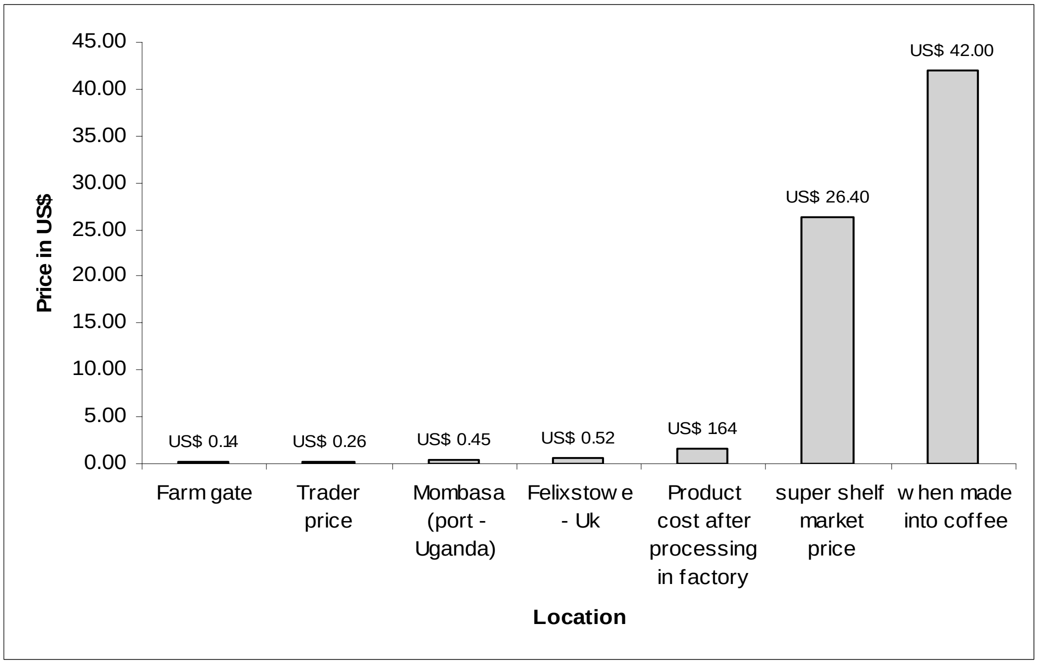
Even though license agreements may promote technology transfer by clarifying roles and responsibilities, IPRs may pose serious risks to research and the use of technologies in development. Even though license agreements may promote technology transfer by clarifying roles and responsibilities in some cases, policy mechanisms are needed to protect and remunerate traditional knowledge and genetic resources from which many industrialized products are derived. Options exist for correcting international policies on intellectual property rights to AKST at the national level to reduce cost, compared to the benefits. In countries where public sector research institutions promote introduction of IPRs in agriculture, this promotion may challenge the public tasks of contributing to poverty alleviation and household nutrition security. Even though IPRs fit in a commercial approach to innovation, in many countries it is the public sector research institutions that promote the introduction of IPRs in agriculture. This is mainly based on a perception that these institutes may obtain significant revenue when their inventions (e.g. plant varieties) may be protected. This revenue is welcomed in a situation of under-investment in public research in many countries, which is common in many countries since the 1990s. This ‘life line’ may, however, have a major setback, i.e. that such benefits can only be obtained in commercial markets (e.g. seed markets) and reliance on IPR based revenues is likely to lead to a change in public research priorities from development to business opportunities, in some cases to commercial crops like maize and oil crops at the cost of research on small grains and pulses, and to benign cropping conditions and market oriented farmers at the cost of a smallholder farmer focus. Such shifts may fit in market orientation priorities of national development strategies, but may at the same time challenge to some extent the public tasks of contributing to poverty alleviation and household nutrition security.

Important reasons for the failure of pro-poor AKST are policies dominated by belief in technology supply push and the market driven global agricultural treadmill; political impasse caused by the refusal by national governments of agricultural export countries to accept global governance to redress marginalization of resource-poor agricultures, and over-reliance of the free market as the design for a desirable society and neglect of material flows and governance mechanisms other than hierarchy and market. International AKST has not resolved the difference between: (1) focus on technology development to enhance productivity at the farm level and drive the global treadmill, i.e., the linear technology supply push model common in the US Mid-West and some European countries, and that continues to inform the policies and strategies of WTO and CGIAR, and (2) a focus on pro-poor AKST pathways that increase opportunity through institutional change, improving access to urban and export markets, by linking local processing and value adding, market and supply chain development, and urban retailing[21]. Pro-poor development assumes a wide-spread *prise de conscience* among neo-classical agricultural economists, agricultural scientists, policy makers and voters to address the assumptions that underpin the pathways for pro-poor AKST impact. A pre-condition for pro-poor AKST is investment in gender-sensitive empowerment, education, information and organization of resource-poor farmers.

Technical innovation at the farm level to increase productivity and incomes in resource-poor agricultures can only be effective if farmers have opportunities to market their produce. Policies must prioritize market access for resource-poor farmers. A key issue is access of small farmers to urban supermarkets in their own countries. Supermarkets are increasingly capturing the urban markets for agricultural products and tend to source from industrial agriculture imports. Figure 5 shows the price of coffee along the supply chain.

[21] (Structural Adjustment has thrown away the child with the bathwater by liberalizing supervised credit schemes. These schemes have so far demonstrably been the most successful approach to putting money in smallholders' pockets. It was not the approach that was wrong but the way parastatals applied it).

Figure 5. The price of coffee along the supply chain



Capacity Development Options

Individuals and communities must be empowered to engage in AKST development and deployment, and to support the resilience of indigenous development. Rural communities are better served when end users participate in the design and implementation, rather than in just the final testing of new technologies, particularly those members of the community who have traditionally been at a disadvantage, such as rural women. Location-specific dynamics determine the effectiveness of AKST in achieving the sustainability and development goals. Local and indigenous communities need to draw on agricultural knowledge and innovation to respond to ongoing and emerging challenges and threats, which requires a decentralization of AKST efforts, linked to centers of advanced science.

Sustainable agriculture requires many actors working in partnership. The AKST needed to meet the development and sustainability goals will require building the capacity of different actors at different levels (local, national, regional and international). Active participation of the various stakeholders, especially farmers and communities with indigenous expertise, in the design and implementation of capacity development programs is essential. There is an increasing role for non-traditional capacity development suppliers from local civil society organisations (CSOs) and the private sector, in addition to more South – South sharing of learning experiences and increased collaboration.

National decision makers will increasingly need access to science advice in decision making, regulation and monitoring. Given the complexity of the science and technology issues, many developing countries will need to build capacity to address some of the scientific and political demands that are inevitable for informed policy formulation.

Educational facilities need to be better equipped to play a major role in human capacity development, research and technological innovation. Strengthening the links among education, research, and society can build a scientifically trained workforce and develop the national systems of innovation needed to meet the challenges of the sustainability and development goals. AKST orientated education needs to start in primary school, continue through secondary school, and into university. Some measures that can further this goal include experiential, problem-solving approaches, enhanced outreach, and linkages, and stakeholder participation in curriculum design and research. Innovative approaches to teacher training and exchanges need to be developed. Curricula should focus less on specific technical knowledge that will quickly become obsolete, and more on enhancing the abilities of students to think and solve problems that are relevant to societal needs. Placing the study of agriculture within the wider context of development, knowledge, science and environmental management will increase its attractiveness to young people.

Effectiveness of capacity development strategies and programs will be better served if women's role in agricultural and development systems is fully recognized. The roles and responsibilities of women (and youth) in agriculture need to be better supported by AKST if farming is to be seen as a viable and attractive livelihood option. Encouraging the increased enrolment of female students in science, technology and agriculture courses will increase national capacity in these areas by allowing countries to benefit from the contributions and expertise of an under-used human resource. Encouraging the involvement of women in the design of technologies can lead to more gender-sensitive products and research agendas and increasing the number of female extension agents will help to expand outreach to women farmers.

Capacity development will increasingly be dependent upon access to a range of technologies such as global positioning systems (GPS), information and communication technology (ICT), and climate forecasting tools. These technologies are also needed to help farmers and to attract and retain good researchers and extension personnel. For example, the heterogeneity in ICT-related capacities and managing agricultural information and communications through ICT enabled systems can affect agricultural development, especially in the ability of a region/trade zone or country to enter global agricultural markets, develop its own agricultural innovation systems and effectively satisfy the demands of a global agricultural market. In addition, staff in remote locations need to be connected to colleagues and offered career incentives.

Promoting the development and use of labor-saving technologies, shifting to less labor-intensive crops, promoting income-generation based on local agrobiodiversity, and sharing and documenting local and traditional knowledge are useful strategies to mitigate the effects of disease and ill-health on family well-being and income. HIV/AIDs and other health issues are placing significant physical and psychological burdens on farming families and threatening the erosion of agricultural knowledge. An estimated 40.3 million people were living with HIV in 2005, two-thirds of whom were in sub-Saharan Africa, where agriculture is the mainstay of most economies and women comprise the backbone of the agricultural labor force. In SSA, 57% of adults (15-49) living with HIV were women.

The needs of capacity development are often underestimated, and thus under-funded in comparison to the R&D endeavors. Capacity development within existing organizations calls for improvements in local managerial capability and skills – a long-term activity with gradual, sustained change, especially in governmental settings. Typically, capacity development budgets have inadequate funds for operational purposes.

Investment options

More investment in public and private research is necessary to reach the IAASTD sustainability and development goals. Developing countries need to increase research intensity levels towards the levels of OECD countries. This would involve major investments by both the public and private sectors in public good AKST, which is justified given the high rates of return and the social and ecological benefits. Likewise, developed countries need to increase their investments in “basic” research to generate new knowledge for long-term goals and sustain a human workforce that is technically competent but not associated with commercial goals.

To meet poverty reduction goals a significant share of AKST investment should be focused on the problems of the poor. Research to increase productivity that is to be pro-poor should focus on major subsistence crops that make up a major component of the expenditures of the poor. AKST should focus on regions where the poor live, such as marginal lands, and problems that are often a particular problem for the poor, such as drought and water use efficiency. AKST should also focus resources on opportunities for the poor that can help them generate income so that they can move out of poverty. Studies have shown that the rates of return are high on research on subsistence crops, even in poor countries and regions. These investments will be particularly high when the poor themselves have a say in how these resources are allocated. But change is required in investment patterns to correct past distortions that have worked against the interests of the poor for both of under- and mis-investment.

More AKST funding must be invested in developing technology and management systems that save on the use of scarce resources such as land, water, and in the future, fossil fuels. The major resource constraint to increasing agricultural production will continue to be good quality agricultural land. Governments, international organizations and private firms have responded to this constraint by developing more intensive agriculture. Future AKST must focus on increasing output per unit of land through technology and management practices. In areas where the impacts of HIV/AIDS are most severe, AKST labor saving and labor efficient production and food processing is a high priority in the small farm sector. Water is an increasingly scarce resource constraint to agricultural production and food processing and is likely to become even more of a constraint in the next 50 years.

Major public and private research and development investments will be needed in plant and animal pest and disease control. Continued intensification of agricultural production, changes in agriculture due to global warming, the development of pests and diseases that are resistant to current methods of controlling them,[22] and changes in demand for agricultural products such as the increasing demand for organic products, will lead to new challenges for farmers and the research system. Investments in this area by the public and private sector have provided high returns in the past and are likely to provide even higher returns in the future.

Recognizing the multifunctionality of agriculture necessarily leads to more public and private investment in AKST to help agriculture provide ecosystem services such as reduced greenhouse gas emissions, reduced water pollution, and slowing or reversing the loss of biodiversity. These investments will be of three types:

- research to develop management practices, technologies, and policies that reduce the ecological footprint of agriculture, such as reducing agriculture's use of fossil fuels, pesticides, herbicides and fertilizer. This would include AKST to develop management practices such as: no-tillage systems to reduce use of fossil fuels for tillage, integrated pest management strategies to avoid overuse of inorganic pesticides, integrated soil management technologies to reduce the need for inorganic fertilizer, rotational grazing, green manuring,

[22] Crop resistance to pests and diseases can also be achieved through crop protection practices.

and support of mixed farming systems to improve the nutrient cycling within agriculture and livestock production;

- o development of biological substitutes for industrial chemicals or fossil fuels. These would include new biopesticides, improvements biological nitrogen fixation, and ethanol from sources such as sugarcane or biomass that do not compete strongly with food production. There is some evidence that research in this area can provide a good economic rate of return, and the rates of return are likely to rise as more governments put policies in place that reward farmers for the provision of these services; and
- o support local and indigenous knowledge to improve rural livelihoods. This knowledge has been neglected but research and management systems based on this knowledge have been shown to have positive ecological and economical impacts. In addition, some of the agricultural technologies to provide these ecosystem services can be designed to use the assets of the poor, such as labor in labor-abundant economies.

Investments in the governance of AKST and on research to better understand the role of governance are needed. If the goal of research investment is to make AKST more inclusive, accountable, and transparent, incentives will be needed to create the appropriate institutional changes. Research in the social sciences to better understand what type of governance will make AKST most effective at procuring financing, most efficient at conducting research, and most responsive to the needs of farmers and consumers is also likely to have high payoffs.

Multi-criteria decision-making processes that make more systematic use of economic RoRs, measures of ecosystem services, poverty, health, and risk could improve the efficiency of research since little use is currently made of formal priority setting tools, such as deliberative monetary valuation, various multi criteria mapping and analysis techniques, citizen juries, and stakeholder dialogues. Explicitly using information on the potential impact of AKST on ecosystem services, poverty reduction, and improved health in research resource allocation would also generate more support for government expenditures on agricultural research from environmental, health, and anti-poverty groups. However, there is clearly a need for more research that documents the limitations and potentials of these methods for guiding AKST investments.