8. Strategic recommendations

Africa has some unique features that differ from Asia, where the Green Revolution had such a pervasive impact. Recognizing these is an essential prerequisite to the formulation of strategies and priorities in science and technology (S&T). They became clear during the Study Panel's deliberations and shaped its recommendations.

The eleven distinct features of Africa are as follows:

- lack of a dominant farming system on which food security largely depends,
- predominance of rainfed agriculture,
- heterogeneity and diversity of farming systems and the importance of livestock,
- key roles of women in agriculture and in assuring household food security,
- lack of functioning competitive markets,
- dominance of weathered soils of poor inherent fertility,
- underinvestment in agricultural research and development (R&D) and infrastructure,
- lack of conducive economic and political enabling environments,
- large and growing impact of human health on agriculture,
- low and stagnant labour productivity and minimal mechanization,
- predominance of customary land tenure.

These delineate the options available to science and technology to influence productivity and imply that African agriculture is more likely to experience numerous 'rainbow evolutions' that differ in nature and extent among the many systems, rather than one Green Revolution as in Asia, where irrigated rice-wheat systems predominated. Hence more investment in agricultural research and development per unit of productivity gain will likely be required in Africa than was the case in Asia.

Improving agricultural productivity and food security in Africa will involve numerous challenges. The Study Panel has referred to them throughout the report. In this chapter the recommended responses to

these challenges are described under five strategic themes:

1. Science and technology options that can make a difference,
2. Building impact-oriented research, knowledge and development institutions,
3. Creating and retaining a new generation of agricultural scientists,
4. Markets and policies to make the poor income and food secure, and
5. Engaging science and technology for the benefit of African agriculture in the near term.

Following are the Study Panel's strategic recommendations with an elaboration of their background, rationale and implications. Table 8.1 at the end of the chapter provides a summary of the target audiences for the strategic recommendations and the time frame for initial impact. The relevant recommendations for each of the target audiences are also identified in Annex B.

The Study Panel purposely refrained from prioritizing the strategic recommendations. All the recommendations encompass the essential elements of an operational agricultural S&T strategy for Africa. And they represent the best prospects for meaningful impact on agricultural productivity and food security towards 2015. The precise priorities and action plans have to be developed by local consortia for the United Nations Millennium Development Goals and must be based on untapped production opportunities on the one hand, and unmet needs in overcoming chronic and hidden hunger on the other.

1. Science and technology options that can make a difference

Recommendation 1.1: Adopt a market-led productivity improvement strategy

A strategy of market-led productivity improvement should be embraced in order to achieve a balance between demand and supply, thereby providing incentives for farmers to close existing yield gaps and become more income secure in the process. Allowing farmers to respond effectively to price signals will result in more productive systems. This involves strengthening the competitive ability of farmers by using information and communications technology to provide speedy and timely market and price information, identifying new niche value-added marketing opportunities, quality literacy (including phytosanitary and safety standards), and encouraging and promoting farmer organizations, including co-opera-

tives. Such a market-led productivity strategy implies in the first place strengthened local and regional markets The emphasis has to be on increasing local consumption particularly by those who are undernourished. Farmers need to organize themselves to strengthen their market orientation and in that process to encourage partnerships with the private agro-service sector, firstly for local and regional markets. African companies should be encouraged by appropriate incentives. Opportunities to improve post-harvest handling to minimize losses and to add value to primary products need to be grasped along with improved grading, packaging, cooling and storage in order to promote exports. These will help to create expanded opportunities for non-farm employment as agricultural productivity improves and frees up labour.

Farmer organizations also need to partner with research, education and extension organizations in a market-driven participatory knowledge quadrangle, which effectively links innovation, information, knowledge and education. Women farmers need particular attention from the point of view of knowledge and skill empowerment, since they play a leading role in the cultivation and commercialization of food crops.

Recommendation 1.2: Adopt a production ecological approach with a primary focus on identified continental priority farming systems

Although other systems should not be neglected, especially at regional and national levels, to have a significant and speedy impact on agricultural productivity and food security in Africa, four production systems merit priority attention: the maize mixed, the cereal/root crop mixed, the irrigated, and the tree crop based. They represent agricultural bright spots. No generic recommendations can be made to enhance their factor productivity, but systematic production ecological analyses are needed to identify constraints and opportunities for system-specific improvement. The production ecological approach has proven its value in enhancing the productivity of specialized systems and has the capability to unravel the complex relationships in diversified systems. Designing mixed and multiple cropping, as well as multi-dimensional cropping based upon the principles of symbiosis and synergy, should receive greater attention. This should include choice of companion crops, which can extract water and nutrients from the soil and sunlight from the atmosphere in an efficient manner. In general soil fertility and water availability are major limiting factors, but pests

and diseases may reduce productivity growth considerably.

Productivity gains in recent decades in irrigated and commercial agriculture and prospects for further improvements of these specialized systems are favourable and to be encouraged. The bulk of African agriculture is however small-scale, often involving more than 15 crops in combination with animal species in highly diversified, rainfed farming systems. Such systems have received scant attention from science and technology, resulting in limited knowledge of their functioning in ecological, economic and social terms. These shortcomings warrant specific attention to identify opportunities for improvements.

The production ecological approach should also involve the revitalization of the cultivation of ecologically adapted and low-input requiring crops like millets, legumes and tubers, referred to as the local crops of Africa. Both dying wisdom and dying crops need to be saved. This calls for an inter-disciplinary project on under-utilized and orphan crops.

The aim in this strategy is to build on the advantages of diversified crop-livestock farming systems in Africa. Reinforcing the synergies within diversified farming systems in the design and conduct of agricultural research and development is a preferred strategy; specialization by definition does not offer such synergies and is not a panacea. The role of livestock in diversified systems must be recognized and accorded appropriate priority in R&D strategies in response to the increasing demands for animal products in the coming decades. Veterinary extension and services must be strengthened to protect animals against endemic and exotic diseases and zoonoses, and improved genetic stock introduced to enhance animal productivity. The private sector must play a key role here.

Recommendation 1.3: Pursue a strategy of integrated sustainable intensification

The aim of science and technology should be integrated sustainable intensification of agricultural production, encompassing a simultaneous increase in the productivity of land, labour and other inputs, while minimizing adverse environmental effects. The complexity of farming systems in Africa demands integrated approaches. Knowledge-intensive and technology-driven approaches that realize the potentials to boost productivity should be integrated with indigenous knowledge and farmers' needs and demands to assure the appropriateness and adoption of innovations. Integrated soil, water, nutrient and pest management approaches to research

and development, both in the priority and other production systems, are essential for sustainable intensification. This will require local institutional innovations such as farmer field schools promoted by Food and Agriculture Organization, Landcare in Australia. and integrated soil fertility programs of the International Soil Fertility Development Center. New breeding technologies, such as marker-assisted breeding and new biotechnological tools, such as the use of genetically modified organisms (GMOs), are expected to become increasingly important options in addressing the many biotic and abiotic constraints facing African farming systems.

Recommendation 1.4: Bridge the genetic divide

A substantial amount of additional investment is needed to respond to the specific needs of African farmers in order for them to derive benefit from the integrated application of both classical plant breeding and genetic modification. Africa cannot rely on external developments in this field because of the specific requirements of the diversified systems. It would be prudent to adopt a regional rather than a national approach to exploit biotechnology. Without substantial investments now, including by the private sector, Africa will be left behind as biotechnology has a significant gestation period before its impact is realized. Capacity in biotechnology must be strengthened, especially so that public institutions can effectively pursue public–private partnerships to bring the benefits of genetically modified organisms to the orphan crops and neglected areas that constrain African smallholders. The non-GMO components of biotechnology need immediate attention since they can help to improve eco-farming.

As the Green Revolution has largely bypassed marginal regions (which are extensive on the African continent), life sciences should focus especially on traits such as drought tolerance and resistances to the wide variety of pest and diseases. Greater attention should be given to breeding for agro-ecological and farming system niches using decentralized breeding and farmer participatory breeding approaches. Both research capabilities and regulatory procedures will need strengthening in order to exploit these opportunities in life sciences and ensure that biosafety aspects are adequately addressed. The well-being of farmers and consumers and the safety of the environment should be the bottom-line of the regulatory policies.

Recommendation 1.5: Recognize the potential of rainfed agriculture and accord it priority

Rainfed agriculture will remain the dominant system in Africa for decades to come. The further scope for economically viable and environmentally benign large-scale irrigation development in Africa is limited. Rainfed systems offer the best opportunities for the improved productivity that reduces poverty and food insecurity, provided there are greatly increased investments in agricultural research and development and infrastructure directed at these agro-ecologies.

Large improvements in water-use efficiency can be obtained in rainfed production systems by exploiting ecological synergies. A comprehensive package of agronomic measures should be pursued, including drought-tolerant cultivars; fertilization and small-scale supplemental irrigation during prolonged drought periods; harnessing underground water, even if quality is poor; or rainwater harvested in small dams. Supplemental irrigation can prevent total crop failure and stabilize and improve crop yields, but it is only likely to be profitable on higher-value crops. Inclusion of risk-reducing information with weather forecasts should be an integral part of such a comprehensive strategy.

Recommendation 1.6: Reduce land degradation and replenish soil fertility

Soil health and fertility management holds the key to enhancing crop productivity. Land degradation, due to overexploitation through cultivated area expansion, is a major threat to the African continent and leads to a downward spiral of productivity. This spiral can be broken with an integrated approach, exploiting the synergistic effect of inorganic and organic fertilization on soil and crop productivity. Low external input agriculture appears inadequate to control nutrient depletion, and to increase labour productivity. It should be realized that the very poor fertility of many African soils requires a long-term investment, which may not be forthcoming if relying only on market forces.

Recommendation 1.7: Explore higher-scale integrated catchment strategies for natural resource management

Strategies on catchment/watershed scales should be explored to optimize land and water use and safeguard biodiversity. This should include management of forest resources and conservation of native vegetation and associated wildlife habitat.

The projected water scarcities in many regions of Africa require strategies and policies for its sustainable use to address the increasingly competitive multi-sectoral demands for water. Appropriate combinations of legal frameworks, education and social mobilization will be required to build a sustainable water security system for Africa.

Recommendation 1.8: Promote the conservation, sustainable and equitable use of biodiversity

Africa has a rich treasure trove of biodiversity in flora and fauna. In many circumstances, properly structured private-public sector partnerships can provide a means of exploiting this potential and creating niche markets (e.g., medicinal plants). Increased investments in national and regional genebanks will be required to fully realize this promise. Tools need to be developed to determine the value and function of the different components of agrobiodiversity to farmers and other sectors of society if it is to be conserved and sustainably used. As well, conservation and commercialization have to become mutually reinforcing so as to create an economic stake in conservation.

To give effect to this will require a strengthening of local, national and subregional policies on agrobiodiversity conservation and use. Policy support is vital to halt genetic erosion; without it, national programs will continue to lack the finances and capacity to support conservation and use initiatives in a meaningful way. As a first step, make information on agrobiodiversity known and readily available in different formats for different audiences and users. In areas rich in the biodiversity of under-utilized crops like sorghum and millets, as for example in the Rift Valley in East Africa, community-managed agrobiodiversity sanctuarities may be established.

Recommendation 1.9: Enhance use of mechanical power

Selective mechanization to increase power-use intensity is an important option where there are labour shortages for specific operations and no adverse environmental consequences. Such an option would improve labour productivity; facilitate timeliness of operations, especially with the increasing labour constraints arising from health-related problems (such as malaria, TB and HIV/AIDS; and reduce drudgery. This would also reduce the dependence on hand-tools in favour of animal and mechanical draught power, which may also serve to attract currently disaffected youth to consider farming as a worthy career.

There is a need to encourage at national and regional levels the local manufacture of agricultural inputs, including agricultural machinery and equipment for all phases of agricultural production, fertilizer, agricultural chemicals, etc., in order to enhance agro-industrial development and reduce African countries' dependence for such goods on the industrialized countries of the world.

Recommendation 1.10: Embrace information and communication technology at all levels

Information and communications technology tools, such as decision-support systems and geographic information systems, should be mobilized to help amplify, accelerate and improve the precision of farmer decisionmaking and harvest the fruits of modern methods such as integrated water, nutrient, pest and disease management and weather forecasting information. Information and communications technology can also be used at catchment levels to investigate emerging issues that arise from increased competition for water within agriculture, and between agriculture and other sectors.

To realize these opportunities to reach the unreached and excluded, there must be vastly improved access to information and communications technology in Africa. Increased investments in communications and knowledge infrastructure are required to enable access to the Internet, libraries and information centres for the participatory knowledge quadrangle of farmers, extension professionals, educators and scientists. Such investments will provide them with the resources of currently available databases and other information. Institutions lacking fast and affordable access to the Internet should make full use of CD-based information sets such as The Essential Electronic Agricultural Library. Better-connected institutions should subscribe to Access to Global On-Line Research in Agriculture. There is also significant potential for web-based distance education and videoconferencing to both complement and supplement courses given in African universities. An integrated application of the Internet and radio will help to transmit timely information to all who may benefit from it.

Recommendation 1.11: Improve the coping strategies of farmers in response to environmental variability and climate change

Climate change and variability highlights the necessity to develop anticipatory short- and long-term forecasting research, and this requires training of scientists. Severe constraints in African agriculture are the high risk of crop failure and death of animals due to variability in weather, particularly rainfall. These constraints will be exacerbated by climate change. Addressing them requires a comprehensive set of agronomic measures, including drought-tolerant crops and supplementary irrigation. Crop improvement strategies should place greater emphasis on robust systems that reduce yield losses due to extreme weather events and greater consideration should be given to changing crop species (e.g., replacing some maize with cassava in Southern Africa).

2. Building impact-oriented research, knowledge and development institutions

Recommendation 2.1: Design and invest in national agricultural science systems that involve farmers in education, research and extension

A paradigm shift is needed towards an innovation, information, knowledge, and education quadrangle coalition in place of the outmoded linear and top-down research-extension-farmer-framework that has failed in Africa. Institutional arrangements to achieve this may differ from country to country and each must be encouraged to learn from its own experiences. There is a need to start from the bottom up in developing rural knowledge systems and institutions using participatory methods. There is also a need for substituting traditional extension systems with farmer participatory knowledge systems that are more gender sensitive. Community-based farmers' organizations must be established more widely and existing ones strengthened to facilitate the development of such farmer participatory knowledge systems and to promote value addition, agro-processing and marketing that can better exploit economies of scale and encompass vertical, horizontal and lateral integration from production to markets. There is a pivotal role to be played by the International Service for National Agricultural Research in action research, designed to distill from the experiences of national agricultural research systems everywhere best practice options to guide this process.

The pay-off to investment in agricultural science and technology will be higher if planning and investments are coordinated and sequenced. Design of organizational structures should promote 'connectivity' between the complementary institutions and a reward structure that encourages managers, scientists, farmers and credit institutions to communicate and cooperate with each other. Connectivity should include closer cooperation between university faculty members and their students working with national agricultural research scientists on priority problems of mutual interest. This will not only add university resources to technology-generating research efforts but will also improve the relevance, realism and quality of students' thesis research and overall educational experience. Farmer science and training centres are required that use farmer field schools and hands-on training to impart technical skills to farmers and their children in a learning-by-doing mode. This would be a part of a farmer participatory knowledge system within the participatory knowledge quadrangle coalition.

The Sub-Saharan Africa Challenge Program has many of the elements required to give effect to this paradigm shift and is to be encouraged. However, high transaction costs are a cause for concern. Of course the expectation is that the Challenge Program will open new funding windows, but the jury is still out on this.

Recommendation 2.2: Encourage institutions and mechanisms to articulate S&T strategies and policies

National governments, subregional and continental agencies should formulate sectoral and multi-sectoral strategies and policies that recognize the importance of agriculture and agricultural science and technology to improving productivity and food security and accord to these the appropriate priorities. These should build upon the national agricultural research systems, subregional organizations, FARA and NEPAD processes and involve the private sector. Academies of science should be encouraged to develop mechanisms to more effectively articulate S&T strategies and policies and become more relevant to the achievement of national goals. National S&T Councils for Food and Agriculture should be formed with well-defined mandates and adequate budgets to give effect to agreed national agricultural R&D strategies and priorities. Such Councils would comprise representatives from users and creators of knowledge and technologies, as well as from relevant government ministries, including agriculture, science and technology, food, trade, industry and finance.

To maximize the synergies in achieving food security and reduce vulnerability to shocks, a coordinated multi-sectoral strategy is needed, including health (hygiene, sanitation and safe drinking water); education; and agricultural/rural planning and development. There is a particular need to recognize the key role of women's education and status in reducing child malnutrition, the most insidious form of malnutrition. The Poverty Reduction Strategy Papers should embrace such strategies: to date there is little evidence of their inclusion. Strategies should include pro-active partnerships between the private sector and public research and extension agencies and, where improved efficiency and effectiveness could be achieved, privatization of public sector extension.

For the short term, an integrated package of appropriate technology options, services, and public policies, particularly in the field of input and output pricing and information, is needed to close yield gaps and move technologies from the shelf to the field. Technologies on the shelf are often not necessarily sufficiently tailored. In some cases adaptation and fine-tuning of technology options will be required (for example, conferring insect resistance to maize and cotton cultivars using genetically modified organisms, as in South Africa). The private sector can play a significant role here. In the longer term, national, regional and continental strategic research capacities need strengthening to increase productivity potentials. Further research on technology exchange and delivery systems is also required.

Recommendation 2.3: Cultivate African centres of agricultural research excellence

The establishment of African centres of agricultural research excellence (ACARE) would enable research on both continental and regional strategic priorities as complements to national agricultural research systems (NARS). These would evolve from and build upon existing national agricultural research institutes, international agricultural research centres and university programs through strategically targeted institutional capacity-building investments, and would not normally involve the creation of another layer of new institutions or bricks and mortar. Such institutions would be virtual centres of excellence, with a concentration of researchers and programs with guaranteed finances and output quality control through international upgrading and updating mechanisms. These virtual centres would be African owned and governed, provide a magnet for African scientists to remain at home, and help strengthen African national agricultural research

systems. A possible model for these is the Cooperative Research Centre (CRC) program in Australia. ACARE will require new and assured funding mechanisms and the CRC offers one approach. Others are explored in the recent InterAcademy Council (IAC) report *Inventing a better future*. NEPAD, FARA and the African subregional organizations should be directly involved in the design and development of the ACARE concept.

Immediate candidates for ACARE research foci might include biotechnology, climate change, biodiversity and post-harvest technology. Programs within CGIAR centres could be core elements or foundations for the ACARE. There is also good scope for the private sector to collaborate and lend support. In many cases, virtual ACARE may evolve from CGIAR centres, for example in biotechnology. ACARE can help address the NARS fragmentation challenge, ensure critical mass and facilitate linkages with international agricultural research centres and advanced research institutions in the North and South. Indeed the latter may be even more relevant to Africa. Clear criteria and mechanisms for the establishment of ACARE will need to be developed; the IAC report also contains useful guidelines in this respect. The InterAcademy Council, the InterAcademy Panel (IAP), and the academies of science could play a role in identifying suitable candidates for ACARE.

Regional research networks should evolve progressively from instruments of information exchange into entities that promote enhanced collaboration among various research partners, including the private sector, in pursuit of agreed priority regional research programs. Competitive research funds and matching grants could provide a mechanism for this.

Recommendation 2.4: Increase support for agricultural research and development

Governments and donor agencies must recognize that building impact-oriented institutions requires sustained and sizeable increases in the support of agricultural research and development that involve both institutional core funding as well as competitive grant provisions. To capitalize on the demonstrated high returns to agricultural research and development in Africa and its unique role in enhancing productivity and food security and reducing poverty across all the heterogeneous production systems, agricultural research funding to national agricultural research systems should increase in real terms by at least 10 percent per year to 2015. This would double the agricultural research investment on average to at least 1.5 per-

cent of agricultural GDP. As a quid pro quo for increased investments, agricultural R&D institutions must accept more stringent monitoring, evaluation and impact assessment to improve accountability and credibility and to become more flexible and responsive learning institutions. Without increased public investment in agricultural research and development, the private sector will remain moribund.

Africa's agricultural science community cannot flourish if it continues to depend upon foreign aid for around 40 percent of its budget. Within national agricultural research systems, this means implementing one or more of the following: generating some revenues through producer levies, pursuing contract research, devolving some commodity research programs to producer groups where feasible, forming alliances with private sector entities and generating revenue from the commercialization of research products and services.

Recommendation 2.5: Strengthen international agricultural research centres

The international agricultural research centres with headquarters and/or programs in Africa should retain their international identities, but operate in more collaborative and complementary modes with national agricultural research institutes and universities in Africa, and in participatory partnership with farmers and consumers. They should immediately integrate their programs at the operational level, in ecoregional consortia, in order to ensure critical mass and to exploit economies and synergies. In this manner they will be more responsive to African priorities. The scope for full institutional integration should be explored by the CGIAR as a matter of priority. They would phase out of applied and adaptive research activities for which national institutions are more cost effective, and develop comparative advantages in those basic and strategic research activities that enjoy economies of scale, require larger investments and for which there are broad global and continental research spillovers.

These African-based international agricultural research centres would provide the proposed African centres of agricultural research excellence with opportunities for improved access to international public S&T goods as peers. The level of investment in the African CGIAR centre programs for research and capacity building should be progressively strengthened by at least 5 percent per year, to at least US$235 million by 2015.

3. Creating and retaining a new generation of agricultural scientists

Recommendation 3.1: Focus on current and future generations of scientists in Africa

A greater effort must be made to retain current and future generations of African scientists to reduce the brain drain, rather than trying to regain the current African scientific Diaspora. This can be done by implementing policies that create more personally and professionally rewarding scientific opportunities in Africa. This will require competitive levels of compensation, opportunities to advance professionally based on rigorous but fair and transparent evaluation systems, well-equipped laboratories, access to current global sources of scientific information, and adequate operating funds. Professional growth funds should be available to actively encourage and enable young scientists to attend international conferences, summer institutes in Africa conducted by renowned professors, workshops and seminars in order to enhance their professional competence and self-confidence by interactions with peers.

There is scope for effective and efficient capacity building and strengthening the involvement and commitment of advanced research institutions and organizations by 'sandwich programs,' institutional twinning and visiting scientist arrangements using the proposed African centres of agricultural research excellence and advanced research institutes. Professional associations of agricultural scientists should be strengthened and encouraged to develop in Africa and to become more politically aware and constructive policy advocates. To stimulate professionalism, it has become essential that codes of conduct/ethics are developed and enforced by the professional associations as a condition of membership. In an era of expansion of the scope of intellectual property rights and genetic engineering, and marketing of proprietary products (e.g., pesticides and biochemicals), this has now become an urgent need.

The number of young scientists completing overseas graduate programs and returning home to pursue careers in national institutions can be increased if on arrival they have access to modern scientific infrastructure, information and communications technology (ICT), adequate research funding, and attractive monetary and non-monetary incentives. The ICT private sector could be especially helpful in this respect. To enhance the professional motivation and social recognition of agricultural scientists in the national agricultural research systems and universities, a professional

career service is required to provide recognition and reward for outstanding and innovative scientists. Leadership training should be a feature of the career services. The scientific infrastructure for effective and lasting academic partnerships includes post-degree networking and mentoring. Start-up research grants and a clear career path are key elements in a strategy to reduce further brain drain. The priority aim would be to cultivate young African scientists rather than expect senior academics and researchers to leave the Diaspora and return permanently to Africa.

Recommendation 3.2: Broaden and deepen political support for agricultural science

Real improvement in agricultural education and research requires strong support from top political leaders. A coalition of supportive agricultural constituencies must be formed, including farmers associations, producer groups, national agribusiness companies, educators and researchers. Deans of agricultural faculties and directors of research must become more politically savvy and entrepreneurial, building political support among farmers, government ministers and donors. The international agricultural research centres, such as International Service for National Agricultural Research (ISNAR) could assist this process by provision of leadership and media communications training.

Recommendation 3.3: Reform university curricula

To improve the effectiveness of agricultural scientists, the undergraduate curricula of agricultural universities should also stress production ecological and multidisciplinary approaches to better prepare them for the innovation, information, knowledge and education quadrangle. Students should be better sensitized to the socio-economic and policy environments in which agricultural development occurs and in which they will be working during their careers, including the role of gender. Virtual universities and colleges on a regional basis could be resource centres for such a pedagogic revolution to better prepare students to collaborate with colleagues in related fields and to competently bridge the gaps separating farmers, educators, researchers and extensionists. The aim would be to supplement narrow disciplinary-based 'bamboo' graduates with more holistic 'baobab' graduates with a problem-solving focus. Field research work with farmers using participatory approaches, exposure to indigenous knowledge sys-

tems and linking them to modern science, would be of great value in many areas. Strong training in information and communication technology is essential. Disciplinary specialists will continue to be required for the strategic research challenges of the future. These skills will be primarily developed at post-graduate levels.

Recommendation 3.4: Mobilize increased and sustainable funding for higher education in science and technology, minimizing dependence on external donor support

Curricula reform, improving faculty and scientist compensation, and modernizing teaching and research infrastructure are expensive, and require stable funding over time. Lasting improvements in higher education in the agricultural sciences must ultimately be funded from national resources.

There is an urgent need for increased investment in and enhancement of both the numbers of students and quality of agricultural education (i.e. science, food, processing, natural resource management, rural development) at primary, secondary and tertiary levels. The international financial institutions, United Nations and bilateral agencies should play a particularly important role in this revolution in education. The African Land Grant University model may need to be reinvented as part of this, with the focus on strengthening and adapting existing universities rather than creation of additional ones.

African educators need to become much more familiar with experiences in educational reform throughout the world, particularly in Asia and Latin America. But models used elsewhere can rarely be imported successfully. Rather they need adaptation to fit local political, social, institutional and economic environments. Participatory planning and close monitoring to guide mid-term corrections are essential. Human and institutional capacity building is a gradual and often incremental process that takes time to have real impact.

There is good scope to explore the potential for efficiencies in regional graduate training models. The large number of small countries in Africa means it is often difficult for individual universities to achieve a critical mass of teachers in specialized areas such as biotechnology. Appropriately designed regional training approaches may provide a solution. However, rather than creating new regional institutions, self-initiated efforts—building 'regional specializations' within existing universities and then developing networked training programs that attract students from a regional wa-

tershed – are generally more successful. Such initiatives may initially rely on external support for design, launch and fine-tuning, but must generate adequate national or regional resources to be sustained over time. They must be professionally competitive with global training alternatives; they must have strong buy-in and commitment for regional cooperation from a critical mass of partner universities; and they have to do business in a fully transparent, apolitical, unbiased and accountable manner.

Because of greater relevance, lower cost, less attrition and the residual long-term benefits of strengthening national institutions, priority should ideally be to provide graduate training in African universities whenever competitive programs exist. Foreign degree programs should generally be reserved for highly specialized areas where competitive programs have not yet been developed. Sandwich-training approaches, already alluded to in Recommendation 3.1, should be adapted where appropriate – to lower costs, increase the relevance of thesis research and to increase graduate returnee rates. The international agricultural research centres in Africa already provide opportunities for thesis research.

Recommendation 3.5: Strengthen science education at primary and secondary school levels

An essential base on which to support the emergence of future generations of agricultural scientists, educators and indeed farmers, is stronger science training from the start. Improved curricula focusing on agriculture, and combining the best of modern and indigenous scientific knowledge, can help attract the brightest young Africans into the agricultural sciences and farming. A special emphasis must be placed on improving the accessibility and friendliness of science training to young women. Farm science schools where the pedagogic methodology is 'learning by doing' are urgently needed for the knowledge and skills empowerment of semi-literate and illiterate farmers.

4. Markets and policies to make the poor income and food secure

Recommendation 4.1: Increase investments in rural infrastructure

Governments need to increase investments in infrastructure such as roads, information and communications technology, storage, post-harvest

technology, and value addition, and ensure the appropriate grading standards, sanitary and phytosanitary regulations are in place and enforced. Unless this is done, neither producers nor consumers will derive full benefit of enhanced production.

Recommendation 4.2: Strengthen capacity to expand market opportunities

Regional cooperation is required to remove formal and informal barriers to trade, strengthen the contract system, establish food quality and food safety standards and increase research capacity in all these areas. Such cooperation can promote interregional trade within Africa and widen international market opportunities, which can provide a floor to commodity prices as agricultural productivity and marketable surpluses increase. There is a need to open up diversified market opportunities in concert with the private sector, including non-food commodities, to promote food self-reliance and security. To strengthen the competitive ability of African farmers, appropriate advanced market intelligence and logistics are required, along with land-use planning.

Recommendation 4.3: Institute effective intellectual property rights regimes to encourage the private sector and facilitate public-private partnerships

If the benefits of modern science and technology are to reach African smallholders it will be important to pay attention to issues of intellectual property rights (IPR). Resource-poor farmers will be excluded from the benefits of modern science, including biotechnology, if specific measures are not taken to avoid social exclusion in the dissemination of new technologies. In cases of patented technology developed by the private sector, suitable institutional devices should be developed by governments, with financial support from multilateral and bilateral donors, for purchasing such technology options and making them available to the national agricultural research systems and smallholder farmers. Models include the African Agricultural Technology Foundation (AATF). Unless mutual trust and dialogue occur, public-private partnerships will remain elusive.

In developing policies in intellectual property rights it is important to provide a mechanism for recognizing and rewarding the contributions of African rural women and men to the conservation and enhancement of in-

digenous agro-biodiversity. The policy should be designed to stimulate inventions and innovations relevant to the needs of the rural poor and to foster food, nutrition and health security for all. The IPR policy should be gender sensitive, since women play a leading role in the selection and conservation of plant genetic resources.

Recommendation 4.4: Reduce barriers to increased African trade with OECD countries

Improved international market access will be a key ingredient in translating increases in African agricultural productivity into improved food security. Current trade negotiations should recognize this. OECD countries should allow developing countries more access to their markets and reduce their domestic agricultural subsidies and tariff/non-tariff barriers to trade. They should also assist developing countries to meet quality, safety and sanitary/phytosanitary standards, and help to improve their negotiation and decisionmaking abilities through collaborative research and capacity building. Africa should not replicate OECD trade and protection policies as a general countervailing response. But to catalyze African agriculture, there should be scope for such things as targeted subsidies for strategic inputs, such as biological and mineral fertilizers, making use of the successful voucher systems that were used in various programs of the International Centre for Soil Fertility and Agricultural Development (IFDC). Public policies should also incorporate safety nets to address risks and nutrition security, as well as payments to farmers for environmental services.

Recommendation 4.5 Improve data generation and analysis related to agriculture, food and nutrition security, and vulnerability

There are major constraints to the analysis of productivity trends and their determinants and the design of appropriate strategies and policies for science and technology. The constraints include the lack of quality statistics on agricultural production, food and nutrition status, and the extent of vulnerability to uncertain events on a disaggregated agroecological and subnational basis. There are also special problems related to the heterogeneous diversified production systems of Africa, and staff members of statistics offices require continuous research and training. The FAO, with WHO and UNICEF, should take the leadership in this endeavour and design strategies and scientific methodologies to ensure in future that such data are free of political influences.

5. Engaging science and technology for the benefit of African agriculture in the near term

Recommendation 5.1: Employ the Study Panel's recommended strategies to implement a series of Participatory Science and Technology Pilot Programs

The Study Panel's recommended strategies should be employed to implement a series of Participatory Science and Technology Pilot Programs, focusing on the priority continental farming systems identified by the Study Panel and on institutional innovations that aim to realize unexploited yield potentials, thereby improving food security. As described in this report, the Study Panel undertook a priority assessment of 10 major African farming systems, using two indicators – an agricultural value-added index and a composite underweight children index. Based on this analysis, four priority farming systems were identified: maize mixed, cereal/root crop mixed, irrigated, and tree crop based. The highland farming systems were not fully represented in this analysis, and they may also have potential. For all these farming systems, there are many technological opportunities for enhancing productivity and profitability in Africa on an environmentally sustainable basis

As 'seeing and harvesting are believing' to resource-poor farming families, the Study Panel proposes the following action agenda:

a. The initiation of Participatory Science and Technology Pilot Programs should be initiated, which can develop appropriate S&T institutional innovation options for unleashing latent productivity potentials, leading to an enhancement of household food and income security. There is a need for operational-scale pilot S&T programs covering small agro-ecological regions. These area-level multi-institutional programs could be developed for the four 'best bet' continental priority farming systems areas and/or priority systems identified regionally or nationally.

b. The UN Secretary-General should take steps to identify appropriate regional, national and international institutions to implement the pilot programs designed to shape Africa's agricultural future. There should be strong African involvement at every step.

c. Such participatory S&T pilot programs should be introduced where the following components of the production-processing-marketing-consumption chain can be developed in a participatory mode:
   - An assessment of indigenous technology options relevant to improvement of productivity and food security;

- An assessment of market potentials and constraints for existing and prospective commodities in the farming systems;
- An assessment of the scope for the following new technology options to enhance productivity and food security:
  - Integrated nutrient and soil fertility enhancement;
  - Integrated pest management;
  - Small-scale water harvesting and efficient and economic use through micro-irrigation systems of delivery of water and nutrients;
  - Biotechnological applications like improved genetic strains (including genetically modified organisms, where relevant), biofertilizers and biopesticides;
  - Use of improved farm implements and appropriate mechanization for increasing labour productivity, reducing drudgery and ensuring timely farm operations;
  - Introduction of appropriated post-harvest processing, storage and marketing techniques;
  - Promotion of non-farm employment through the introduction of technology options for adding economic value to primary products and through agri-business enterprises based on micro-credit;
  - An information and communication program to provide location-specific information relating to meteorological, management and marketing factors and to promote genetic, quality and trade literacy among smallholder rural farm families;
  - Establishment of farmer field schools for integrated pest, disease and weed management, integrated water and fertility management and the other aspects of production and post-harvest technologies based on the principle of learning by doing;
  - Promotion of institutional structures like cooperatives and self-help groups that can confer the power of scale to smallholders at the production and post-harvest phases of farm operations.
- Exploring the scope for institutional innovations such as:
  - The promotion of a participatory knowledge quadrangle coalition led by smallholders involving them and universities, national agricultural research institutions and extension agencies to explore new modes of partnership;
  - The identification of candidates for African centres of agricultural research excellence that would serve the interests of smallholders;
  - The stimulation of public-private partnerships that would address priority constraints that cannot be alleviated by independent activi-

ties and aimed at building trust and synergies;
- Identifying the constraints at the national, regional, continental and global levels that prevent the realization of the promise and potential of the Participatory Science and Technology Pilot Programs to improve agricultural productivity and food security at the local level.

d. The Study Panel suggests that interdisciplinary teams from the quadrangle of national agricultural research systems, universities, extension services and farmers' organizations be constituted to prepare business plans for policy changes and research in priority farming systems. Nothing succeeds like success, and hence the sites for the initial pilot schemes should be developed where there is a socioeconomic, political, scientific and ecological environment conducive to the achievement of the goals of this program. A local farmers' advisory council involving both men and women should be constituted to assume ownership and undertake monitoring and evaluation of the program.

e. Within the pilot schemes, plans should be developed that stimulate convergence and synergy among the range of programs designed to achieve the following UN Millennium Development Goals:
- Eradicate extreme poverty and hunger through a paradigm shift from unskilled to skilled work and through sustainable farming systems intensification, diversification and value-addition;
- Achieve universal primary education;
- Promote gender equality and technological and skill empowerment of women;
- Improve maternal health and nutrition, so as to avoid the birth of babies characterized by low birth weight;
- Combat HIV/AIDS, malaria and other diseases;
- Ensure conservation and enhancement of basic life-support systems (i.e., land, water, forests, biodiversity and the atmosphere).

f. To mobilize the necessary technological, financial, managerial and institutional resources essential for the successful implementation of these pilot programs – designed to harness the best in frontier science and traditional wisdom for enhancing the productivity, profitability and sustainability of major farming systems – it is necessary to organize local- or regional-level consortia or coalitions of farmers, government, nongovernment, community, research, educational, mass media and financial and donor institutions. The Participatory Science and Technology Pilot Programs should not draw resources from existing programs, but build upon them.

g. These pilot programs should entail action research. There will need to

be an effective monitoring and evaluation capability to assess their performance and draw appropriate lessons for designing operational programs which involve upscaling and adaptation to the diverse environments in Africa.

Table 8.1. Target audiences and time frames for impact of strategic recommendations

Strategic recommendations	Target audiences: National governments	NARS[1] & university managers	Private sector	Subregional organizations	FARA[2]	NEPAD[3]	International agencies	OECD/donors	CGIAR[4]/ IARC[5]/ARI[6]	Time frame for initial impact (yrs): Near term <5	Medium term 5-10	Long term >10
1. SCIENCE AND TECHNOLOGY OPTIONS THAT CAN MAKE A DIFFERENCE												
1.1 Adopt a market-led productivity improvement strategy	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
1.2 Adopt a production ecological approach with a primary focus on identified continental priority farming systems	✓	✓		✓	✓	✓	✓	✓	✓	✓		
1.3 Pursue a strategy of integrated sustainable intensification	✓	✓		✓	✓	✓	✓	✓	✓	✓		
1.4 Bridge the genetic divide	✓	✓	✓	✓	✓	✓			✓		✓	
1.5 Recognize the potential of rainfed agriculture and accord it priority	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
1.6 Reduce land degradation and replenish soil fertility	✓	✓		✓	✓	✓	✓	✓	✓	✓		
1.7 Explore higher scale integrated catchment strategies for natural resource management	✓	✓		✓		✓	✓	✓	✓			
1.8 Promote the conservation, sustainable and equitable use of biodiversity	✓	✓		✓	✓	✓	✓	✓	✓			✓
1.9 Enhance use of mechanical power	✓	✓	✓			✓				✓		
1.10 Embrace information and communication technology at all levels	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
1.11 Improve the coping strategies of farmers in response to environmental variability and climate change		✓							✓		✓	
2. BUILDING IMPACT-ORIENTED RESEARCH, KNOWLEDGE AND DEVELOPMENT INSTITUTIONS												
2.1 Design and invest in national agricultural science systems that involve farmers in education, research and extension	✓	✓	✓			✓				✓		
2.2 Encourage institutions and mechanisms to articulate S&T strategies and policies	✓	✓		✓	✓	✓			✓	✓	✓	✓
2.3 Cultivate African centres of agricultural research excellence	✓					✓					✓	
2.4 Increase support for agricultural research and development	✓						✓	✓		✓		
2.5 Strengthen international agricultural research centres							✓	✓	✓		✓	

1 NARS: National agricultural research system
2 FARA: Forum for Agricultural Research in Africa
3 NEDAP: New Partnerships for Africa's Development
4 CGIAR: Consultative Group on International Agricultural Research
5 IARC: International agricultural research centre
6 ARI: Advanced research institute

Strategic recommendations	Target audiences: National governments	NARS[1] & university managers	Private sector	Subregional organizations	FARA[2]	NEPAD[3]	International agencies	OECD/donors	CGIAR[4]/ IARC[5]/ARI[6]	Time frame for initial impact (yrs): Near term <5	Medium term 5-10	Long term >10
3. CREATING AND RETAINING A NEW GENERATION OF AGRICULTURAL SCIENTISTS												
3.1 Focus on current and future generations of agricultural scientists	✓	✓							✓		✓	
3.2 Broaden and deepen political support for agricultural science	✓	✓	✓	✓	✓	✓				✓		
3.3 Reform university curricula	✓	✓										✓
3.4 Mobilize increased and sustainable funding for higher education in S&T, minimizing dependence on donor support	✓	✓					✓	✓		✓	✓	
3.5 Strengthen science education at primary and secondary school levels	✓	✓										✓
4. MARKETS AND POLICIES TO MAKE THE POOR INCOME AND FOOD SECURE												
4.1 Increase investments in rural infrastructure	✓					✓	✓	✓		✓		
4.2 Strengthen capacity to expand market opportunities	✓					✓	✓	✓		✓		
4.3 Institute effective intellectual property rights regimes to encourage the private sector and facilitate public-private partnerships	✓					✓	✓	✓			✓	
4.4 Reduce barriers to increased African trade with OECD countries								✓		✓		
4.5 Improve data generation and analysis related to agriculture, food and nutrition security, and vulnerability	✓						✓			✓		
5. ENGAGING SCIENCE AND TECHNOLOGY FOR THE BENEFIT OF AFRICAN AGRICULTURE IN THE NEAR TERM												
5.1 Employ the Study Panel's recommended strategies to implement a series of Participatory Science and Technology Pilot Programs	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		

Note: The strategic recommendations are not arranged in a priority sequence. Rather the complete set of recommendations are regarded by the IAC Study Panel as an operational strategy that needs to be implemented in its entirety.