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Technologies to address challenges in areas such as agriculture and water

Report of the Secretary-General

Executive summary

This report seeks to identify ways to support sustainable agriculture in developing countries through science, technology, and innovation. It addresses key challenges facing smallholder farmers and presents findings and recommendations.

The report underscores the need to review existing agricultural science, technology and innovation systems with a view to strengthening the support to smallholder farmers through sustainable agriculture, and integrating a gender perspective in the design of these policies.

Contents

Introduction

1. Food is essential for human survival and improving food security is critical for achieving the Millennium Development Goals (MDGs). Alleviating hunger and ensuring adequate, accessible food supply in the future requires rethinking how food is produced, stored and distributed, including the use of water in agriculture.

2. At the thirteenth session of the Commission on Science and Technology for Development (CSTD), held in May 2010, the Commission decided to examine "Technologies to address challenges in areas such as agriculture and water" as one of its priority themes during the 2010–2011 intersessional period. To contribute to further understanding of the issue, and to assist the CSTD in its deliberations at its fourteenth session, the UNCTAD secretariat convened an intersessional panel meeting in Geneva, Switzerland, from 15 to 17 December 2010. The present report is based on the findings of the panel, national reports contributed by CSTD members, and other relevant literature.

I. Agriculture challenges

3. Agriculture accounts for 20–60 per cent of GDP in most developing countries and provides a livelihood for approximately 2.6 billion people—representing 40 per cent of the global population, including 370 million indigenous farmers and up to 65 per cent of the labour force in developing countries. At the same time, agriculture has a major influence on clean water supply, pollination, pest and disease control, and carbon emissions.[1] Improvements in agriculture can significantly impact many aspects of life for many people and contribute to the attainment of the internationally agreed development goals, including those in the Millennium Development Goals (MDGs).[2]

4. One of the clearest connections between agriculture and the MDGs is the important role of food production in alleviating hunger. Nearly 1 billion people are undernourished[3] and this number may increase even further as a result of the global financial crisis, sustained high levels of unemployment, increased food price volatility, shortages and predictions of further widespread droughts and floods.[4] Higher oil prices are increasing the cost of food by increasing shipping costs (resulting in higher delivered prices of agricultural products) and diverting more crops such as corn and soybeans to biofuel production, further tightening supplies for livestock and human consumption.[5] Higher food prices also threaten peace and security.

5. Hunger is not simply a production problem – enough food is being produced globally to feed everyone in the world. Over the past 50 years, global per capita agricultural production has outpaced population growth – the world produces 17 per cent more calories per capita and on average people have 25 per cent more food than they did in 1960, even with a doubling of the global population, and there is enough to provide everyone in the world with at least 2,720 kcal per day. In fact, in some countries, 30–40 per cent of food produced is wasted. However, increased food supply does not automatically mean increased food security. The dramatic increase in production over the past few decades, mostly a

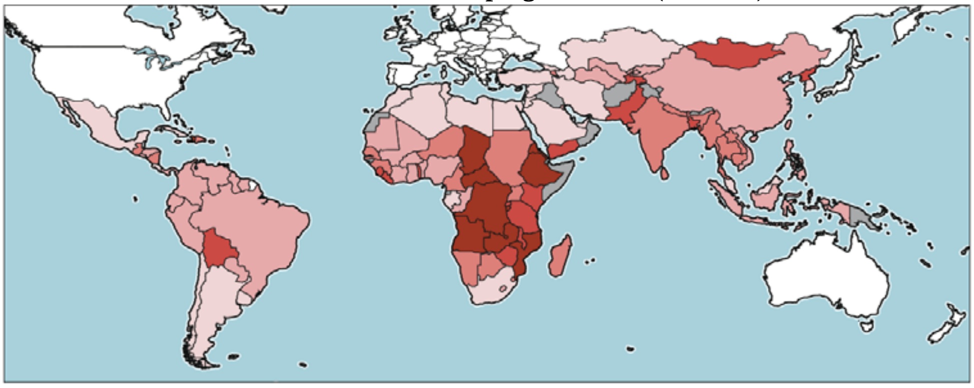
1 IAASTD (2009) and UNCTAD (2010a).
2 For a discussion on the relationship between agriculture and the MDGs, see Rosegrant, MW *et al*. (2006).
3 IFAD (2011).
4 Vidal (2010).
5 Schoen (2011).

result of the Green Revolution, has not led to major reductions in hunger and poverty in developing countries.[6]

6. The majority of the chronically hungry in developing countries are smallholder farmers, most of whom reside in Africa and Asia. They manage around 80 per cent of the farmland in Asia and Africa and supply about 80 per cent of the food consumed in the developing world.[7] As shown in figure 1 and table 1, the bulk of child malnutrition lies in these two continents, where the average farm size is 1.6 ha, compared to the average farm size of 121 ha in North America. Globally, 95 per cent of farms less than two hectares are in Asia (87 per cent) and Africa (8 per cent).[8]

7. Challenges particularly facing smallholder farmers are lack of access to knowledge, skills, inputs, credit, markets and infrastructure. Furthermore, they live and work on marginal lands at increased risk of soil degradation, droughts, floods, storms, pests, and erratic rainfall, and the poorest farmers with little safeguards against dramatic climate changes often live in areas prone to natural disasters.[9] Sustainable agriculture – building on the principles of economic, social, and environmental sustainability – holds the promise to address many of these challenges faced by resource-poor farmers.

Figure 1
Prevalence of undernourishment in developing countries (2005–07)[10]



[6] FAO (2002) in World Hunger Education Service (2010) and UNCTAD (2008).
[7] IFAD (2009).
[8] Nagayets (2005) and von Braun (2005).
[9] UNCTAD (2010b) and Hoffmann (2010).
[10] Copied from FAO (2010) based on FAOSTAT 2010.

Table 1
Average farm size by region[11]

Region	**Average farm size (ha)**
Africa	1.6
Asia	1.6
Latin America and Caribbean	67.0
Western Europe	27.0
North America	121.0

II. Science and technology applications and farming practices for sustainable agriculture

8. A range of existing science and technology applications and farming practices at all stages of agricultural processes can significantly increase agricultural productivity. Some of these technologies, applications and practices may be well suited for smallholder farmers. Smallholder farming is generally labour-intensive, does not rely heavily on external inputs, and is more dependent on the local environment. Introductions of modern science and technology to smallholder farming should take into account these characteristics and be based on farmer knowledge networks, better infrastructure, and a system approach involving crop rotation and integrated crop and feedstock production.

9. Sustainable agriculture adopts interrelated soil, crop and livestock production practices to continuously recreate the resources used while reducing or discontinuing harmful external inputs. As shown in table 2 and the examples described in boxes 1 and 2, sustainable agriculture draws on practices and technologies that integrate and are adapted to local knowledge, natural processes, and agro-climatic environments.[12]

[11] Adapted from Nagayets (2005) and von Braun (2005).
[12] United Nations (2009).

Table 2
Examples of prominent sustainable agricultural practices[13]

Category	Examples of practices
Soil and water management	▪ Terraces and other physical and biological structures to prevent soil erosion ▪ Contour planting ▪ Hedgerows and living barriers ▪ No-till farming ▪ Mulch, cover crops including biological nitrogen fixing legumes ▪ Water harvesting
Soil fertility management	▪ Manure and compost ▪ Biomass transfer ▪ Agro-forestry ▪ Integrated soil fertility management
Crop establishment	▪ Planting pits ▪ System of rice intensification ▪ Inter-cropping Alley cropping
Weed and pest control	▪ Inter-cropping and rotation ▪ Integrated pest management

Box 1. Sustainable farming practices: the push-pull method

The push–pull method is an integrated production system in which a crop combination deals with a number of issues at once. To illustrate, stem borers are insect pests that affect corn. Planting a trap crop, Napier grass, around a corn field attracts stem borers away from the corn. A cover crop, *Desmodium*, repels stem borers while at the same time attracting natural enemies of the stem borer which eliminate the few stem borers that enter the field. Because the ground is covered in permanent crops, erosion is stopped. In addition to high corn yields, the system produces fodder for livestock. Soil fertility is enhanced at each cropping cycle and although *Desmodium* fixes nitrogen, manure from livestock restores nitrogen and other important nutrients.

Box 2. Sustainable technology: fighting pests with wasps[14]

An example of a living, proven and sustainable technology is the use of the wasp *Anagyrus lopezi* to eradicate a species of mealybugs that feeds exclusively on and threatens cassava crops in Africa and Thailand. The wasps, each smaller than a pinhead, exclusively find mealybugs and pierce and lay their eggs inside them. The larvae devour the mealybugs from within and in a few days emerge from their mummified shells to seek new hosts.

10. Sustainable production systems can substantially improve crop yields of subsistence farmers in tropical regions with rapidly growing populations and severe food insecurity. Additionally, by locally sourcing inputs such as labour, organic fertilizers and bio-pesticides, a greater share of local farming expenditures remains in the local economy, supporting local economic development.[15]

11. One type of sustainable agriculture system, organic agriculture, is characterized as "holistic production management [whose] primary goal is to optimize the health and

[13] Tripp (2006).
[14] Mydans (2010).
[15] UNCTAD (2010a).

productivity of interdependent communities of soil, life, plants, animals, and people."[16] Organic and near-organic agricultural methods and technologies are ideally suited for many poor, marginalized smallholder farmers, as they require minimal or no external inputs, use locally and naturally available materials to produce high-quality products, and encourage a systemic approach to farming that is more diverse and resilient. Environmental benefits from organic agriculture include increased water retention in soils, improvements in the water table, reduced soil erosion, and improved organic matter in soils, resulting in better carbon sequestration and increased agro-biodiversity. Organic farmers also benefit economically: they avoid the need to purchase synthetic pesticides and fertilizers, obtain premium prices for certified organic produce, and add value to products through processing activities. Under marginal conditions, when smallholder farmers who use relatively low amounts of synthetic inputs convert to organic agriculture, yields do not fall and at least remain stable. The better organization and management of organic farmers tend to increase yields. Over time, yields increase further as capital assets in systems improve, thus outperforming those in traditional systems and matching those in more conventional, input-intensive systems.[17]

A. Adequate water management

12. Multiple practices and science and technology applications tackle one of the key challenges for agriculture – agricultural water use. Global food production accounts for 70 per cent of all water withdrawn from rivers and aquifers. Water resources are under stress in many areas and the demand for water is expected to increase as competition intensifies among municipalities, industry and agriculture.

13. Irrigation is practiced on 20 per cent of global cultivated land area but contributes to 40 per cent of global food production. Additionally, Africa produces 38 per cent of its crops by value from 7 per cent of cultivated land on which water is managed, suggesting that further investment in irrigation in Africa can significantly improve food security.[18] Irrigation technologies generally fall into two main categories: water-saving technologies that increase water productivity, and water-storage technologies that make water availability more consistent despite seasonality, variable and unpredictable rainfall, flooding, and drought. Water storage has great potential. Examples of water storage that can benefit farmers in developing countries include storing water from evening river flows for daytime use and groundwater storage.

14. For relatively large and sophisticated farming systems, new irrigation techniques include automated canal and piped water delivery systems, laser land leveling for surface irrigation applications, automated sprinkle irrigation, micro-irrigation and sophisticated control systems.[19] Many large-scale, centrally managed irrigation systems in Asia are in need of modernization to support modern farming practices and changing food demands. Ninety-five percent of irrigation relies on surface flooding, so technologies that improve canal irrigation are of high priority. Better design and management of large dams and irrigation systems can maintain aquatic and riparian ecosystems, avoid siltation and salination, and improve equity between upstream and downstream users.[20] Micro-irrigation

[16] FAO/WHO in UNCTAD (2008).
[17] UNCTAD (2008).
[18] Svendsen (2009).
[19] UNCTAD (2010b).
[20] IAASTD (2009).

should be targeted at selected environments where water costs are high, surface irrigation is impractical, and high value cash crops can be grown and marketed.[21]

Box 3. Using nuclear science to study groundwater[22]

With assistance from the International Atomic Energy Agency (IAEA), the Philippine Nuclear Research Institute has developed capabilities in isotope hydrology, which can be useful for understanding groundwater systems, particularly aquifer recharge and discharge processes, flow and interconnections between aquifers, and sources and movement of pollutants. Based on a general concept of tracing, isotope techniques enable researchers to assess dam leakage and identify groundwater zones that are vulnerable to contamination from surface water and irrigation water.

15. Smallholder farmers rarely have the means for permanent or comprehensive irrigation and the bulk of crop production in developing countries is rain-fed. Rain-fed farming is practiced on 80 per cent of cultivated land and accounts for 60 per cent of the world’s food production. Some smallholder farmers have invested in locally adapted technologies such as small storage ponds, PVC piping, and pumping equipment to access groundwater and gain greater control over water supplies.[23] These mostly unregulated withdrawals might over-exploit groundwater and may be unsustainable.

16. More sustainable options for smallholder farmers in rain-fed areas include contour farming, ridging, increasing soil organic matter, rainwater harvesting, and no-till farming; these practices can increase soil water retention and reduce runoff.[24] No-till farming consists of planting new crops over dead leaves and vegetation left after harvesting prior crops; this technique helps avoid soil loss from erosion. Other suitable irrigation techniques and system components particularly suitable for smallholder farmers include: affordable drip irrigation for more efficient water application, treadle pumps for water lifting, plastic water tanks, micro-sprinklers, and irrigation decision support systems. Additional potential solutions on the horizon to supply water for all farmers include seawater desalination, recycling and treatment of wastewater, multiple use water (for rural drinking water and agriculture), and the use of municipal water.[25] Seawater desalination may be able to supply water for agriculture, although it is likely to be energy–intensive. There is also significant potential for smarter water management using information and communications technologies (ICTs) such as geographic information systems (GIS), moisture sensor-based irrigation systems, meters, controllers, computers, and mobile phones.

B. Improved plants, livestock and fish

17. New cultivation techniques and improved varieties of crops, livestock, fish, and trees can be developed through accelerated processes, such as traditional and participatory breeding combined with marker-assisted selection, genomics and transgenic approaches. Several biotechnology developments are promising for agriculture, including smallholder farmers. New Rice for Africa is the result of crossbreeding African and Asian rice to produce progeny with high yields, earlier maturity, hardiness and resistance to stress. New stem-resistant varieties of wheat have also been developed in collaboration with Consultative Group on International Agricultural Research (CGIAR) centres and will soon

[21] Cornish (1998).
[22] Country report, CSTD initersessional panel (2010).
[23] Mukherji (2009).
[24] IAASTD (2009).
[25] UNCTAD (2010b) and Molden (2009).

be delivered throughout the Horn of Africa and South Asia. Additionally, drought-tolerant maize can benefit more than 30 million people in Africa.[26]

18. Plant tissue culture entails cultivating plant cells, tissues or organs on specially formulated nutrient media under the right conditions to regenerate an entire plant from a single cell. This represents an important technology for the production of disease-free, high quality planting material and the rapid production of many uniform plants.[27]

19. Genetic breeding, the incorporation of resistance genes into high-yielding crop varieties and other genetic modifications can produce crops with improved crop yields, appearance, taste, nutritional quality, and resistance to drought, insects, disease and herbicides. However many developing countries lack the scientific and regulatory expertise to develop and manage these technologies and assess uncertainties about their socio-economic and environmental benefits and risks. For example, purchasing genetically modified seed can expose farmers to liabilities and long-term dependencies and the inadvertent contamination of organic farms from neighboring genetically modified crops can disqualify produce from organic certification.[28]

20. Harnessing these technologies for sustainable development would require significant efforts to build capacity, increase public awareness, and put in place a regulatory framework that ensures consistency of measures between provisions of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) and the Convention on Biological Diversity.

C. Available, affordable ICTs

21. The availability of affordable ICTs holds great promise for improving natural resource management, food security and livelihoods in rural communities. A primary challenge that smallholder farmers face is their isolation from knowledge and information systems, which makes them particularly vulnerable and unprepared to respond to external and internal shocks.[29] Internet access and the spread of mobile phones already facilitate the exchange of scientific, technological, and market information among farmers, scientists, commercial enterprises, extension workers, and others. Advances in nanotechnology, remote sensing, GIS, global positioning systems (GPS), and other ICT applications could provide opportunities for more resource-efficient and site-specific agriculture.[30]

22. Examples of the myriad applications of ICTs include pest and weed control. Modeling the dynamics of pest and alien species can reduce the reliance on chemicals and new technologies can assist farmers in applying herbicides efficiently to eliminate weeds. For example, sophisticated GPS can allow farmers to implement specifically designed plans for spraying herbicides and pesticides. Another example is infrared weed detectors that identify specific plants by their unique rates of infrared light reflection and then transmit signals to pumps to spray preset amounts of herbicide.[31]

23. ICTs can also be important tools for anticipating and coordinating responses to disasters. The Famine Early Warning Systems Network, funded by the United States Agency for International Development (USAID), uses GIS and remote sensing technologies

[26] Country report, CSTD initersessional panel (2010).
[27] UNCTAD (2010b).
[28] Carrasco (2009).
[29] *Ibid*.
[30] IAASTD (2009).
[31] UNCTAD (2010b) and IAASTD (2009).

and several data sources to predict food assistance needs in more than 25 countries. USAID and NASA have also established hubs in Central America, East Africa, and the Himalayas for SERVIR, a Web-based environmental management system that supports short-notice prediction tools for precipitation, storms, and early flood warnings.[32]

24. Illiteracy poses a major obstacle to the adoption of ICTs and integrated pest management by smallholder farmers so education, extension, and farmer field schools have an important role in helping farmers benefit from these technologies. Another obstacle to ICT adoption is that farmers are usually much more prepared to pay for tangible services such as inputs or veterinary service than information, which was often provided for free in the past[33]. Potential solutions include lowering the cost of Internet access, public financing, and encouraging farmers to collectively purchase information subscriptions.

D. Post-harvest enhancements

25. In considering applications of science and technology to agriculture, the post-harvest stage should not be overlooked. The post-harvest stage is one of the most inefficient aspects of agriculture and losses are often up to 80 per cent depending on food type and location. By applying readily available post-harvest technologies and innovative management systems, crop losses could be reduced and world food supply increased by 30–50 per cent with minimal additional resources.[34] Maximizing the nutritional impact of available food through improved preparation, processing, preservation or storage processes may have a greater impact on the well-being of the poor than trying to increase yields on tiny plots.[35] For example, millions of poor people in Africa depend on the cultivation of perishable root and tuber crops such as cassava, yams and cocoyams. Appropriate technologies for processing these and other roots, tubers, cereals and legumes into flours can enhance the shelf life and acceptability to consumers of indigenous foods as well as develop value added, exportable products. The greatest potential lies in primary processing technologies, such as cleaning, drying, pre-cooling, grading, packaging, storage and transport.[36] The adoption of post-harvest technologies can also significantly improve the livelihoods of women who do the bulk of post-harvest processing and free up time for other activities.[37]

III. Agricultural innovation

26. Experience has shown that innovation and technology development and diffusion approaches should involve a shared understanding of principles and coordination of practices across multiple levels.[38] Innovation is rarely triggered by agricultural research and instead is often a response of entrepreneurs to new and changing market opportunities.[39] Indeed, a wide range of actors or agents beyond the public sector, including farmer organizations and commercial enterprises, should be engaged in developing new ideas for smallholder farmers.[40] As diagrammed in figure 2, many types of individuals and

32 Country report, CSTD initersessional panel (2010).
33 Christopolos (2010).
34 UNCTAD (2010a).
35 Christopolos (2010).
36 UNCTAD (2010b).
37 Meinzen-Dick (2010).
38 IAASTD (2009).
39 Hall (2007).
40 IAASTD (2009).

organizations should be involved and collaboratively linked to form agriculture innovation systems.[41]

27. The strength of agricultural innovation systems rests not only on the strength of individual actors in the system, but more importantly, the strength of their interactions, just as the health of the human body requires healthy circulation and communication among all body parts to function properly. Agricultural innovation systems involve the integration of different sources of knowledge, including local knowledge. For example, a recent study found that women and other marginalized groups often hold local knowledge of low-impact, low-cost methods and coping strategies that can make farming systems more resilient.[42] Conditions that nurture eclectic approaches to innovation must exist and competitors need to work together to continually adapt institutional and policy frameworks for innovation. Coordinated networks relevant to specific challenges, opportunities, or locations are required along with supporting policies. Scientists, policymakers, consumers, and entrepreneurs need to align to mobilize knowledge and continuously innovate.[43]

28. Public policy is essential in creating an enabling environment which encourages technology uptake, innovation and development.[44] Sectoral mechanisms are critical for coordinating the interaction needed for innovation.[45] One example of how policies can foster innovation is the development of varietal release procedures and criteria to accept and certify farmer-generated seed in the Netherlands, where potato breeders and commercial organizations cooperate with potato hobby specialists to breed and select potato varieties; farmers are able to negotiate formal contracts that recognize and reward them for their contributions to all potato varieties that are brought to the market.[46]

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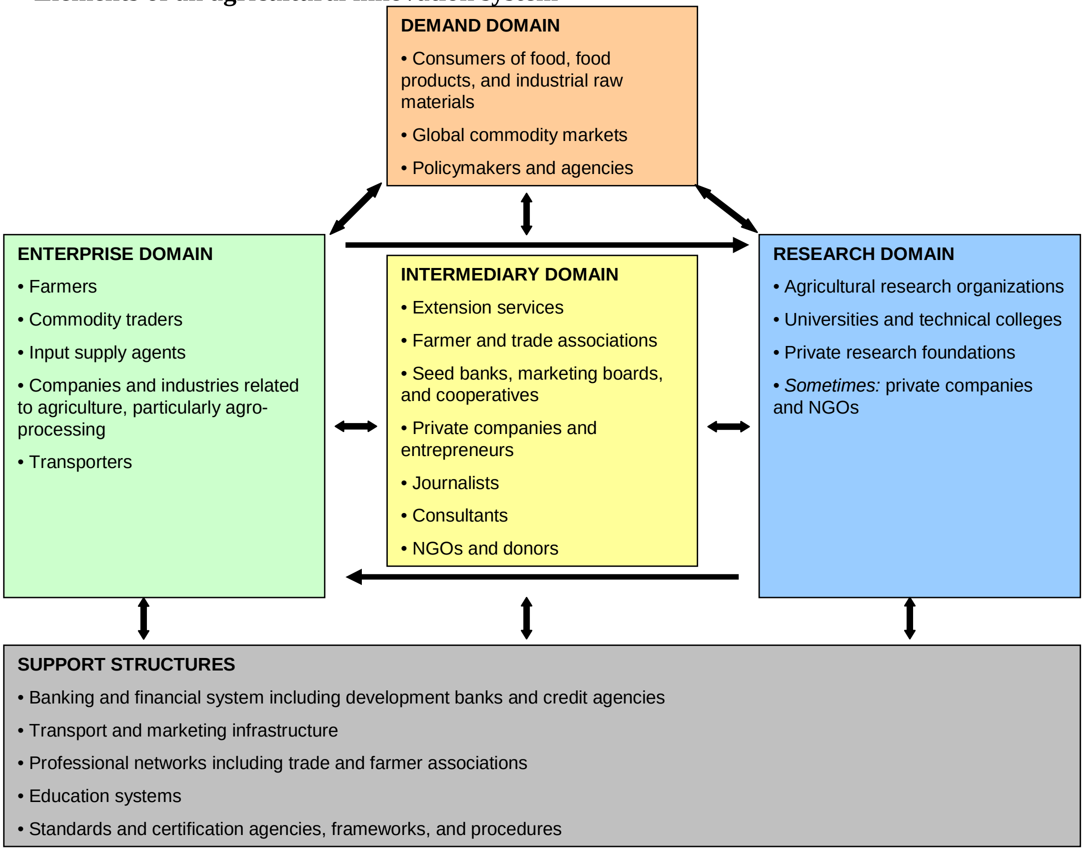
[41] UNCTAD (2010b), Albright (2007), and Hall (2006).
[42] Meinzen-Dick (2010).
[43] Hall (2007) and Albright (2007).
[44] *Ibid*.
[45] Hall (2007).
[46] IAASTD (2009).

Figure 2
Elements of an agricultural innovation system[47]



29. Supporting smallholder farmers in joining subregional, regional or global networks and value chains will help provide them with access to international markets and inputs, finance and technology. Efforts to support links to value chains can be supported by actively increasing market efficiencies and access, especially to markets for high value added agricultural exports including processed agricultural exports, putting in place market information systems and designing and implementing trade facilitation programmes. Subregional cooperation can address capability and financing shortages as well as scarcity of scientific laboratory equipment. National innovation coalitions and innovation platforms around particular technologies, policies, or processes can be effective vehicles for innovation. There is also room for increased collaboration among international agricultural research centers and national agricultural research systems;[48] CGIAR's work is a step in this direction.

A. Research institutes and education systems

30. Despite the important role of research in agricultural knowledge creation and innovation, investment in publicly funded agricultural research and development (R&D) in many countries has stalled or declined.[49] Nearly half of global public agricultural R&D

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47 Adapted from Hall (2006).
48 UNCTAD (2010b) and Albright (2007).
49 IAASTD (2009), UNCTAD (2009), and Beintema and Elliott (2009).

spending is concentrated among five countries – the United States, Japan, China, India and Brazil[50] – and the international community has shown decreasing interest in supporting African agriculture over the past 30 years. Now only 3 per cent of science, technology and innovation-related aid is destined for agricultural research in the least developed countries and developing countries as a whole invested only 0.6 per cent of their agricultural value added in R&D in 2000, compared to 5 per cent invested by developed countries.[51] This is despite the fact that doubling agricultural research expenditures per hectare in Africa can increase agricultural productivity by 38 per cent and increasing the agricultural GDP in Africa by 1 per cent will reduce poverty by three or four times as much as a 1 per cent increase in non-agricultural GDP.[52]

31. Persistent problems with research and education include (a) lack of competence in some scientific fields; (b) movement of capacity to industrialized countries; and (c) lack of incentives to address social needs, especially those related to the poor, which often call for multidisciplinary approaches.[53] Agricultural R&D has also been oriented towards conventional, industrial agriculture rather than sustainable agricultural sciences. Additionally, there is a particular need for much greater capacity in agricultural water management, as training is often a very minor add-on to water project budgets.

32. Governments and international organizations can facilitate and develop capacity by investing in education and promoting new skills and technologies among farming communities.[54] Resources spent on promoting R&D activities should be linked to local demands for specific products, processes and services. Incentives include (a) restructuring academic systems for researchers and academics to reward applied research and collaborations with agricultural communities and firms (especially participation of farmers); (b) focusing on disseminating ideas and putting them into practice; and (c) creating special, competitive R&D grants only for the development of specific local varieties of food grains.[55]

33. Support of R&D should not be limited to R&D centers and institutes. Public research grants tend to favour established names, and peer-reviewed articles and patents require large, specialized teams. Additionally, the private sector hesitates to fund complex innovations with negligible market returns. An alternative option that can incentivize the private sector and engage the greater public, including smallholder farmers, is establishing innovation prizes.[56] Apps4Africa is an example of a successful innovation contest that challenged East African technologists to develop applications useful to the public. The first place winner was a Kenyan developer who created a voice-based mobile application to help farmers better manage breeding periods and to monitor cow nutrition.[57]

34. A number of academic reforms could bolster agricultural research and make it more relevant to the challenges of smallholder farmers. For example, curricula at all levels could be modified to improve the attractiveness and social relevance of agricultural studies, increasing access to technology education and science-informed farm and agroecosystem management, including sustainable agriculture, to all those working in agriculture, improving collaboration between government agencies and universities, developing

[50] Beintema and Elliott (2009).
[51] UNCTAD (2010b) and UNCTAD (2009).
[52] UNCTAD (2009) and HOC (2009).
[53] IAASTD (2009).
[54] *Ibid.*
[55] UNCTAD (2010b).
[56] *Financial Times* (2010).
[57] Country report, CSTD initersessional panel (2010).

infrastructure to facilitate ICT use in informal and formal education systems, mobilizing funds to support agricultural education reform, and encouraging university participation in recovering and recognizing traditional and local knowledge.[58] University systems can also expand graduate training to meet the demand for more highly trained researchers in climate change, price volatility in global markets, and water scarcity.[59] Establishing and enforcing codes of conduct for universities and research institutes can reduce conflicts of interest and ensure a focus on sustainability and development in agricultural knowledge, science and technology.[60]

35. Options for capacity-building in the field include occupational education for farmers, on-line distance learning and education, and competitive grant funding to cover field study in tertiary and post-doctoral training.[61] With improved training in critical thinking and problem solving, extension agents can be better prepared to meet local farmer needs.[62] Other resources for R&D and capacity-building are research networks, consortia, and decentralized R&D facilities in collaboration with village development centers, non-governmental organizations and farmer organizations.[63]

B. Extension services

36. Extension services, the intermediaries that connect the enterprise and research domains as shown in figure 2, lie at the heart of agricultural innovation systems. They can make publications accessible to smallholder farmers in layman terms in local languages with illustrations. A wide variety of agents such as input vendors, weather broadcasters or farming lobbyists can serve extension roles, as well as national or regional extension services that deploy extension workers to connect knowledge producers with farmers.[64]

37. To be successful, extension services require personal contact and adequate resources. It has been observed that public support to and funding of extension services are critical in ensuring that they contribute to public goals. Public–private partnerships have increasingly been recognized as of great importance in successful extension services.

Box 4. Privately funded extension services for Malawian tea farmers[65]

Funding or provision of extension services does not have to come solely from the public sector. In Malawi, privately provided extension services have seen positive results in the quickly developing smallholder tea industry. Tea estates, which buy the green leaf tea and have a vested interest in ensuring a continual, quality supply, provide tea husbandry extension. The estates provide farmers with advice and fertilizer on credit. Some of the smallholder farmers have become fair-trade certified and they are investing the associated price premium in tea garden improvements and social development services.

38. Information flow among extension services, the enterprise domain (primarily farmers), and the research domain does not necessarily ensure extension success but lack of

58 IAASTD (2009).
59 Beintema and Elliott (2009).
60 IAASTD (2009).
61 *Ibid.*
62 Christopolos (2010).
63 IAASTD (2009).
64 Christopolos (2010).
65 *Ibid.*

it will guarantee failure.[66] Extension services should ensure that there are effective means of disseminating up-to-date information to extension advisors in the field and strong two-way communication between advisors and farmers. Managers of extension services in many countries are centralized, urban-based, and insensitive or out of touch with the realities of field work and under "top-down" planning, farmers and rural communities are excluded from the planning process or the determination of objectives.[67] To succeed as technology brokers, extension agents need their clients' trust to perform their core tasks; mandates to collect taxes or loans or enforce regulations can interfere with this trust[68] and regulatory duties or other non-advisory work takes time away from serving farmers and can make farmer services superficial.[69]

Box 5. Involving farmers in extension services in Peru[70]

The Puno–Cusco area in Peru offers an example of how extension services can be more responsive and organized with more farmer involvement. Public contests were held there in which communities presented competing funding proposals. The winners received public funding to contract a technical assistant and were required to invest a matching sum to ensure ownership and maximize impact. In another example of reversing traditional societal hierarchies and power relations, the local people themselves also selected the technical assistant through a public competition.

39. A one-size-fits-all approach to extension rarely works. Sometimes the poor are excluded from markets because they do not have the capacity to meet high standards of quality, uniformity, bulk, timeliness and food safety. Extension can help farmers understand the entry barriers to different markets and make informed choices about marketing, production and livelihood strategies. In isolated areas distant from major markets, there may be little market access, so it may be more appropriate for extension to give priority to crops that support subsistence or are intended for local markets.[71]

40. To become more client-oriented and effective, extension services should also be designed with gender issues in mind. In some communities, women do most of the agricultural work and are prohibited from any contact with men outside their immediate family or community, so there is a clear need for female extension field staff.[72] Extension services for women should also be tailored to their needs, preferences and priorities. In many countries, extension is directed to promote agriculture for cash crops for export or national grain self-sufficiency. However, female farmers may have little or no incentive to produce cash crops because they will not control the associated income. Lack of access to and control of land can also cause women to have far less interest than men in investing in expanded or intensive agricultural production. Rather, women often prefer to focus on sources of income they can more easily control, such as subsistence crops, petty trade or casual labour,[73] and because women generally have access to fewer resources, they may be better suited to adopt high-value crops that do not require large initial investments.[74]

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[66] Schwass (1983).
[67] Schwass (1983); Dirimanova and Labar (2010).
[68] Christopolos (2010).
[69] Schwass (1983).
[70] Christopolos (2010).
[71] *Ibid.*
[72] Schwass (1983).
[73] Christopolos (2010).
[74] Meinzen-Dick (2010).

C. Financing agriculture and agricultural innovation

41. Since the global food crisis of 1974, the role of economic access in food security has gained increasing prominence; any approach to improving food security must go beyond farming practices to include rural development and expansion of economic opportunities through income generation infrastructures and marketing. Key economic factors for achieving food security include access to credit and markets, infrastructure and land ownership. Relatively recent factors include the production of biofuels, animal feed, availability and efficient use of irrigation water, methods of using arable land and technologies to increase productivity and generate income.[75]

42. Sufficient financing is also a key requirement for agricultural science, technology, and innovation. Insufficient financing hampers new innovation and the inability of farmers to access capital to adopt technology renders it useless. Indeed, many technologies potentially of use in sustainable farming are not adopted because smallholder farmers lack access to the means and supporting services necessary to employ the technologies profitably. For example, lack of cash and inadequate credit facilities have prevented some farmers in India from obtaining micro-irrigation systems. Inadequate access to capital is also the most commonly reported obstacle to investment and entrepreneurship in the non-farm rural economy.[76]

43. Increased investments in agricultural knowledge, science and technology – particularly if complemented by supporting investments in rural development such as infrastructure, telecommunications, and processing facilities – can yield high economic rates of return, reduce poverty, and have positive environmental, social, health, and cultural benefits.[77] Segmenting banking systems can protect extremely vulnerable parts of the economy from external shocks. Specialized banks can be created for sectors like agriculture and small and medium enterprises, which may not appear very attractive to private banks. Microfinance initiatives have proven to be a successful institutional innovation in financial services for micro-entrepreneurs, including smallholder farmers in developing countries.[78] Insurance and derivatives can also serve as a means of hedging some of the exposure to price volatility, changing environmental conditions and other variables.

44. Merely supporting farmers may be of limited impact if the required infrastructures are absent or weak, or the rest of the market chain in dysfunctional.[79] Improvements in physical infrastructures can help farmers of all sizes. Infrastructure improvements should be based on a comprehensive approach that integrates post-harvest storage and processing considerations to reduce losses and add value to agricultural products. This includes distribution and marketing infrastructures connecting farmers to markets. Physical infrastructures should support the capacity of developing countries to rehabilitate and develop rural and agricultural infrastructure through investments in marketing processing and storage facilities, irrigation facilities and relevant modes of transportation.[80]

45. Private firms have been major suppliers of inputs and innovations to commercial and subsistence farmers, and can make significant contributions toward meeting development and sustainability goals. There are considerable spillovers from private suppliers of technology to farmers and consumers; for example, when private investment is made in

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75 UNCTAD (2010b).
76 IAASTD (2009) and UNCTAD (2010b).
77 IAASTD (2009).
78 UNCTAD (2010b).
79 Christopolos (2010).
80 UNCTAD (2010b).

agricultural production, public investment for promotion of agricultural marketing infrastructure soon follows.[81] The participation of transnational corporations has also introduced new farming methods, knowledge for enhancing production, soil and water management know-how, and various technologies intrinsic to inputs.[82] Government regulations can optimize private investments in agricultural knowledge, science and technology, by addressing negative externalities and monopolistic behaviour and supporting good environmental practices, while at the same time providing incentives for investments that aid the poor.[83] Transnational companies could be required to contribute to infrastructure development when receiving permits for large-scale projects.[84] Private investment into agriculture can also be promoted through public–private partnerships with the international private sector and national agricultural organizations. Investments in outgrower networks that also share knowledge, information systems and supportive hard and soft infrastructures can make a significant contribution to scaling up sustainable agriculture methods. Agriculture can be made a sectoral priority in other policies that seek to attract international private investment, such as policies for foreign direct investment, with a special focus and additional incentives for firms to engage in tacit know-how transfer.[85]

46. Various other means can reduce the risk of financing innovation in agriculture, including government-support soft-loans, R&D subsidies, public risk capital funds and public support for private enterprises through grants, subsidies and private equity. Seed-financing programmes, angel investor networks, enterprise subsidy programmes, common placement funds for innovation, and research tax credit programmes are also means of financing innovation. Other methods of providing access to credit – such as “starter packs” of free bio-fertilizer and seeds – can facilitate the use of an existing technology by smallholder farmers.[86] In some cases – as in multi-organizational arrangements involving supermarkets or commercial actors in market-oriented value chains – the transaction costs of interaction among innovation partners can be recovered from commercial returns[87].

47. Innovative procurement and programme practices can also reduce the risks faced by smallholder farmers. Examples used by the World Food Programme to reduce risks faced by smallholder farmers include forward contracting and warehouse receipt programmes that can serve as collateral for loans and the support of value added production and local food processing. Another way to support producers is by improving tendering systems so that smallholder farmers are in a better position to compete for locally issued contracts.[88] Additionally, brokered long-term contractual agreements – such as market alliances, commodity chains, and public and private outgrower schemes – have been effective in improving the livelihoods of smallholder farmers. These arrangements can promote value-chain activities, generate employment and allow smallholder farmers to take advantage of opportunities through institutional arrangements that provide market access and credit for inputs and planting materials, as illustrated in box 6.[89]

[81] IAASTD (2009) and UNCTAD (2010b).
[82] UNCTAD (2009).
[83] IAASTD (2009).
[84] UNCTAD (2009).
[85] UNCTAD (2010b).
[86] *Ibid.*
[87] IAASTD (2009).
[88] UNCTAD (2010b).
[89] IAASTD (2009).

Box 6. Supporting smallholder pineapple farmers in Ghana with brokered long-term contractual agreements[90]

In 2002, global pineapple demand shifted from the Cayenne variety that Ghana exported to the extra sweet MD2 variety, causing smallholder farmers to cease production. When BOMARTS Farms Ltd. (with approximately 400 ha of pineapples) was facing contract termination, it set up a commercial tissue culture lab with assistance of the University of Ghana. The Government contracted BOMARTS to produce 4.8 million plantlets at cost over a two-year period, which were distributed to farmers on credit and at a tenth of the price. The number of smallholder farmers growing MD2 is rapidly increasing; for many of these farmers, pineapples are their main source of income.

48. Farmer groups, cooperatives and other partnerships also have an important role in supporting agriculture by providing guarantees with regards to investments, a supply of agricultural inputs and credits, and a platform for education and training. Cooperatives also provide opportunities for marketing agricultural products, particularly in the case of smallholder farmers who, in most cases, cannot meet quantitative and qualitative thresholds so rely on communal storage and marketing instruments. Additionally, cooperatives can be instrumental in linking smallholder farmers into the agrifood chain. These partnerships enable and enhance agricultural entrepreneurship and strengthen rural development.[91]

D. Governance

49. The potential impact of science, technology, and innovation on agriculture will be severely stunted without adequate government and policy support, including in areas that might at first glance seem unrelated to agricultural, science, technology and innovation. Policy options to enable developing countries to respond to crises and achieve food security and sovereignty include greater democratic control and public sector involvement in agricultural policy, specifically through empowering farmer organizations, national governments, and regional trading blocs. Other policy options include (a) improving the security of tenure and access to land, germplasm and other resources; (b) diversification with locally important crop species; (c) access to credit and nutrients; (d) supporting rural livelihoods by transparent price formation and functioning markets with the objectives of improving small farm profitability and helping ensure that farm-gate prices are above marginal costs of local production; and (e) strengthening social safety nets.[92]

50. Tenancy rights and access to credit are closely interrelated. Land tenure security encourages farmers to improve land productivity in the medium and long term, and farmers are more likely to adopt technology and innovate. With the availability of credit markets, technologies and farm inputs, improved land tenure security leads to higher investment. Transferability of land rights also plays an important role, as land right transferability can improve a landholder's creditworthiness, especially for long-term credit. This enhances the land's collateral value and lenders' expected return. Investment may be encouraged by better land tenure security, easier convertibility of land into liquid assets and emergence of a credit market.[93]

51. An open approach to innovation should be supported by science, technology and innovation policies. This involves addressing issues pertaining to intellectual property

[90] *Ibid*.
[91] UNCTAD (2010b).
[92] IAASTD (2009).
[93] UNCTAD (2010b).

rights, increasing R&D intensity (especially public investments in sustainable agriculture R&D), and actively attracting leading researchers. Intellectual property rights regimes that protect farmers and expand participatory plant breeding and local control over genetic resources and related traditional knowledge can increase equity. Open-source or non-proprietary models can encourage a combined academic–philanthropic–business approach. For example, grants can be provided for the development of nutritionally enhanced seeds to be made available for royalty-free distribution in areas of need.[94] Policy options to strengthen and improve equality in current rights systems for intellectual property and genetic resources may include (a) a closer connection between protection levels and development goals; (b) explicit policies regarding intellectual property management in public organizations; (c) the preservation, maintenance, promotion and legal protection of traditional knowledge and community-based innovation; and (d) options for benefit-sharing of genetic resources and derived products as illustrated by the Dutch potato partnership scheme.[95]

IV. Findings and suggestions

A. Main findings

52. Sustainable agricultural systems with an emphasis on supporting smallholder farmers can contribute to the achievement of the MDGs.

53. Most sustainable technologies required to improve local agricultural productivity of smallholder farmers already exist. The international community has a key role to play in assisting governments to make these technologies accessible to smallholder farmers, overcoming the digital divide, and strengthening agricultural innovation systems.

54. Intergovernmental forums such as the CSTD could provide a platform for the sharing of best practices and promoting North–South and South–South partnerships in agricultural science, technology and innovation.

B. Suggestions

55. The following suggestions have been put forward:

(a) Governments should review their agricultural science, technology and innovation system with a view to strengthening the support to smallholder farmers through sustainable agriculture, and integrating a gender perspective in the design of these policies;

(b) Governments and the international community should consider an increase in the share and effectiveness of public expenditure for agricultural development;

(c) Public investment should be carefully targeted towards improving physical and R&D infrastructures (including rural road networks, power and Internet connections, education and health), linkages among farmers, agricultural product processing and marketing, and extension education and services, primarily supporting sustainable, regenerative production methods;

[94] UNCTAD (2010b) and IAASTD (2009).
[95] IAASTD (2009).

(d) There is a need to review research and education systems to ensure that they adequately address the challenges faced by smallholder farmers through sustainable agriculture;

(e) Participatory research which engage farmers, especially women, should be encouraged;

(f) Sustainable agriculture can be supported by removing or modifying tax and pricing policies that incentivize overuse of pesticides, fertilizers, water and fuel, or encourage land degradation, as well as internalizing the health, environmental and social costs of agricultural products;

(g) There is a need to re-examine international trade policies so that they support sustainable agriculture, including effective agreements and biosecurity measures involving transboundary water, emerging human and animal diseases, agricultural pests, climate change, environmental pollution, food safety and occupational health;

(h) Developed countries can consider reducing domestic support and export subsidies while improving market access for developing country producers.;

(i) Developing countries can consider reducing tariffs on imported pump sets or other irrigation and soil improvement technologies to lower costs and make agriculture more profitable for smallholder farmers;[96]

(j) Agrarian reform to assure stability in land management and tenure systems should be at the top of governments' political agenda;

(k) Recognizing the important role of intellectual property in innovation, developing countries are encouraged to make use of existing information resources, such as the Global Information Services of the World Intellectual Property Organization.

56. The CSTD is encouraged to:

(a) Provide advice, upon request, on how to strengthen national agricultural innovation systems, in collaboration with UNCTAD;

(b) Promote the exchange of best practice examples in the area of agricultural science, technology, and innovation;

(c) Promote an integrated, sustainable, international, and collaborative approach to agricultural innovation to meet the needs of smallholder farmers.

[96] FAO (2004).

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