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Addendum

Contribution by the scientific and technological community**

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I. Introduction

1. This paper, prepared by the scientific and technological community, provides an overview of the key science and technology issues related to the themes of the sixteenth and seventeenth sessions of the Commission on Sustainable Development: agriculture, rural development, improved management of land resources and combating drought and desertification. Throughout the paper special attention is paid to Africa, the regional focus for the current biennial cycle of the Commission.

2. Agenda 21 and the Johannesburg Plan of Implementation call for numerous science- and technology-based actions relating to the themes under review. This paper presents a discussion of the progress that has been made and the obstacles that still exist in implementing such actions. It also outlines major new challenges and opportunities in harnessing science and technology for a more sustainable path to development in the five themes under review. The first target is to meet the Millennium Development Goals by 2015.

3. As with all major sustainable development challenges, the issues of agriculture, land, rural development, drought and desertification must be addressed in a way that integrates the three pillars — social development, environmental protection and economic development. In order to help decision-makers define and implement these integrated approaches, the scientific and technological community must continue striving to become more policy-relevant, participatory and capable of responding to issues ranging across the geographical scale, from local to global. There is also a strong need for more integrative, interdisciplinary approaches, which will require continued efforts to overcome persistent barriers that exist among the natural, social, engineering and health science domains.

4. In preparing this paper, the International Council for Science and the World Federation of Engineering Organizations, co-organizers of the scientific and technological community major group, consulted their members worldwide, who have expertise across the relevant scientific and technological disciplines. The International Social Science Council also provided valuable input. This paper has particularly benefited from: the International Assessment of Agricultural Science and Technology for Development; the findings of the Millennium Ecosystem Assessment; and the work of the Global Environmental Change and Food Systems project. Information on these and other relevant scientific initiatives is provided under “Major relevant international scientific endeavours”.

II. Agriculture, land and rural development

A. Progress in agricultural sciences and their contribution to reducing hunger and poverty

5. Agriculture plays an important economic and social role and currently engages some 2.6 billion people around the world. The majority of the world’s poor and hungry live in rural settings and are directly or indirectly dependent on agriculture for their livelihoods. The proportion of the population dependent on agriculture ranges from 3 per cent in Europe and North America, to more than 60 per cent in South-Eastern and Southern Asia, the Pacific, and sub-Saharan Africa.

6. Agricultural knowledge, science and technology have contributed to some major developmental achievements, including reducing hunger in many parts of the world and ensuring food security at a scale not seen before in history. The science that made the Green Revolution of the 1960s and 1970s possible has increased the income of many small farmers, particularly in Asia, and preserved millions of hectares of forest and grasslands — conserving biodiversity and reducing the amount of carbon released into the atmosphere.

7. Advances in agricultural knowledge, science and technology have enabled substantial gains in agricultural production in industrialized and developing countries alike. Over the past 30 years, food production has tripled in developing countries, outstripping population growth. Over the same period, the proportion of undernourished people in developing countries has dropped from 35 to 17 per cent and poverty has decreased. However, the poorest and most marginalized rural and urban people continue to miss out on the benefits provided by advances in agricultural knowledge, science and technology.

B. Challenges in feeding a growing world population and in meeting increasing demands for dietary improvements

8. These successes notwithstanding, future challenges are daunting. World population is expected to reach nine billion by 2050 and the demand for food is expected to more than double in a similar time frame, with the per capita meat consumption in developing countries also projected to increase significantly. Science-based solutions for sustaining increases in productivity while protecting ecosystems are the key to addressing these challenges.

9. In many circumstances, the benefits of increasing agricultural production are outweighed by the drawbacks in the efforts to achieve them, including: degradation of the natural resource base; declining human health (associated with agricultural practices); and social exclusion. Some 30 per cent of irrigated lands are already degraded and water use is expected to increase by 50 per cent over the next 30 years. There is concern that the agricultural growth required to meet society's increasing demand for food will further degrade the environment and that this will, in turn, further undermine food systems and destabilise long-term food security. These concerns are particularly pertinent to Africa, where food security is already a major issue.

10. The findings of the Millennium Ecosystem Assessment were a wake-up call concerning the degradation of many agroecosystems worldwide, increased risks of non-linear changes and the exacerbation of poverty for many people.

11. Preliminary findings of the International Assessment of Agricultural Science and Technology for Development point in the same direction: agriculture policies can no longer externalize the costs of food and agricultural production without great economic, environmental, social and health risks. Future increases in food and other agricultural production will have to come from sustainably intensified agriculture and more efficient use of the natural resource base, particularly water. Successfully meeting sustainability and productivity requirements places increased importance on the multiple functions of agriculture:

(a) Producing food and fibre;

(b) Providing ecosystem services, and conserving natural resources and biodiversity;

(c) Providing livelihoods (income, health and nutrition) and supporting the quality of rural life.

12. Climate change will soon have a major impact on food systems. The challenge is to reduce the vulnerability of the agricultural sector to climate variability and the projected changes in extreme weather events, that is, floods, droughts and heat waves and also to reduce climate- and weather-related risks to regional and global food supplies. Climate change and changes in other aspects of the biogeophysical environment will add to the difficulties of existing food-insecure populations, particularly in parts of Africa, and may generate more widespread food insecurity in many parts of the developing world.

13. Another challenge for agricultural knowledge, science and technology is to address the needs of small-scale farms in diverse ecosystems and to create realistic opportunities for their development where the potential for improved productivity in the area is low. Smallholder economies in developing countries continue to be the poorest communities in the world today. The situation of the majority of rural and farm women in developing regions has not fundamentally improved in recent decades and is often worse compared to men with regard to work conditions, health and access to and control over natural resources, employment and income.

14. According to the International Assessment, the main challenges for agricultural knowledge, science and technology posed by multifunctional agricultural systems in developing regions are:

(a) How to increase food, fibre and fuel productivity and diversity while maintaining environmental and cultural services;

(b) How to improve welfare and rural livelihoods and enhance economic benefits of agriculture;

(c) How to empower marginalised stakeholders to sustain the diversity and productivity of their agriculture and food systems;

(d) How to increase sustainable production in marginalised, rainfed areas and link rural populations in these areas to local, national and global markets;

(e) How to increase profitability and environmental integrity in a sustainable manner for small-scale farmers in less well-endowed areas.

C. Interactions between climate change and agriculture, particularly in developing countries

15. Climate change influences and is influenced by agricultural systems. The two challenges are:

(a) To adapt to climate change while reducing the vulnerability of the agricultural sector — including the risks to regional and global food supplies — to climate variability and the projected changes in climate and associated extreme weather events, that is, floods, droughts and heat waves;

(b) To reduce the impact on the climate system by reducing the emissions of greenhouse gases from the agricultural sector and associated agrofood systems.

16. Both challenges need to be addressed through the generation and use of agricultural knowledge, science and technology — that is, through changes in agricultural practices, technologies and policies. Understanding the trade-offs between achieving food security and environmental goals involved will be critical.

17. Climate change is already being felt in terms of gradual increases in temperature; increased variability in annual rainfall; greater prevalence of extreme events, such as drought and floods; and changes in land and biodiversity resources. Rural communities must adapt to these changes if any development progress is to continue and if further impoverishment is to be avoided.

18. In general, the poor are the most vulnerable to climate change. However, the vulnerability of people and their agricultural systems is very complex, due to interacting climate-related stresses. The year-to-year variability in climate already contributes to rural poverty in places where exposure is high and adaptive capacity is low. Thus, agricultural adaptation and mitigation pathways need to be developed that are pro-poor.

19. While a few areas stand to be positively affected by climate change, which will offer some opportunities, the impact of climate change on agriculture is predicted to be detrimental and expected to threaten food security in many parts of the world, particularly in Africa. In some regions, climate change has the potential to forestall or reverse the gains made during and since the Green Revolution, for example, by reducing the water available to irrigation-dependent systems. New solutions will be required to increase resilience in high-potential regions, and to reduce vulnerability in areas where the Green Revolution has not had a significant impact, for example, in sub-Saharan Africa.

20. In many areas, there is a huge knowledge gap on how best to adapt agricultural systems to climate change. There is a need to better understand how climate change will affect cropping systems, agroecosystems and the livelihoods of farmers and to better understand the impact of these changes on the global agricultural and food sector. There is also a need to strengthen policymaking and policy implementation to support the mainstreaming of agricultural knowledge, science and technology, targeting adaptation and mitigation of climate change in the agricultural sector of developing countries.

D. Science and technology for small-scale farmers in developing countries

21. Disparities between small-scale farming and industrial agricultural systems have increased over the past 50 years. A key factor is labour productivity, which has increased enormously in industrialized agriculture and stagnated in most smallholder systems in developing countries. The smallholder systems have not been able to compete with modern production systems, resulting in the impoverishment of rural populations and countries. Countries and communities based mainly on smallholder economies are the poorest in the world today and the most threatened by ecosystem degradation. The average farm size in industrial countries has increased from around 10 hectares to more than 100 hectares, while in

developing countries, farms have decreased in size from around two hectares to less than one — making investment, innovation or change very difficult.

22. Scientific advances and new technologies do not necessarily reach the smallholders who could benefit most because extension services and basic agricultural research are underfunded in the countries that need them most, particularly in sub-Saharan Africa. Uptake of new scientific developments — whether biotechnology or land use and drought management — depends on extension to rural areas, and despite excellent work carried out by agricultural research centres, the poorest and most marginalized communities are often not reached. Universities, technical schools and extension services are often so underfunded as to be non-functional. In some cases, extension services through non-governmental organizations have been more successful, provided they are working with the scientific, engineering and technological communities.

23. Extreme poverty and hunger push people onto marginal lands and fragile ecosystems characterized by low soil fertility, drought stress and increasing land degradation. The current global system of supporting agriculture pits small-scale, largely subsistence farmers in rainfed agriculture systems against farmers who up to now have been provided with much support from their own Governments to increasingly capture economies of scale — through specializing their farms and by externalizing social and environmental costs. Research to develop new technologies and production methods, which are relevant to the poor, is seriously underfunded.

24. Ensuring the development, use and adaptation of agricultural knowledge, science and technology by small-scale farmers requires acknowledging the inherently diverse conditions in which people live and work, as well as gender issues. Hence, technology development would benefit from knowledge about farmer-specific environments and the gains that can be achieved from participatory methodologies that empower small-scale producers. The development of more sustainable low-input practices to improve soil, nutrient and water management will be particularly critical for communities currently without access to markets. Resource-poor farmers must be given help so they can use their local knowledge to develop innovative methods of managing soil fertility, genetic diversity of crops and natural resource conservation, and they must be empowered through appropriate policies and institutional arrangements to gain access to markets.

E. Making agriculture more environmentally sustainable

25. Sustainability issues in agricultural development are numerous, and include:

(a) Conservation of renewable natural resources;

(b) Providing ecosystem services;

(c) Conserving biodiversity;

(d) Management of the nitrogen cycle;

(e) Reduction in greenhouse gas emissions;

(f) Addressing adaptation and vulnerability to climate change.

26. Advanced knowledge in agroecology offers the potential to increase productivity while providing critical ecosystem services, including improved soil

and water quality and carbon sequestration. There is a need for integrated land and water management. Often land resources are poorly managed due to lack of access to information and lack of alternatives, or they are poorly managed deliberately in order to exploit short-term benefits of resource use. Increasing rates of soil degradation in many regions may further limit the ability of agriculture systems to reduce food insecurity.

27. Water availability for agriculture is one of the most critical factors for food security and sustainable agriculture. The expansion of irrigation will continue to depend on availability of water resources sufficient both to produce food for the growing world population and to meet increased municipal, industrial and environmental requirements.

28. Soil fertility is another critical factor for the production of food, fibre and fuel crops. For nitrogen-poor regions, including Africa, the overall challenge is to increase the nutrient status of soils. Currently, small-scale farmers in developing countries most often lack the money needed to buy industrial fertilizers. Governments and the development and industrial fertilizer communities are increasingly aware of the need for a concerted, integrated effort, including biological nitrogen fixation, to address this challenge. From a biogeochemical perspective, this effort should include studies on the fate of the added nitrogen to ensure that losses from the agroecosystem to groundwater, for example, are minimized.

29. For regions with nitrogen-rich soils, actions should focus on decreasing the amount of nitrogen fertilizer required for agricultural production through, in particular: increasing the nitrogen use efficiency of crop grains; increasing the nitrogen retention efficiency of animals; and decreasing the amount of food wasted.

30. Environmental technologies, such as integrated pest management, agroforestry, low-input agriculture, conservation tillage and pest-resistant genetically modified crops, often face policy gridlock with formal agricultural knowledge, science and technology, the Government, private industry, the public and media taking highly polarized positions.

F. Agriculture and the growing demand for biofuels

31. Bioenergy is being developed in many countries to increase energy security, reduce greenhouse gas emissions and stimulate rural development. However, economic, social and environmental issues limit the extent to which these goals can be met with current biofuel technologies. There is great concern expressed in many developing countries about the future of biofuels and their effect on food prices and food policies. Nevertheless, numerous countries already have promising programmes for producing bioethanol and biodiesel from a variety of crops — cassava, castor beans, cotton seeds, jatropha, palm oil, soybean, sunflower and sweet potato.

32. First generation biofuels such as bioethanol and biodiesel are economically competitive with fossil fuels only in the most efficient feedstock production markets and under favourable market conditions of high oil and low feedstock prices. In most countries they depend on direct and indirect subsidies. While non-market benefits such as energy security and reduced greenhouse gas emissions may justify

these subsidies, the net benefits remain uncertain. The intensity of land and water use in the production of first generation biofuels can lead to serious threats to the environment and reduce food security in developing countries.

33. Millions of people in developing countries, particularly in sub-Saharan Africa, South Asia and parts of Latin America, depend on traditional bioenergy, such as wood fuels, for their basic cooking and heating needs. This can hold back development by posing considerable environmental, economic and social challenges. Efforts are needed to improve traditional bioenergy and to accelerate the transition to modern forms of energy.

34. In some areas, bioenergy options such as biogas and power generators operating with locally available biomass — including vegetable oils, manure and agricultural and forestry by-products — can become the most economical and reliable providers of energy for the poor. Liquid biofuels may become an interesting option for rural areas where biomass is available locally. In remote rural areas and on islands, where fossil fuel prices are usually high due to transport costs, bioenergy systems may prove to be the most economic option. In countries where large numbers of farmers subsist on very low incomes, local processing of bioenergy through community cooperatives could provide extra income and social inclusion for poor families.

35. A shift towards cellulose-based second-generation biofuels using wood and grassy crops would offer greater reductions in carbon dioxide emissions and less land used per unit of energy. However, technical breakthroughs would be required to achieve this. The potential of second-generation biofuels to be economically, environmentally and socially sustainable needs to be further explored.

G. The opportunities of biotechnology

36. Gene technology has many applications that can be used to improve the management and efficiency of agricultural practices. Although experimental transgenic strains have been developed for various species of crops, trees, livestock and fish, only transgenic crops are used commercially in agriculture today.

37. The first wave of commercially available genetically modified crops addresses production traits, and includes soybean, corn, cotton and oilseed rape with insect resistance and/or herbicide tolerance. The second wave, which is being developed, addresses quality and nutritional traits; and the third wave addresses complex stress response traits and the production of specific compounds.

38. Biotechnology developments could significantly increase agricultural productivity, addressing the need for greater food production in the coming decades and potentially providing important benefits also for small-scale farmers in the developing world. However, there is widespread public debate about genetically modified crops and the risks to human health and the environment, the efficacy of the new products and the socio-economic and ethical issues surrounding their development and use.

39. In 2003, International Council for Science commissioned and published a meta-analysis of existing authoritative reports from national science academies and other expert bodies on the risks and societal dilemmas of genetically modified organisms. The analysis found no known instances of harmful effects on human

health resulting from the consumption of genetically modified food crops. When genetically modified crops are developed with novel characteristics, they need to be assessed for health risks on a case-by-case basis. As with foods which are not genetically modified, consumers must be informed by appropriate labelling if the food contains known or suspected allergens.

40. Current agricultural practices have both positive and negative impacts on the environment. The same can be said about current and future genetically modified crops, with specific impacts depending on the genetic application, the agricultural system and the environment (agroecosystem) in which it is used. Consequently, environmental impacts need to be assessed on a case-by-case basis, taking into account specific risk factors. There is broad agreement that each country needs regulatory systems that are science-based, transparent and involve community participation. Known risks of environmental impacts such as gene transfer to non-genetically modified crops or a genetically modified crop establishing itself as a weed or invasive species can be managed through appropriate regulations and monitoring.

41. Other concerns relating to the use of genetically modified crops by small-scale farm holdings in developing countries must be addressed. The benefits must be shared equitably by holders of genetic resources, owners of indigenous knowledge and inventors. In poor societies, the current perception is that small-scale farmers receive more of the socio-economic costs than the benefits, as crop yields are not necessarily higher. The issue of poor farmers in developing countries becoming dependent upon a small number of global seed companies should be considered in a holistic sense, ensuring sustained socio-economic benefits to the farmers while capturing the great opportunities provided by advances in biotechnology.

H. The need for a fundamental shift in agricultural research and development strategies

42. A fundamental shift in science and technology strategies, related policies, institutions, capacity development and investments is required. Such a shift will recognize and give increased importance to the multifunctionality of agriculture and will take account of the complexity of agricultural systems within diverse social and ecological contexts. The shift will depend on new institutional and organizational arrangements to promote an integrated approach to the development and deployment of agricultural knowledge, science and technology. Success will require increased public investment in agricultural knowledge, science and technology; development of supporting policies; revaluing traditional and local knowledge; and an interdisciplinary, holistic and system-based approach to knowledge production and sharing. These policies and institutional changes should be directed primarily at those who have been served least by previous agricultural knowledge, science and technology approaches: resource-poor farmers.

43. Agricultural research needs to develop new models and approaches at the system level, rather than at crop or plot level. This is particularly true for Africa. One of the reasons for the relative failure of Green Revolution approaches is the heterogeneity of the physical, social, cultural and economic environments in Africa. Calls for approaches other than the Green Revolution have been made over the past decades. However, it is difficult to create innovative scientific and engineering

approaches in the absence of a supportive institutional framework. Institutional arrangements in Africa have, so far, emphasized traditional approaches to research in agriculture and rural development. An institutional framework which is facilitating broader interdisciplinary work and more creative research is required.

44. A systems approach will focus on a better understanding of the interactions and feedback mechanisms of biophysical and socio-economic processes, which determine food system viability, and management practices, which enhance the resilience of these systems to future shocks and stress. To address the complex interactions, trans-disciplinary collaboration between the natural and social sciences is required. There is an urgent need for increased collaboration between the agricultural research and global environmental change communities to address climate change adaptation and mitigation.

45. Most national agricultural research institutions and subregional organizations in Africa, South and South-East Asia and Latin America emphasize that increasing agricultural productivity is the way forward. While this emphasis is essential in countries where food security is uncertain, the increase of agricultural productivity needs to occur in the context of sustainable management of natural resources and equitable economic development. This needs to be reflected in improved scientific approaches and innovative engineering. If productivity is emphasized and sustainable resource management and equitable distribution of the benefits are ignored, serious conflicts can be expected and the vulnerability of agriculture in many developing countries, particularly in Africa, could increase to threshold levels of irreversibility.

46. On their own, advances in science and technology will not lead to relevant effective and efficient broad-scale applications unless investment in society in rural areas in health, education, extension services and women's needs is increased. The challenges ahead demand a greater focus on management systems: from crop to whole farm to agroecosystems. Management systems require a sophisticated understanding of the institutional dimensions of management practices and of decision processes that must be coordinated across variable spatial, temporal and hierarchical scales. The increasing focus on intellectual property rights in agricultural research and development, particularly given that many resource-poor farmers save seeds from season to season and also breed for local conditions, requires serious considerations. Agricultural knowledge, science and technology specialists will need a profound understanding of the legal, trade and policy frameworks that will increasingly steer agricultural and food system development. Agricultural knowledge, science and technology organizations should interact more with academic institutions in biological, ecological, earth, social and engineering sciences to address the challenges of sustainability, poverty, market-oriented innovation, and demand-led technology generation, access and use.

I. Investments in agricultural science and technology: a rich and poor countries divide

47. Globally, public sector research and development is becoming increasingly concentrated in a handful of countries. In 2000, the United States and Japan accounted for 54 per cent of public spending, while three developing countries — China, India and Brazil — accounted for 47 per cent of the developing world's

expenditure on public agricultural research. Meanwhile, 80 countries, with a total population of more than 600 million in 2000, spent a combined total of six per cent of the worldwide investment in agricultural research and development.

48. Declining investments in formal agricultural knowledge, science and technology by international donors and a number of national Governments is causing concern among developed and developing countries. Data analysed by the International Assessment indicates that public investments in agricultural research and development continue to grow. However, rates declined during the 1990s and investments stalled or declined in many industrialized countries. Investments by countries from South and South-East Asia and the Pacific grew relative to other regions, with an annual growth rate of 4 per cent in the 1990s. As a result, this region now accounts for a greater share of global public research and development investment — from 20 per cent in 1981 to 33 per cent in 2000.

49. The annual growth rate of total spending in sub-Saharan Africa decreased from 1.3 per cent in the 1980s to 0.8 per cent in the 1990s. In 24 countries in sub-Saharan Africa for which time series data are available the public sector spent less on agricultural research and development in 2000 than a decade earlier. This is an alarming trend.

50. In the industrialized countries, investment by the private sector has increased and is now higher than total public sector investments. In contrast, private sector investment in developing countries is small and will likely remain so, given weak funding incentives for private research. In 2000, private companies accounted for 8 per cent of total spending on agricultural research and development in the developing world. Private investment in agricultural knowledge, science and technology is, and is likely to remain, largely confined to commercial technologies, with intellectual property protection, which can earn significant revenues in the market.

III. Drought and desertification

51. Desertification is defined by the United Nations Convention to Combat Desertification as land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. Land degradation is in turn defined as the reduction or loss of the biological or economic productivity of drylands. In drylands, water scarcity limits the production of crops, forage, wood and other ecosystem provisioning services. Drylands occupy 41 per cent of the Earth’s land area and are home to more than 2 billion people.

52. Desertification occurs on all continents and affects the livelihood of many millions of people, including a large proportion of the poor living in drylands. According to the Millennium Ecosystem Assessment Desertification Synthesis report, some 10-20 per cent of drylands are already degraded. If unchecked, spreading desertification will threaten future improvements in human well-being and possibly reverse gains in some regions. Therefore, desertification ranks among the greatest environmental challenges and is a major impediment to meeting basic human needs in drylands.

53. On average, dryland populations, at least 90 per cent of whom live in developing countries, lag well behind the rest of the world in human well-being and

development indicators and suffer from the poorest economic conditions. For example, in Asia, drylands have the lowest Gross National Product per capita and the highest infant mortality among all bioclimatic systems. The relatively low rate of water provisioning in drylands in developing regions limits access to clean drinking water and adequate sanitation, leading to poor health.

54. Poverty-ecosystem links are typically ignored in poverty reduction policies of dryland countries. Even when these links are included, only the economic values are considered. Successful responses should include broader definitions of poverty, which include access to water and energy, health and education, and should try to mainstream the role of ecosystem services in poverty reduction programmes.

55. Inter-annual variability in rainfall and drought events are the natural phenomena associated with desertification. The magnitude and impacts of desertification vary greatly from place to place and change over time. Desertification can be caused by human population pressures and unsustainable land use, or by climate-related processes.

56. Rangelands are resilient to seasonal changes under traditional mobile grazing practices, commonly called transhumance. However, with increasing population pressure, nomads have reduced herd mobility, leading to overgrazing and degradation of rangelands. Moreover, the transformation of rangelands to cultivated systems in order to increase food production and economic benefits has significantly accelerated during the Green Revolution of the past five decades. Transformation of traditional rangelands and sylvo-pastoral dryland systems to croplands increases the risk of desertification due to increased pressure on the remaining rangelands and/or the use of unsustainable cultivation practices. Removal of the natural vegetation cover when combined with unsustainable soil and water management practices in the converted rangelands brings about soil erosion, soil structure change and soil fertility decline.

57. One of the potential new risks for drylands is growing biofuel crops using unsustainable cultivation practices, leading to accelerated soil erosion and desertification. On the other hand, growing biofuel crops using sustainable cultivation practices on semi-arid and sub-humid lands that are unsuitable for food production would not compete directly with food production and could help rehabilitate such soils.

58. Effective prevention of desertification requires both local management and macro policy approaches that promote sustainability of ecosystem services. Focusing on prevention is preferable because rehabilitating desertified areas is costly and delivers limited results. Protection of vegetative cover and integrated land and water management are key methods for preventing desertification. Improved water management practices include use of traditional water-harvesting techniques, water storage, and diverse soil and water conservation measures. Improving groundwater recharge through soil-water conservation, upstream revegetation and floodwater spreading can provide reserves of water during periods of drought.

59. Effective restoration and rehabilitation of desertified drylands require a combination of policies, technologies and the close involvement of local communities. Measures to restore and rehabilitate include restocking organic matter

in the soil and programmes that promote higher plant establishment and growth, including reforestation, seed banks and reintroduction of selected species.

60. The impacts of climate change in drylands will vary from region to region, depending on changes in rainfall and drought patterns. An increase in temperature will also increase evapotransporation. For the vast drylands of sub-Saharan Africa and Central Asia, it is predicted that the frequency and duration of droughts will increase and further reduce water availability and vegetation productivity.

61. Consequently, the Millennium Ecosystem Assessment Desertification Synthesis report states that climate change is a much greater threat in drylands than in non-dryland systems. In particular, the projected increased scarcity of freshwater as a result of climate change will cause greater stresses in drylands and, if left unmitigated, will exacerbate desertification. The greatest vulnerability is ascribed to sub-Saharan and Central Asian drylands.

62. Desertification also contributes to greenhouse gas emissions. Dryland soils contain more than a quarter of all of the organic carbon stores in the world and nearly all of the inorganic carbon. Unimpeded desertification may release a large portion of this carbon into the atmosphere, with significant feedback consequences to the global climate system. Since carbon dioxide is also a major factor in plant productivity, water-use efficiency may improve in some dryland species that can respond favourably to its increase. This demonstrates that the effect of global climate change on desertification is complex and not yet sufficiently understood.

63. As regards engineering and technology suitable to drylands conditions, applying a combination of locally available sound traditional technology with the selective transfer of locally acceptable technology is a major way to prevent desertification. Conversely, there are numerous examples of practices, such as inappropriate irrigation techniques and technologies, that accelerate, if not initiate, desertification processes. Thus, technology transfer requires in-depth evaluation of impacts and active participation of recipient communities.

64. While our scientific knowledge on dryland environments and socio-economic dimensions has increased during the past 50 years, there are still major gaps in our knowledge, in particular in regard to using holistic approaches and action plans to combat desertification and foster sustainable development of drylands. Dryland research must also address new challenges and opportunities that have emerged.

65. The 2006 United Nations Educational, Scientific and Cultural Organization Declaration on research priorities to promote sustainable development in drylands, commonly called the Tunis Declaration, identified the following research priorities:

(a) Integrated management of water resources in the context of a looming water crisis;

(b) Assessing and forecasting dryland ecosystem dynamics in order to formulate adaptation strategies in the context of global change and to alleviate poverty in order to achieve the Millennium Development Goals;

(c) Agriculture and pastoralism as opportunities for sustainable land use;

(d) Coping with and managing natural and man-made disasters;

(e) Formulating and implementing scenarios and policy options for good governance in drylands in the context of global change;

(f) Identifying viable dryland livelihoods and policy options for the benefit of dryland dwellers, for example ecotourism;

(g) Education and knowledge sharing for sustainable development;

(h) Reversing environmental degradation and promoting rehabilitation;

(i) Costs related to inaction in the field of land degradation;

(j) Renewable energies suitable for dryland development;

(k) Evaluating dryland ecosystem services and their trade-offs;

(l) Interdependence and conservation of cultural and biological diversity.

66. Most of the improved natural resource management strategies for drylands require effective user rights and a high degree of collective action. For example, agroforestry and perennial tree crops are long-term investments and individual farmers will only plant trees if they have secure land or tree property rights to secure future returns from their investment. Customary property rights also remain important. There is a need for effective local institutions, to ensure that common property resources are managed and regulated. Indigenous institutions that perform these roles successfully are often undercut by population growth, encroachment from outsiders and State interventions.

67. There are considerable scientific challenges in detecting thresholds beyond which the changes to dryland systems would be irreversible. This stems partly from our lack of understanding about the interactions between biophysical, social and economic factors, and requires more interdisciplinary research involving natural scientists, social scientists and economists.

68. Another weak point, which is hampering policies and programmes to combat desertification, is the insufficient capacity for long-term monitoring of drylands and desertification. While drylands lend themselves to remote sensing because they are mostly cloud-free, valid interpretation for desertification requires careful calibration and validation against ground measurements — such as evapotranspiration, soil fertility and compaction, and erosion rates. Continuity of ground and satellite-based observations is required to account for the high inter-annual variability of dryland ecosystems. Long-term monitoring is indispensable for identifying changes in the inter-annual variability (that is, detecting climate change) and distinguishing the roles of human actions and climate variability in vegetation productivity.

69. Most of the countries in sub-Saharan Africa and Central Asia that have drylands lack a critical mass of scientists, engineers and other relevant experts, and have a woefully weak institutional capacity in science and technology. These countries must address this problem by increasing their investment in higher education and scientific and technological capacity. Bilateral donors and other funding providers should include science and technology capacity-building among their priority areas of development cooperation and increase the funds they allocate to this end.

70. There is concern in the scientific and technological community that the current process of providing scientific and technological advice for the implementation of the United Nations Convention to Combat Desertification is relatively weak. This weak link to the best available science and technology is a serious obstacle to the accelerated implementation of the Convention and the relevant chapter in the

Johannesburg Plan of Implementation. Consequently, concrete measures should be taken to strengthen the links between drylands research, long-term observations, scientific assessments and policymakers.

IV. Major international scientific endeavours

71. Sound policymaking and action for sustainable development, from local to global levels, in agriculture, land resource management, rural development, drought and desertification require the best available scientific knowledge. This can come only from research, long-term observations and scientific assessments. In order for the continuum, from research to developmental impact, to function effectively, strong links must be built between interdisciplinary research, long-term earth observations, scientific assessments and policymaking.

72. At the global level, agriculture and related issues are the focus of several international scientific endeavours, which together cover the continuum from research to scientific assessment and feed directly into policymaking bodies such as the Commission on Sustainable Development, the Food and Agriculture Organization of the United Nations and the United Nations Environment Programme; intergovernmental forums; multilateral environmental agreements and conventions, in particular the United Nations Framework Convention on Climate Change, the Convention on Biological Diversity and the Convention to Combat Desertification; and regional intergovernmental bodies.

A. International interdisciplinary research

73. Two international research endeavours with global scope and relevance to this paper deserve particular attention: the Consultative Group on International Agricultural Research and the Global Environmental Change and Food Systems programme.

74. The first endeavour consists of the 15 international agricultural research centres supported by the Consultative Group. It was established in 1971 as a strategic partnership of countries, international and regional organizations and private foundations.[1] In collaboration with national agricultural research systems, civil society and the private sector, the 15 centres foster sustainable rural poverty reduction through high-quality science aimed at benefiting the rural poor through enhanced productivity, food security, better human nutrition and health, higher incomes and improved management of natural resources. The research portfolio of the Consultative Group Centres has evolved from the original focus on increasing productivity in critical food crops. Today's approach recognizes that sustainable development, environmental integrity and sustainable natural resources management, and policy research, to name a few, are essential areas of focus.

75. Major reforms of the Consultative Group on International Agricultural Research system, designed to strengthen science, streamline governance and maximize impact are gaining ground and yielding benefits, including the recent creation of the Alliance of the Consultative Group on International Agricultural

[1] See www.cgiar.org.

Research Centres for increasing programmatic and institutional synergies and strategic collective action. The innovative Challenge Programme initiative is designed to address global and regional issues of critical importance. To date, these focus on:

(a) Combating micronutrient deficiencies that affect more than 3 billion people;

(b) Addressing water scarcity by improving water-use efficiency in agriculture;

(c) Unlocking crop genetic diversity by using molecular tools to create new varieties of major food crops that meet farmers' needs;

(d) Employing integrated agricultural research for development approaches to build sustainable livelihoods in sub-Saharan Africa.

76. Global Environmental Change and Food Systems started in 2001 as a 10-year comprehensive programme of international interdisciplinary research focused on understanding the links between food security and global environmental change.[2] The research agenda is specifically designed to underpin policy formulation in this area. Global Environmental Change and Food Systems was launched by the Earth System Science Partnership, involving the International Geosphere-Biosphere Programme; the International Human Dimensions on Global Environmental Change Programme; the World Climate Research Programme; and DIVERSITAS.

77. Another relevant interdisciplinary initiative is the Global Land Project, a joint research effort of the International Geosphere-Biosphere Programme and the International Human Dimensions on Global Environmental Change Programme. The Global Land Project agenda focuses on understanding the interactions between people, biota and natural resources in a coupled human-environmental system. The Global Land Project is concerned with the implications of land use change and with the decision-making processes related to land use management.

78. Each of these international research programmes of global scale has different institutional sponsors. In addition to international scientific organizations, the World Climate Research Programme (the World Meteorological Organization and the Intergovernmental Oceanographic Commission of UNESCO), DIVERSITAS (UNESCO) and the International Human Dimensions on Global Environmental Change Programme (the United Nations University) have United Nations system organizations among their sponsors. The programmes all have one sponsor in common: the International Council for Science, ensuring that the activities are anchored in the scientific community concerned worldwide.

79. A particularly important collaboration is now emerging between the international agricultural research community (spearheaded by the Consultative Group and its partners in the North and South) and the worldwide global environmental change research community (spearheaded by the Earth System Science Partnership). Together, these two bodies possess the combined strengths and capabilities required to meet the research and capacity-building needs to develop more robust agriculture and food systems in the face of climate change. This new initiative is being developed as a Challenge Programme on climate change,

[2] See www.gecafs.org.

agriculture and food security of the Consultative Group and the Earth System Science Partnership.

B. Data needs and long-term terrestrial observations

80. Policymakers, land use planners, natural resource managers and research scientists, in particular those involved in the above-mentioned programmes, are seeking reliable data and information based on long-term observations of numerous parameters related to the topical areas covered by this paper. These data needs include: changes in land cover and land quality; availability of freshwater resources; loss of biodiversity; extent and impacts of pollution and toxicity; and impacts of climate change.

81. To meet these data requirements, FAO, UNESCO, WMO, UNEP and ICSU established the Global Terrestrial Observing System in 1996. The Global Terrestrial Observing System represents a "system of systems", formed by linking existing and new satellite remote sensing systems and in situ monitoring sites and networks. Progress in making the Global Terrestrial Observing System a truly operational system is woefully slow due to insufficient support at the global and national levels. For Governments and international organizations concerned, it should be a priority during the coming years to increase long-term observations of terrestrial environments by accelerating the implementation of the Global Terrestrial Observing System as part of the Global Earth Observation System of Systems.

C. Scientific assessments

82. Scientific and technological assessments play a crucial role on the continuum, from research and long-term observations to policy formulation and developmental impact. There are several major international assessments of direct relevance to agriculture, desertification and other issues being dealt with by this Commission on Sustainable Development biennial cycle.

83. The Millennium Ecosystem Assessment[3] was the first state-of-the-art scientific appraisal of the condition and trends in the world's ecosystems and the services they provide — such as food, forest products, clean water and natural resources. The Millennium Ecosystem Assessment findings were published as a series of reports in 2005. The Millennium Ecosystem Assessment had an innovative governance structure that was representative of not only scientists and experts, but also of United Nations institutions and conventions, international scientific organizations, civil society groups, business and industry and indigenous peoples.

84. The main finding of the Millennium Ecosystem Assessment was that the major changes which have been made to ecosystems, mainly over the last 50 years, have contributed to net gains in human well-being and economic development. However, these gains have been achieved at ever-increasing costs: the degradation of many ecosystem services. These problems, unless addressed, will substantially diminish the benefits that future generations obtain from ecosystems. It is crucial for policymakers and practitioners to take action now to address these problems. It will also be important for the scientific and technological community, with support from

[3] See www.millenniumassessment.org.

Governments and in cooperation with intergovernmental organizations both inside and outside the United Nations system to address the gaps in knowledge identified by the Millennium Ecosystem Assessment and establish a process for regular periodic global and regional ecosystem assessments.

85. The International Assessment of Agricultural Science and Technology for Development was a three-year collaborative effort (2005-2007) launched and co-sponsored by FAO, the Global Environment Facility, UNDP, UNEP, UNESCO, the World Bank and the World Health Organization, with a multi-stakeholder bureau which included representatives from Governments, agricultural producers, civil society, private sector and scientific institutions around the world (among them the Consultative Group on International Agricultural Research and the International Council for Science). The findings of this assessment will be available online during the first half of 2008.[4] However, this paper was able to draw on early unpublished results.

86. The Land Degradation Assessment in Drylands partnership is geared towards developing and testing an effective assessment methodology for land degradation in drylands. The Assessment focuses on the status and trends of land degradation in drylands, including: biodiversity loss; identifying areas with the most severe land constraints and degradation (hot spots); and identifying areas where conducive policies and actions have slowed or reversed the degradation (bright spots). The partnership includes governmental agencies in countries concerned, United Nations system organizations and Convention secretariats, bilateral donors, non-governmental organizations, national scientific institutions and international scientific organizations.

87. The consultative process, initiated by the Government of France, towards establishing an International Mechanism of Scientific Expertise on Biodiversity was completed in November 2007. The process identified the need to improve the interface between biodiversity science and policy at global and sub-global levels, in particular the need for proactive scientific expertise on emerging threats and issues associated with loss of biodiversity. Consequently, the International Mechanism Steering Committee has invited UNEP to convene an intergovernmental meeting in collaboration with the Government of France, other governments, the Convention on Biological Diversity and the partners of the International Mechanism consultation process to consider establishing an efficient science-policy interface mechanism on biodiversity.

V. Education, training and institutional capacity-building in science and technology

88. Achieving the Millennium Development Goal of universal primary school education will be crucial for enhancing rural development; sustainable agriculture and management of natural resources; mitigating the impacts of drought and combating desertification; and poverty reduction, particularly in developing countries. It is especially important to ensure that girls and young women receive high quality education, given their current under-participation in basic education and in scientific and technical courses at all levels.

[4] See www.iaastd.org.

89. Education for farming and pastoral communities must be made more context- and problem-specific. In particular, investment in occupational education and learning opportunities for small-scale farmers which are also accessible and relevant to traditional and indigenous people must be stepped up in developing countries. The more widespread application of collaborative approaches in agricultural knowledge, science and technology practices would require: complementary investments in the education of agricultural knowledge, science and technology technicians and professionals in order to strengthen their understanding of and capacity to work with local and indigenous individuals and communities; and support for developing curricula that value and provide opportunity for field-based experience and apprenticeships under the educational guidance of the communities.

90. There is a need to:

(a) Give higher priority to agro-ecological and integrated approaches in primary through tertiary education and research;

(b) Invest in a broader range of social sciences to understand and help design solutions to power asymmetries in agricultural knowledge, science and technology and arrangements for effective encounters between knowledge implementers and knowledge organizations;

(c) Make an active effort to extend connectivity and information and communications technologies to traditional and local knowledge players.

91. The United Nations Decade of Education for Sustainable Development 2005-2014 is a major instrument for reorienting education for rural communities. Agriculture, sustainable land and water management and drought and desertification should receive particularly high attention within different domains of education, including basic and higher education, specialized training and developing public awareness and understanding of sustainability. The scientific and technological community is committed to making an active and important contribution to the Decade in this respect.

92. Building and maintaining the quality of key national institutions of learning and research, especially universities, is critical to sustainable development. The responsibility for this capacity-building lies squarely on the shoulders of national Governments. However, the global development assistance community and the international scientific and technological community should enhance collaboration and partnerships with developing countries in this field. Experience shows that international scientific and technological cooperation, through efforts such as the creation of scientific and technological networks, scientific exchanges and the establishment of scientific centres of excellence among nations with weak scientific infrastructure, are excellent strategies for building scientific and technological capacities. At the same time, coordinated measures must be taken to counter the negative effects of "brain drain" upon countries that are working to develop their own scientific and technological community and institutional capabilities.

93. Bridging the widening gap in scientific and technological capacity between developed countries and the majority of developing countries is particularly critical in agriculture, natural resource management, combating desertification, addressing climate change and poverty reduction. Developing countries must address this problem and significantly increase investment in higher education — natural, social,

engineering and medical sciences — and in research and development institutions dedicated to the above topical areas.

VI. Conclusion

94. **Progress in meeting sustainable development goals in the areas under review at the sixteenth Commission on Sustainable Development session will require substantial innovative advances in science and technology. Massive efforts will also be required to involve farmers and other stakeholders in scientific and technological agenda-setting; to strengthen the scientific and technological capacity in developing regions that still lack this capacity; and to get improved knowledge, approaches and technologies to the farmers (in particular small-scale farmers who could benefit most) to other natural resource managers, policymakers and development agencies.**

95. **Science and technology for sustainable development must be global in its reach, yet local and national in its application. Enhanced North-South and South-South scientific and technological cooperation, knowledge networking and dissemination, and technology transfer will be essential for ensuring a better harnessing of science and technology in agriculture and the other areas under review.**

96. **The scientific and technological community remains committed to helping identify and implement sustainable solutions to the pressing problems of food security, poverty reduction, maintaining ecosystem services and climate change. To this end, our community seeks to enhance further cooperation with Governments, farmers, business and industry, and all other major groups in the pursuit of a sustainable path of development.**