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SUBSTANTIVE THEMES: (c) THE SCIENCE AND TECHNOLOGY ASPECTS OF THE SECTORAL ISSUE TO BE DISCUSSED BY THE COMMISSION ON SUSTAINABLE DEVELOPMENT IN 1995

Science and technology for integrated land management

Report of the Panel

Pursuant to Economic and Social Council resolution 1993/74, the Panel on the Science and Technology Aspects of the Sectoral Issue to be discussed by the Commission on Sustainable Development in 1995 has completed its work. The report of the Panel is submitted to the Commission for its consideration.

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Executive Summary

The goal of integrated land management is to optimize the combination of economic and environmental benefits to society that are provided by the land's soil, and water resources, while preserving or increasing the capability of the land to provide these and other benefits in the future. Science contributes to effective land management by providing the information and understanding needed to evaluate consequences of alternative approaches to land management problems, and by developing technologies for land use and management that more effectively achieve society's objectives, including meeting basic human needs and reducing gender inequities. The integrated approach to land management is not a fixed procedure, but rather a continuous, iterative process of planning, implementation, monitoring, and evaluation that strives to meet as many of the multiple economic, social and environmental needs of society as possible.

Sciences and technologies that support (1) information needs, (2) evaluation of options, (3) applications for solution of specific problems, and (4) infrastructural capabilities provide the foundation for an integrated approach to land use planning and management. Most of the basic scientific knowledge and applied technologies needed for integrated land management are already available. The effective use of many of these technologies in the developing countries that are experiecing the most severe land use problems, however, is hindered by a number of factors, including: (1) limited access to appropriate information and technology; (2) lack of appropriate infrastructure to use science and technology effectively; (3) problems caused by current unsustainable land use practices; and (4) unresolved conflicts between different land-use goals.

Elimination of these barriers requires approaches that are tailored to the specific conditions and needs of each country, and that take advantage of local knowledge and human resources that are already available. On the basis of its analysis and past experience, the Commission has identified four approaches as having the greatest potential impact on the effective implementation of integrated land management: (1) intra- and inter-governmental cooperation; (2) private public partnerships; (3) targeted training and technology support programmes; and (4) direct public investment in resource protection.

The Panel recommends that the principles developed in this report be further elaborated to provide specific guidelines for the implementation of technologies that support integrated land management. In this regard, CSD and CSTD may consider the establishment of a joint working group for identifying specific technological needs and monitoring progress toward integrated land manangement. Such internationally developed guidelines, once adopted by CSD and CSTD, could provide a framework for cooperative action at the national level.

Contents

I. CHALLENGES AND OPPORTUNITIES

1. The increasing severity of environmental, social, and economic problems being experienced by both developed and developing countries around the world has focused global attention on the sustainability of human activities. The necessity of improving current conditions for much of the world's population and the needs of future generations are combined in the concept of sustainable development. The essential role of the earth's surface, with its minerals, water, and other renewable and non-renewable resources, in supporting all current and future human activities requires that land management be one of the primary tools of sustainable development. Current land management efforts around the world address a multitude of problems, including deforestation, desertification, air and water pollution, and uncontrolled expansion of human settlements in urban and rural areas. However, effective land management is hindered by a piecemeal and uncoordinated approach to these interrelated problems, often with duplication of effort or conflicting sectoral goals. A more holistic and integrated approach to land management offers the possibility of solving multiple problems within a single coherent framework.

2. The goal of integrated land management is to optimize the combination of economic and environmental benefits to society that are provided by the land, while preserving or increasing the capability of the land to provide these and other benefits in the future. The integrated approach to land management is based on the recognition that land serves multiple functions in society, and that there are competing or conflicting needs for land, multiple sectors of society with interests in every land-use decision, and diverse social, economic, and environmental considerations that influence current and future land uses. By examining all potential uses of land in a logical manner, integrated land management makes it possible to: (1) **minimize conflicts** over competing land uses; (2) **maximize benefits** obtained from the land by using it efficiently; (3) **improve social and economic development;** and simultaneously (4) **protect and enhance the environment.** Integrated land management is an essential prerequisite for sustainable development.

3. Potential opportunities to reduce gender inequities should be emphasized in all aspects of the development and application of science and technology for land use management. The importance of this consideration is emphasized by the knowledge that in a significant proportion of developing countries, women bear a disproportionate burden with respect to land-related activities.

A. Elements of an integrated approach to land management

4. An integrated approach to land management involves a logical sequence of procedures that identifies the needs of all stakeholders in society in terms of their social, economic, and environmental requirements, develops possible land-use options, and indicates the combination of options that would optimize achievement of these requirements on a sustainable and long-term basis. This approach includes the following steps:

(1) **Interaction among stakeholders**, including decision-makers, land management planners, land users, land owners, and beneficiaries of land services to identify requirements and needs;

(2) **Collection of information** about the physical, social, and economic conditions of the land area, and the storage and analysis of this information in order to evaluate current land conditions and future potentials;

(3) **Identification of spatial planning units** for the land area, as well as possible use options for each unit, in terms of use, long-term economic returns, input/output relationships, and

predicted social, economic, environmental impacts;

(4) **Agreement among stakeholders**, based on discussions among decision-makers, land users and beneficiaries, of the optimum land use and management system for each land planning unit;

(5) **Establishment of infrastructure** at the institutional, legislative, and cadastral levels needed for implementation of the agreed-upon land uses and long-term land management.

5. The integrated approach to land management is not a fixed procedure, but rather **a continuous iterative process of planning, implementation, monitoring, and evaluation** that strives to meet as many of the multiple economic, social, and environmental needs of society as possible, without penalizing any sectors of society or sacrificing future benefits. The essential components of this integrated approach are independent of scale, and are therefore **applicable at global, national, district, village, and farm levels.** The basic technical methodologies for carrying out each of the steps of this integrated approach to land management are already available, but their application in many parts of the world is **limited primarily by training, financial, and institutional constraints.** Access to appropriate technologies provides the key to effective implementation of integrated land management on a global scale.

B. Problems caused by poor land management

6. Failure to manage land resources in an integrated, holistic manner has led to a number of serious problems that can prevent the achievement of sustainable development. Environmental problems are inevitably linked to social and economic problems, including unemployment, poverty, disease, and starvation. The main problems include:

(1) **Permanent destruction or degradation of the land's capability to provide economic and environmental benefits.** Examples of this can be found throughout the world in both developed and developing countries, such as erosion, desertification, collapse of fisheries and other resource stocks, groundwater depletion, salinization of soils, toxic mine wastes, and the extinction of species and loss of biodiversity. This degradation of the land's capability to support human populations can also lead to uncontrolled urbanization, mass migration, and social conflicts.

(2) **Inefficient use or waste of resources.** Lack of an integrated approach to land management often leads to use of technologies that are inappropriate for a particular region or type of land. Examples include the development of irrigation projects in dry regions where agricultural production is actually limited by soil nutrients rather than water. Excessive use of valuable resources, such as fertilizers and pesticides, may be unnecessary or even have a negative effect on agricultural efficiency and lead to pollution and health problems that can affect both rural and urban areas. Increasing costs for water purification and treatment of pollution-caused disease are often born by sectors of society that had nothing to do with the cause of the pollution. Inefficient use of energy resources is a major impediment to all aspects of sustainable development. Experience throughout the developing world has demonstrated that the most effective solution to many land use problems is the combination of local knowledge with advanced technologies.

(3) **Accumulating Impacts.** In addition to the damaging local and national effects that result from poor land management, cumulative international problems are becoming increasingly serious as the earth's population increases. For example,

acidification of freshwater lakes in Scandinavia is apparently caused by industrial air pollution from north-western Europe. Deforestation in Nepal and the surrounding mountains leads to downstream flooding in the Ganges and other river systems that pass through countries downstream. In Europe, pollution of the Rhine River by industrial activities in upstream countries results in problems associated with reduced water quality in downstream countries. Land degradation and desertification in some countries may lead to mass migrations, serious refugee problems, and even land degradation in neighbouring countries, particularly during periods of extreme climate conditions.

7. While the basic problems of land management around the world have many common features, local variation in environmental, social, and economic conditions requires that technological solutions be specifically adapted to local conditions.

Box 1: The high costs of soil erosion

Many of the damaging effects of land degradation are interconnected, with the effects of a problem in one area causing a cascading chain of problems in other areas. For example, soil erosion resulting from inappropriate farming methods on steep slopes has the serious local effect of reducing the food production and economic output of the eroded lands. However, other local effects such as landslides that block roads or rail lines affect not only agriculture, but many other components of the local economy. Further away, the soil lost from the eroded hillslopes can pollute and clog rivers, increasing the frequency and severity of floods, affecting navigation, and reducing the fish harvest on which some downstream communities may depend. Still more distant, where the river enters the sea, siltation may harm coral reefs and estuaries, damaging both subsistence and commercial fisheries.

Soil erosion is one of the major causes of reduced food production potential in both the developed and developing worlds. For example, the United States has lost approximately one third of its topsoil since farming began less than three hundred years ago, and continues to lose 12 tons/ha/year for a total loss of 50 million tons of plant nutrients each year. The Huang River of China is the most sediment-laden river in the world, and annually carries 1.6 billion tons of soil from China's rich farmlands into the East China Sea. In Brazil, the huge Paso Real reservoir in Rio Grande do Sul has lost 18% of its original volume in less than 8 years, and continuing input of sediment from soil erosion threatens to reduce the life of this 530-megawatt hydroelectric plant to less than 30 years. 86% of the Andean Zone in Colombia has some degree of erosion, with 21% at a critical level. Throughout history, there are examples of societies that have collapsed because their agricultural activities destroyed the productivity of their land. In the modern world, the future human and economic security of both developed and developing countries continues to be threatened by land degradation.

8. Unintentional effects of agricultural activities, such as loss of vegetation or nutrient depletion, can result in erosion or desertification to the extent that the land loses its capacity to produce the desired agricultural products and other essential goods and services. At the other extreme, manufacturing and agricultural industries often inadvertently produce toxic or harmfully high concentrations of chemicals that are extremely beneficial at moderate concentrations, such as agricultural fertilizers and industrial chemicals. Most land-use problems can be understood in terms of this continuum from depletion to pollution. Because the concentration of resources generally requires the input of energy and use of advanced technologies, pollution problems tend to be most serious in developed countries and in countries in transition. In the absence of integrated land management, resource depletion and the associated land

degradation can be quite serious in areas dependent on agriculture and forestry, both in developing and developed countries.

9. The issue of land degradation is particularly critical in the developing countries of the tropical zone. Problems of food security and rural poverty are of urgent concern in many of these countries, where high populations and weak or unstable economies severely limit the economic resources available to each person, often exacerbating gender inequities. Although developing countries often possess valuable mineral and energy resources, the national economies of many developing countries depend much more heavily on agriculture than do the developed countries of the higher latitudes. This heavy dependence on agriculture for both food production and national economic output makes any degradation of the productive capacity of the land a serious threat to meeting basic human needs and achieving sustainable development. The inherent irreversibility of most forms of land degradation and the critical importance of food resources for the Earth's future generations emphasizes the essential contributions of science and technology to addressing issues related to land degradation. This choice does not ignore problems related to urbanization, industrialization and mining, all of which must be considered for integrated land-use planning and management.

II. CONTRIBUTIONS OF SCIENCE AND TECHNOLOGY TO INTEGRATED LAND MANAGEMENT

10. Science involves the combination of information and understanding that allows prediction of the consequences of specific actions or events, and thus the comparative evaluation of alternative actions or different options. Technology is the application of science to provide better options for achieving human objectives. Solution of the complex, interacting issues of land management requires the contributions of many disciplines of the physical, biological, and social sciences. Fortunately, most of the basic scientific knowledge and applied technologies needed for integrated land management are already available, including global satellite surveillance systems, powerful computer-based geographical information systems, as well as methods for land-use planning and evaluation, reducing wind and water erosion and increasing the productivity of the land. Some of these technologies have been well developed for many years, while others are currently undergoing rapid development. Many of these technologies are already being applied to land management problems around the world. However, in many cases, these critical technologies that are widely used in developed countries are not available in the developing countries where they are most needed, contributing to many of the environmental and socio-economic problems currently being experienced around the world. Even where technology and information are already available in developing countries, they are at present not optimally used because of ineffective or inefficient information storage, retrieval, and/or sharing.

11. The sciences and related technologies needed to implement an integrated land management programme can be grouped into four general areas:

(1) **Information sciences and technologies.** Accurate information in a form useful to all stakeholders is essential for integrated land management. Information technologies and their supporting scientific disciplines provide access to the basic information about the current status, potential uses, and limitations of the land, as well as market and transportation conditions and other business information. These technologies include traditional cartography and statistical analysis, as well as remote sensing from satellites and airplanes, ground-based monitoring and surveys, socio-economic information, and the computer databases that allow land users and decision-makers access to this information. Monitoring of the status and changing conditions of land, water, and biotic resources, using traditional methods as well as advanced technologies, is an essential component of integrated land management.

(2) **Evaluation sciences and technologies.** These methods allow the interpretation and evaluation of information about the land, and also the determination of the options that will lead to the most desirable pattern of land use. These methods include statistical analysis, decision support models such as Multiple Goal Planning, and computer simulation models for crop production, econometric analysis, environmental impact analysis, and manufacturing design. All of these tools facilitate communication among stakeholders and provide input into the sociopolitical process of prioritizing land use alternatives.

(3) **Application sciences and technologies.** These technologies are derived from many different areas of science, as well as from traditional knowledge and land use practices. They address the specific land uses, agricultural practices, and engineering activities that are implemented by land users to achieve the objectives of an integrated land management plan. They include methods from forestry and agriculture, plant breeding and genetics, water resource management, non-destructive extraction of mineral resources, biotechnology, manufacturing sciences, energy sciences, and economic planning.

(4) **Supporting technologies and infrastructure.** These capabilities help implement the above technologies and are an essential part of the infrastructure necessary to achieve integrated land management. They include training and extension facilities, analytical laboratories for soil and product analysis, development of product standards, water and air quality analysis, and veterinary and medical analysis, as well as survey methods and databases for land evaluation, cadastral mapping and land registration systems, and socio-economic evaluations.

12. Each type of technology is supported by a number of different scientific disciplines, such as agronomy, applied physics, geology, ecology, and economics. Scientific research is essential to improve understanding of specific land management issues, to refine existing technologies, and to develop new technological capabilities. The first two areas of science and technology contribute primarily to the planning and evaluation components of integrated land management, while the last two deal with implementation of specific land management practices in order to move from the current situation to the desired future condition.

Box 2: Challenges and successes of land management in China

The world's most populous nation has made effective use of its land resources, feeding 22% of the world's total population with only 7% of the world's total farmland. Yet, the growing population and agricultural intensification in China have led to a variety of environmental problems that are currently being addressed. Soil erosion is not only reducing current and future agricultural production, but threatening water quality, navigation, flood control, and hydroelectric power generation. A vast system of reservoirs for water storage and flood control has been constructed, with a storage capacity of 408.6 billion cubic meters. However, nearly one quarter of that volume has already been lost to siltation, and 22 major reservoirs have ceased to function (China, country report). The Chinese Government is making great investments in science and technology related to agriculture, water conservation, and forestry through its university and extension services. China addresses the problem of land degradation in harsh and marginal environments by providing governmental support for agricultural intensification, as well as for re-vegetation of degraded lands (Breman, 1987). Massive reforestation efforts are well underway to control wind and water erosion, including the largest ecological project in the world, covering 42.4% of the total territory of China. The Great Green Wall parallels the Great Wall of China with a reforestation project that has reduced the duration of spring dust storms in Beijing by up to 90%, while increasing soil moisture available for agriculture in the reforested regions (Parungo et al., 1994). The economic and technical support needed to allow a decent and productive life for farm families in marginal lands is often more cost-effective than the creation of employment for them in urban areas, and has the added benefit of protecting economically and ecologically sustainable land use in nearby productive regions. Integrated land management efforts in China are likely to have global effect, as well as local and national benefits.

A. Information sciences and technologies

13. Many types of information are necessary to achieve effectively integrated land management. Existing historical and current information about land conditions and land use practices is often scattered and difficult to access in a comprehensive or integrated manner. Modern information technologies can help make more effective use of traditional information sources and local knowledge by combining them with new information from advanced technologies. Computer-based information and analytical capabilities make integrated land management more feasible than it was in the past. Efficient collection and analysis of the most needed information is facilitated by the combination of digital databases and statistical methods that allow identification of critical processes and limitations.

14. Advanced information technology is epitomized by satellite images of the Earth that indicate the current conditions of the land and clarify the interconnections between different regions. Analyses of digital information from satellites and aerial photography makes possible the accurate monitoring of land conditions over large areas, and increases the value of traditional ground-based surveys of soil properties, land use, crop productivity, mineral resources, and land ownership. Around the globe, international boundaries and even fencelines within farms, are visible from space because of the different land uses on either side. Dissemination of this type of information in a form useful to all stakeholders in land use decisions requires a number of different approaches.

15. The basic form of information needed for integrated land management is maps, either printed on paper in traditional formats or contained as electronic data in computer-based Geographical Information Systems (GIS). Obtaining and analysing this information is the first step in identification of options for land management. Remotely-sensed data have proven

indispensable for (1) accurate soil surveys, (2) evaluation of deforestation, desertification, mining impacts, and other forms of land degradation, (3) evaluation of the response of natural vegetation and agriculture to variations in climate such as droughts, monsoons, and freezes, (4) determination of actual land-use patterns, including urbanization and industrialization, as well as agriculture. Satellite imagery provides a powerful vehicle for guiding land-use policies at the regional and national levels, as well as at the local level. This information brings home to governmental policy-makers the large-scale impacts of local activities, and provides a means of integrating local knowledge about effective land use practices into a regional or national land management framework.

Box 3: Satellite images used to evaluate land-use patterns in Colombia

Colombia encompasses a wide range of environmental conditions from high montane regions to lowland rainforests to semi-arid savannas, each with its own unique environmental problems. To develop a coordinated, country-wide approach to land management, the National Geographic Institute "Agustin Codazzi" used satellite images to compare actual land uses with the most suitable land uses in each region. Analysis for land use sustainability indicated that 68.5% of the country's land area is best suited to forestry, but only 49% is actually in forests. Cattle pastures occupied more than 40% of the land area, in spite of the fact that only 16.8% of the land is suitable for cattle raising. These analyses help identify land use problems, and the regional and national goals that are needed to develop an integrated land use planning programme.

16. Land users involved in market economies need accurate, up-to-date information on current and predicted market conditions, transportation and storage capabilities, and changes in regulations or other important factors. Long-distance educational programmes can provide critical training in technology applications and business practices in developing regions.

17. In developing countries that are dependent upon agriculture, important products of land evaluation include information on the best suited cropping and/or grazing systems in relation to soils, climate, and other environmental, social, and economic factors, and impacts of the agricultural systems on the land. The maximum sustainable productivity of these agricultural systems determines the land's ability to continuously support human populations (the carrying capacity). Integrated land management allows sustainable agricultural productivity to be increased toward its theoretical maximum. For example, FAO's Agroecological Zones project for Africa indicates that the continent could produce enough food, fiber, and fuel to support a population far larger than the current 500 million. However, it is evident that the needs of even the current population are not being adequately met. Meeting the basic human needs of Africa's population will require a continent-wide integrated land management strategy that includes a major effort in soil conservation and restoration of degraded lands, along with socio-economic measures.

Box 4: Planning for economic success in Botswana

Economic growth and environmental planning are closely connected in the African country of Botswana, which has had the highest rate of GNP growth of any country in the entire world. Careful economic and environmental planning, along with good fortune, have made Botswana a showcase of the developing world. While diamonds and trade with European Common Market dominate the economy, a long history of attention to land resources has laid the basis for strong growth in the livestock sector. A thorough evaluation of land potentials for grazing and cultivation was completed in the 1970s (Sims, 1981), including recommended stocking rates for different regions. In spite of the difficulties of improving food security in a climate with frequent droughts, the government has developed and implemented plans to maintain and strengthen rainfed arable agriculture by supporting rural communities during droughts and recovery following droughts. A strong institutional framework for land use planning is implemented at both the national and the regional levels, with land use planning groups in each of the districts corresponding to the eight tribal regions. Botswana's recent history suggests that a continuing governmental commitment to careful planning, along with implementation of new integrated land management technologies will allow continued sustainable development of this country's land resources.

B. Evaluation sciences and technologies

18. Many of the decisions involved in integrated land management are socio-economic and political in nature and cannot be resolved by technology alone. Alternatives must be evaluated in terms of societal values and agreed-upon strategic goals. For example, socio-political considerations such as employment may justify policies to encourage crop production even at very low yields. Many African farmers cultivate land classified as economically unprofitable for dryland farming because even low yields contribute to bringing total production up to a subsistence level. Land management cannot be effectively integrated without the cooperation of the land users and local communities, as well as the input of decision-makers and political bodies. Evaluation technologies can assist planners and decision-makers in working with the land users to choose the combinations of land use alternatives that best meet a specified set of objectives.

19. Evaluation technologies are essential at numerous points in the land-use planning process. Computer-based analyses and models can be used to evaluate the consequences of alternative land-use scenarios in terms of both profitability and environmental sustainability. These models can help identify the critical limiting factors for different land uses, as well as the maximum potential for specific uses. Systems analysis allows the construction of mathematical models of different components of land use, including biological components such as crop production and forest growth, physical components such as hydrology and erosion, and socio-economic components such as households, villages, and national economies. Moreover, systems analysis can help identify those situations where technological solutions are required and those where socioeconomic interventions are necessary.

Box 5: Planning for conservation and agriculture in the United Republic of Tanzania

Efforts to improve land use for agriculture and conservation have a long history in the United Republic of Tanzania. Integrated land management is essential for the future of a country such as Tanzania, with generally infertile soils, a difficult climate, concentrated areas of overpopulation, and spectacular natural beauty, wildlife, and biodiversity. In 1976 the World Bank planned a Rural Integrated Development Project for the Tabora region in western Tanzania. The project included land evaluation, estimation of carrying capacities, and agro-economic studies at the village level to provide the basis for land planning. Tanzania has continued efforts to plan for sustainable development while protecting and enhancing its natural resources, but this is an extremely challenging and difficult task for a poor African nation with many pressing social and economic problems. Current natural resource conservation efforts are being supported by Finland (Forestry Action Plan), Sweden (National Conservation Strategy), Denmark (environmental assistance), and Norway (soil conservation and afforestation in the Shinyanga Region). Major challenges exist in virtually all areas of technological and infrastructural support for integrated land management.

20. The monitoring of indicators characterizing key processes related to land use and economic development is an essential tool for evaluating policy measures. A variety of methods and systems are available to monitor the quantity and quality of natural resources. However, governmental commitment and investments are required to guarantee a consistent and unbiased source of both environmental and economic information. The type of measurement will depend on temporal and spatial scales, properties of the land and the objectives of the land users. Indicators for resource use should characterize the rate and the direction of change of the processes underlying the functions of the natural resources, reflecting their degradation, depletion, pollution, etc. The monitoring of socio-economic indicators should be given as much attention as the agro-ecological ones. They concern changes in production systems (e.g. degree of integration of animal husbandry and arable farming), processes like urbanization, industrialization, resource extraction, income, price and trade statistics, and so on.

21. Even with adequate monitoring data and analysis of alternative scenarios, it may not be obvious what the best combination of land uses might be. Tools such as Interactive Multiple Goal Programming can help organize and prioritize socio-economic and agro-ecological alternatives. The method is based on the observation that the various interest groups in society have different objectives that at least partly conflict. The values attached to goals such as food production, export, employment, environmental protection are likely to differ for different sectors of society. The method allows all stakeholders to participate in exploration of the possibilities for a compromise that is acceptable to everyone, although it may not be ideal for any specific group. The strength of Multiple Goal Programming is its ability to stimulate societal discussion about the consequences of specific policy options. Nevertheless, these methods alone cannot provide the final solution to land use issues, which must be resolved on the basis of agreed-upon values and goals.

Box 6: Atmospheric science allows advanced planning for droughts

Recent advances in atmospheric science offer the promise of long-range predictions of droughts. Strong correlations have recently been reported between the El Nino warming of the Pacific ocean and severe droughts in Zimbabwe and other parts of Africa (Cane et al., 1994). Because of developing abilities to predict the El Nino warming a year or more in advance, it may soon be possible to predict future growing season weather before crops are planted in Africa. The ability to plan in advance for growing season weather conditions would be a major contribution to agricultural planning and a totally new component of integrated land management. Continuing development of such technologies can potentially improve land management and help stabilize food availability in countries such as Zimbabwe and Botswana.

C. Application sciences and technologies

22. These are the "on the ground" methods that are implemented to achieve the goals identified during the process of land use planning. The contributions of human innovation and experience, as embodied in many types of indigenous knowledge, have made possible the rapid development and adaptation of methods to improve all aspects of land use. Technologies for specific applications are derived from many different sciences, including agronomy, forestry, hydrology, geology, soil science, wildlife biology, physics, chemistry, mining, civil engineering, etc.

23. One of the best-known successes of an applications technology is the "Green Revolution," which produced high-yielding varieties of cereals that greatly improved food security in parts of the developing world. Continuing work in crop breeding and genetics is developing varieties that are tolerant of less favourable conditions and do not require the high inputs needed by the original Green Revolution varieties. Agricultural experiment stations around the world are continuing to make great progress in developing productive crop varieties that are successful with lower inputs and compatible with more effective soil and water conservation. Modern genetic engineering techniques and more effective use of the genetic resources contained in wild varieties and indigenous crops offer the promise of continued improvement. Similar gains in production and disease resistance are being obtained through animal-breeding programmes as well. However, these new technologies cannot be effectively applied where they are most needed without better information on the distribution of soil and climatic conditions in developing countries.

24. In many cases the most effective application technologies result from a hybridization of traditional methods with modern technologies that involve high efficiency input of resources. The growing body of global experience in land restoration and other aspects of integrated land management offers to accelerate the process of solving environmental and development problems in the developing world. Continued testing and refinement of these technologies should lead to further improvements and adaptation to a wider range of the environmental conditions in developing countries.

Box 7: Land use planning decreases erosion and increases food production in China

China's Loess Plateau (530,000 km2) is one of the most severely eroded areas in the world. Beginning in 1979, the Chinese Government, in cooperation with UNDP, set up an experimental erosion control station at Mizhi, in the north of Shaanxi Province. A variety of technologies were evaluated on a 100 km2 experimental watershed that was shared by three villages. Technologies included conversion from cultivated annual crops to perennial crops, building additional terraces, controlling gully erosion, and introducing new crop varieties and animal breeds. By the late 1980s the project had achieved most of its goals. The total land area used for food production was reduced by more than 50%, while stable farmland also increased by more than 50%. 47% of the total land area is now covered by grassland and forest, which have greatly reduced erosion rates. Total food production increased by 70%, in spite of the large decrease in cultivated area. This and several similar projects in the Loess Plateau, implemented in collaboration with WFP and FAO, have demonstrated unequivocally that integrated land management can simultaneously reduce erosion, increase production and raise living standards. These methods are now being extended throughout Shaanxi Province and into the Yulin Prefecture as well (FAO, 1992).

D. Supporting technologies and infrastructure

25. A strong educational, research, and analytical infrastructure is essential to support an effectively integrated approach to land management. Integrated land management projects are unlikely to succeed unless there is a sufficient level of in-country expertise to carry out the process and sufficient cooperation across traditional institutional and sectoral boundaries to make efficient use of the expertise. A strong agricultural extension service can provide critical practical experience and access to indigenous knowledge, as well as the means to communicate the goals and methods of the integrated land management to the land users. Modern analytic and research equipment, as well as computer hardware and software, must be sufficiently available to meet the evaluation, research, and monitoring needs of land management.

26. Because effectively integrated land management requires the support of all stakeholders and a central authority for implementation, a public that is sufficiently well-educated to understand and appreciate the goals of sustainable land management is essential to the long-term success of such efforts. Both informal and formal education, using all available media, and the legislative and cadastral structures to support long-term economic security are critical to sustainable development.

27. While support technologies may not be as glamorous and exciting as remote sensing and biotechnology, they are equally important to the success of integrated land management. Support technologies can sometimes serve as integrating mechanisms that encourage different sectors of society to work together. For example, linked computer networks in which each group is responsible for providing a specific portion of the information that is needed by everyone can encourage cooperation between agencies or groups that have not formerly cooperated. Investment in this type of infrastructure provides the foundation for successful implementation of integrated land management.

III. CONSTRAINTS TO LAND MANAGEMENT

28. There are numerous barriers to effective implementation of an integrated approach to land management at both local and global scales. Some of these barriers have technological solutions, however many of them result from the fact that existing technologies are not available in the locations where they are most needed. Removal of many of the barriers to integrated

land management requires decisions about resource allocation at national and international levels, which will affect the future of specific sectors of society. Barriers to integrated land management can be classified into four general areas:

(1) **Limited access to appropriate information and technology**

(2) **Weaknesses in institutional infrastructure**

(3) **Unsustainable land use practices**

(4) **Conflicts between different land-use goals**

29. Owing to variation in environmental and socioeconomic conditions, the appropriate technologies for integrated land management vary, and the barriers to integrated land management are different from region to region and from one country to another. While science and technology can make some contribution to the removal of each of these barriers, the contributions of the political and economic sectors are essential for providing the commitment and resources to solve these problems.

A. Limited access to appropriate technology and information

30. The starting point for integrated land management is knowledge and information on the quality of land resources and their actual land use. This includes (1) information on **basic land properties** such as the potential for forestry, agricultural production, mineral extraction, biodiversity, etc.; (2) **inherent limitations** to the various land use forms; (3) **susceptibility t**o desertification, erosion, groundwater pollution and other forms of degradation; (4) **distribution** of land use, ownership and regulatory constraints; and (5) urban and industrial **impacts**, etc. Unfortunately, for many critical land management situations in the developing world the needed information either does not exist or is not available in a useable form.

31. A primary reason for lack of basic information is the difficulty of obtaining access to the technological tools needed to obtain and analyse the information. Tools and scientific methods already exist to evaluate information for making decisions on land use and development. However, they are not uniformly available in all parts of the world. This lack of availability result from inadequate financial resources to acquire the technology, or an inadequate infrastructural and educational base to support the technology after it is acquired. The need for tools like remote sensing and multiple goal programming in land use planning increases with decreasing resource quality. But at the same time, the low productivity of marginal lands is less able to support the costs of the equipment and training required to effectively use these evaluation technologies.

32. In some cases, the needed information is available, but it is ignored or neglected. The lack of a timely response to a known problem may be as serious as the lack of early warning of a previously unknown problem. Frequently, only incidental use is made of the tools that are actually available, resulting in limited and inadequate land use planning and management. In such cases long-term observations on the state of the environment will be scarce. Monitoring of resources and their use through indicators of sustainability is essential for the analysis of effectiveness of policy measures and the resulting land use management. Such monitoring must have a strong local component, with measurements and observations by trained personnel. Advanced technologies such as remote sensing will often be useful.

33. Currently, effective transfer of specific technologies and knowledge from one country to another is hampered by the lack of common methods and definitions for basic land properties such as soils, climate, land uses, and land cover types. Standardized definitions for these fundamental land

properties are being developed through a joint UNEP/FAO/Habitat initiative, which should greatly facilitate the implementation of integrated land management.

34. Science and technology cannot solve all problems. In some cases the lack of useful information may be related to the imprecision of available science and technology. Not all questions about land use and its implications for the environmental, economic and social sectors will have a definitive scientific answer. Available data may be so ambiguous as to hinder an appropriate interpretation or hamper extrapolation to other environments. More difficult is the fact that the dynamic interaction between humans and environmental processes are complex and poorly understood. For example, the impacts of human behaviour on the global atmosphere and potential greenhouse effect are ambiguous. Scientific research on global climate change predicts consequences ranging from cooling to a warming of the global atmosphere. Such information is worthless for decision-makers. A fundamental lack of understanding of complex processes is the basis for this and other information failures. In these cases, further scientific research is the only way to improve the decision-making process.

Box 8: Pakistan's national conservation strategy

Growing population, coupled with rapid industrialization and urbanization, was posing a great challenge to optimal resource utilization in Pakistan. The National Conservation Strategy was formulated by the Government of Pakistan as a response to organize and coordinate public action on issues of concern in resource use. The NCS comprehensive action plan envisages an investment of about $50 billion over a ten year period in 14 core areas, which include steps to maintain soils in croplands, increase irrigation efficiency, protect watersheds, support forestry and plantations, restore rangelands and improve livestock, protect water bodies and sustain fisheries, conserve biodiversity, increase energy efficiency, develop and deploy renewables, prevent and abate pollution, manage urban wastes, and support institutions for common resources concerning land management.

B. Weaknesses in institutional infrastructure

35. Although in recent decades knowledge of many aspects of land use has increased considerably, the dissemination of this information has not kept pace. Reasons include the lack of adequate transfer mechanisms, the limited use of existing mechanisms, and lack of communication and cooperation between agencies with responsibility over different aspects of land use. The mechanisms for transfer of information include public awareness and education, recovery and use of indigenous knowledge, trained professionals, institutional infrastructure, and methods for local, regional, interagency, and international exchanges of knowledge and technologies.

36. A well-conceived and effectively implemented framework is needed to promote resource management at different levels of society, from central, regional and division level to the local (village) planning level. Unfortunately, trained personnel and staff acquainted with land resource management and environmental education are often lacking at critical levels. In some cases, particularly in the past, insufficient attention has been paid to environmental issues in public education. Extension services sometimes focus on the male part of the population, neglecting the role of women in relation to agriculture, household energy, and other environmental impacts. The accessibility of education to women is of crucial importance for development programs aimed at integrated land management.

37. Lack of cooperation and communication between agencies may lead to duplication of efforts and waste of resources. Inadequacy of institutional mechanisms for the transfer of information about market conditions and business opportunities may be as damaging as the lack of information about

agricultural technologies. In some cases, science-based technologies have been introduced without emphasizing the drawbacks, such as the toxic side-effects of an over-use of biocides.

38. Without two-way transfer of information, extension services are not able to create the required link between farmer needs and research findings, so research is often ineffective. Research institutes that concentrate on well-endowed regions may produce results that have little relevance to the less endowed regions. A rich fund of indigenous knowledge built up over generations can be quickly lost, reducing opportunities for maintaining sustainability. Hybridization of the indigenous ecologically sound farming with modern high input agriculture may result in the most efficient use of the inputs involved and create the best chance for economic feasibility, with restricted ecological side effects.

C. Unsustainable land use practices

39. Unsustainable land use results from over-exploitation, pollution, and destruction of natural resources. No individual or society intentionally destroys its future well-being or survival by unsustainable practices. However, economic pressures resulting from pricing structure, subsidies, and tax incentives, as well as simple necessity driven by needs for short-term survival, can lead to the degradation or destruction of the resource base needed for long-term survival and economic well-being. Governmental pricing, subsidies, and trade policies in relation to food, wood, energy, and mineral resources may encourage or even force land users to deplete natural resources, causing situations where they undermine their own livelihood. Both national and international economic policies can drive land use toward unsustainable practices.

40. Land degradation resulting from pressure for survival can occur when the land's carrying capacity is reduced by extreme weather conditions, such as droughts, or by gradual deterioration due to overgrazing or erosion. Some regions are much more susceptible to these problems as a result of climate, soils, topography, or other factors.

41. Inequitable distribution of land and other resources can effectively reduce carrying capacity and create a situation in which land degradation is accelerated when people are forced to use marginal lands that are not able to support them. Lack of long-term land tenure or the absence of technology needed to determine or assign land tenure can lead to land degradation by users who have no incentive to improve or conserve resources for the future.

Box 9: Scientific knowledge helps preserve biodiversity

Scientific knowledge can help identify situations where apparently conflicting land uses are actually compatible. For example, biodiversity conservation is often considered to conflict directly with agricultural food production. Yet recent work indicates that many components of biodiversity are naturally low on the productive lands that are best suited for agriculture, while many components of biodiversity are actually highest on marginal lands of lower productivity, where the economic value of genetic material for biotechnology may be quite high. Thus, protecting productive lands from degradation and using them efficiently for food production with methods such as mixed cropping can help preserve biodiversity by keeping marginal lands out of intensive agriculture and using them instead for such purposes as watershed protection, aquifer recharge, water quality improvement, and tourism, in addition to the protection of wildlife and other components of biodiversity.

42. While the concentration of population in urban areas has advantages in terms of increased efficiency and reduced costs for social and physical infrastructure, expansion of urban areas has also a direct effect on the adjacent environment. Critical thresholds may be exceeded in relation to the

environment's self-cleaning potential, or the availability of water and energy resources for urban development and industrialization, as well as basic human needs. For example, firewood is a common energy source for cooking and heating in most developing countries. The need for fire wood in urban areas can easily exceed the annual production. More expensive energy is not the only consequence. The decreasing buffering capacity of the adjacent environment through deforestation leads to erosion and less efficient agriculture, transport, and industry. Deposition of air pollutants from urban waste incinerators or industrial blast-furnaces can lead to harmful concentrations of toxic materials in agricultural products, and the pollution of surface water due to industrial and urban discharges can make the water unsuited for agricultural irrigation purposes.

Box 10: A long history of land evaluation in Japan

Assessment and improvement of the human carrying capacity of the land played an important role in the social and economic development of Japan. Careful record-keeping and evaluation of agricultural production during the Tokugawa period allowed Japanese rulers to determine their tax base and regulate the distribution of their rural and urban populations (Sato (1769-1850); Sansom, 1931). The fertile soils of the region surrounding present-day Tokyo contributed to the development of an integrated agroeconomic system that supported a high population density and a rich social and economic structure.

43. Because the carrying capacity of a region results from economic and social conditions, as well as the quantity and quality of the natural resources, overpopulation is a relative condition, rather than an absolute number. One of the causes for self-destruction of a society's resource base is overpopulation relative to the current economic conditions. The situation is particularly difficult where the local or regional soil and climate are too poor to guarantee profitable sustainable use of external inputs in agriculture, while a low supply of qualified labour and other economic conditions hinder the creation of employment outside agriculture, such as in desert margins and semi-arid regions. Large-scale technological investments in these regions are not economically feasible because the purchasing power of the local population and the possibilities for increased production are insufficient. In the long run, however, such neglect of marginal regions will threaten the more productive areas, through the deterioration or loss of the ecological, social, and economic functions of the marginal areas, which may be critical to the well-being of the more productive areas. Public investments to support sustainable land uses may be the most cost-effective formula to maintain the functions of eco-systems in marginal regions and to avoid migration and the accompanying social and economic problems.

D. Conflicts between different land-use goals

44. Land use planning is directed at the "best" use of land, in view of accepted objectives and aspirations. However, it is inevitable that there will be conflicts between various interests groups that have goals and perceptions about land use. For example, urban and industrial development often requires land that is extremely valuable for agricultural production. In arid regions, migration of transhumance pastoralists usually results in conflicts with farmers of arable lands. Conservationists usually have goals for how land should be managed that differ from those of farmers or businessmen. Many of these objectives are interrelated and it is obvious that they partially overlap as well as compete. Where multiple goals are at stake, trade-offs among these goals have to be made. There are often no simple technological solutions, and societies are forced to make difficult decisions and compromises.

Box 11: Conservation, development, and management of land resources in India

With India's high population density and rich natural and cultural resources, land use management is a critical concern. Major policy issues were identified at the National Consultation on the Prospective Plan for Conservation, Development, and Management of Land Resources in 1991, which called for an integrated, scientifically sound approach to the management of land resources in the country. A number of initiatives were highlighted, including: comprehensive land use planning to govern mining, quarrying, industrial uses, and urban development; coordination of related sectoral activities such as National Forest Policy, National Water Policy, National Housing Policy, National Land Use Policy, etc.; higher priority for protective and regeneration aspects of forestry; diversification of agriculture with special attention to problems of soil salinity, waterlogging, acidity and drought-prone and desert areas; mitigation of hazards such as floods and earthquakes in susceptible areas; proper training of personnel; and continued updating of the information base on land resources in India through remote sensing and computerized data banks. National and regional land use planning is facilitated by the Agro-Climatic Regional Planning Project of the Indian Planning Commission, which delineates the country into 15 agro-climatic regions to provide technical and scientific inputs for agriculture and allied sectors during the Eighth Five-Year Plan (1992-1997) and beyond. Science and technology will contribute on a continuing basis to the process of planning, implementation and management of the programmes initiated to address the above issues.

45. The appropriate response to conflicts is not always obvious. For example, high-input agriculture usually attains higher efficiencies of inputs per unit of output than low-input agriculture because production resources are used more efficiently thanks to a further optimization of the growing conditions. However, owing to the high chemical inputs, local contamination of the environment is much more likely to occur than with low-input agriculture. In addition, the higher productivity of high-input agriculture allows a smaller area of land to produce the same amount of food as a much larger area of low-input agriculture. Thus, a larger area remains available for nature conservation, maintenance of biodiversity, watershed protection, and other socially important land uses. In this contrast, the complex nature of the trade-offs are particularly obvious. Do we employ our non-renewable resources as efficiently as possible in the well-endowed regions and allow locally high pollution of the environment, or do we use them less efficiently and ensure low pollution of the environment? Such issues cannot be separated from the prevailing socio-economic conditions, which may emphasize subsidies on external inputs, creation of employment outside agriculture, or income support. Careful evaluation of all issues at stake are required to decide which option is preferred.

46. Some kind of public authority, such as village councils, boards of public works, development councils, regional or national governments, must be involved in negotiating and implementing solutions to conflicting land uses. The consequences of the absence of such public authority are demonstrated in those parts of the world where efficient systems regulating land use in the past were weakened during the colonial era. Legislation based on colonial jurisdiction was introduced while indigenous land tenure systems were still in place, resulting in weak and confusing regulations. As a consequence, agro-ecological conditions were neglected, resulting in serious deterioration of land resources.

47. Integrated land management requires that choices be based on valid and explicit objectives. Because land is multifunctional, it is inevitable that conflicts occur due to these choices. However, the lower the availability and quality of natural resources, the higher the risk of postponing decisions and of neglecting integrated land-use planning and management. Unequal access

to natural resources and to external inputs, and lack of involvement of the population as a whole, accelerate the destructive processes. Irreversible degradation of less-endowed regions will occur and will threaten the functions of the adjacent better-endowed regions.

Box 12: Scientific research helps avoid waste of scarce resources

Assessment of agricultural limitations and potential human carrying capacity is particularly critical in marginal areas where extreme climatic fluctuations may cause destabilizing swings in agricultural production and human population densities. In Mali, as in the rest of the Sahelian region, periodic droughts cause the collapse of agricultural and grazing systems, with the associated mass migrations and humanitarian crises. Analysis of the limitations imposed by climate and soils on the productivity of agricultural and grazing systems indicated that the primary limiting factor was not water, but rather soil nutrient availability. Thus, expensive irrigation projects would be a waste of money unless other limiting factors were addressed first. A similar example of how an integrated approach to land management can avoid the waste of resources comes from Ethiopia, where the FAO performed a land suitability analysis, based on the concept of Agro-Ecological Zones, for a proposed dam in the Kesem region. Soil analysis found soil properties and spatial distributions that were incompatible with a successful irrigation project. However, the land evaluation also identified areas that would be suitable for various types of rainfed agriculture.

IV. RECOMMENDATIONS AND CONCLUSIONS: APPROACHES TO TECHNOLOGY TRANSFER AND CAPACITY-BUILDING

48. The constraints to integrated land management discussed in the previous section imply a number of specific actions that could help overcome them. Science and technology contribute to the solution of some of those constraints, particularly those directly related to land management planning and implementation (see sections III. C and D). However, other problems require social and economic solutions, particularly those related to the lack of the required information and the inaccessibility of the needed technology (see sections III. A and B). Education and infrastructure development are cross-cutting themes through all components of integrated land management. Specific barriers related to education and extension, high costs, lack of use or bad use of equipment are addressed in other reports, such as "Report of the Inter-sessional Ad Hoc Open-ended Working Group on Technology Transfer and Cooperation" (E/CN.17/1994/11). Nevertheless, these barriers remain significant limitations on the effective integration of land-use planning and management in many developing countries.

49. Both the types of constraints encountered in efforts to implement integrated land-use management and the land-use issues themselves are highly specific to local environmental and socio-economic conditions. Consequently, it is important to identify approaches to overcoming these constraints that are flexible and adaptable enough to provide the appropriate level of technology and the type of solution needed in each specific country or region. Experience in both developed and developing countries identifies a number of methods that have been successful in eliminating the constraints that hinder the effective integration of land management planning. These methods can be grouped under the following general headings:

(1) Intra- and intergovernmental cooperation

(2) Private/public partnerships

(3) Targeted training and technology support programs

(4) Direct public investment in resource protection

A. Intra- and intergovernmental cooperation

50. Limitations on the financial resources required to obtain needed information and technologies, as well as limitations in terms of within-country infrastructure, personnel training and expertise, can both be addressed by pooling resources among countries with common interests. This approach can increase the quality and level of information and technology that can be obtained by cooperating countries, as well as provide an effective mechanism to share solutions to common problems.

51. Among past efforts at cooperative ventures of this type, not all have succeeded. Successful and unsuccessful experiences help identify the elements that are important for the success of cooperative efforts. **(1) Common goals and common methods.** It is essential that all cooperators share common goals that are clearly addressed by the specific information or technology that will be shared by the cooperative. Some past "top-down" efforts by international agencies to provide advanced information from satellite remote sensing have failed because the information was not provided in an appropriate form or because it was too general and did not address the specific needs of individual countries. Successful cooperatives must be developed in a participatory manner to meet specific shared goals with an appropriate technology that is sufficiently flexible to provide useful results at many different levels of technological development. **(2) Commitment by all partners.** The long-term nature of building a base of trained and experienced personnel with the supporting technical infrastructure requires a serious financial investment and long-term commitment of personnel and institutional support in order to succeed. Potential cooperators must be willing to make a commitment to a sustained effort in order to participate. Programmes that require no commitment rarely succeed. **(3) Neutral administrative structure.** Successful cooperation requires that all partners be treated equally and that none dominate the resources or the selection of goals. Structures with neutral and independent administration or rotating leadership are essential to avoid domination by any single partner. Care must also be taken to respect and provide legal protection for the intellectual property rights of participants.

Box 13: International rice research institute: successful cooperation for technology transfer

An example of how to effectively develop technology where it is most needed is the IRRI-(International Rice Research Institute)-based collaborative research effort by institutes from developed and developing countries, including sixteen National Agricultural Research Centres (NARC's) in Asia. Improved rice-based production systems through the transfer of modelling and simulation skills is the major goal of the program. To establish a critical mass within the NARC's multidisciplinary teams were formed. Hardware and software were donated, and courses how to use them organized. All participating institutions were required to make long-term commitments of personnel and support. The common 'language' acquired and the network created permits direct exchange of results, access to common databases, and coordination of ongoing and complementary efforts. The combination of field and laboratory experimentation with modelling resulted in the identification of key-variables and processes allowing improved crop management systems. Moreover, NARC's can now benefit from the scientific capabilities at international levels.

Experiences in China, the Philippines, and India show that this approach can be easily adapted for use at the national level, enhancing inter-institutional and interdisciplinary work, and the integration of knowledge (Penning de Vries, et al., 1991). The Agricultural Research Information System , in development by the Indian Council of Agricultural Research and the State Agricultural Universities, with assistance of the International Service for National Agricultural Research (ISNAR), will be an invaluable tool for international information exchange in the future.

52. This cooperative networking approach can be used at a number of different levels. Among small countries within a region that share resources (e.g., watersheds, mountain ranges) or have common problems such as desertification, **international cooperation** allows an efficient pooling of resources to achieve what no single country could accomplish alone. Within larger countries, this approach has been successful in **intrasectoral cooperation** (e.g., agricultural research stations in different regions) and could also be used for **intersectoral cooperation**, as with shared computer systems for accessing satellite data or traditional information sources. Networks are an effective mechanism for pooling and sharing governmental resources, but can also be an effective and cost-efficient structure for **donor-supported activities.**

53. Cooperative arrangements of this type can make important contributions in the areas of **education, training, infrastructural development, and institution-building.** Although most of the current examples of this approach are in agriculture and natural resource areas, there are no limits to the land management and sustainable development issues that could be addressed using this approach. Important areas could include conflict resolution methods, manufacturing technologies, energy-efficiency, recycling, and reuse technologies, environmental geology technologies, urban and land use planning methods, and many other specific science and technology issues.

B. Private/public partnerships

54. The private sector can make major mutually-beneficial contributions to technology development and infrastructure-building in many different areas that support an integrated approach to land management. The mechanisms by which this can occur are highly varied. Banking credit that supports the implementation of proven technologies or the development of new technologies is a powerful tool that can link sustainable land use with economic development. Successful investment programmes based on community lending and women's cooperatives provide good examples of how capital can be provided to support technology transfer. Joint private/public **support for research and development** institutes for new technologies or products, or to investigate specific issues of importance to the private sector, are already implemented in many developed countries and some developing countries. This type of private investment goes hand-in-hand with market development and will tend to increase as markets develop. **Market development** that involves training of technical support staff and provisioning of field offices can also contribute to integrated land management when it involves appropriate technologies. In this same area, **corporate fellowship programmes** can build in-country expertise. **Product incentives** can help develop markets while making technology available and providing experience and training. Examples include providing computers to schools and municipalities or providing technical training with the purchase of a product. **Existing private infrastructure**, such as the distribution networks for products and product information, can be used to support the dissemination of information related to land management technologies. This is particularly important where the channels of public communication are not well developed, such as in rural or mountainous areas, and field research stations or agricultural extension offices have difficulties communicating and shipping materials.

55. This approach may prove extremely effective in furthering integrated land management, particularly as national and international corporations adopt the long-range goals of sustainable development.

C. Targeted training and technology support programmes

56. Currently unsustainable land uses are the most serious threat to the future sustainable food production over much of the Earth's marginally productive lands. In some cases, specifically targeted applications of technology can help remove the primary constraint to sustainable land use planning. For example, effective integration of land use planning activities

may be extremely difficult at the village level because of lack of needed information on surrounding lands, including ownership and jurisdictional boundaries, the boundaries of protected or reserved areas, the current conditions of the lands, and the potential future values of the land for agriculture, mining, tourism, watershed protection, and other uses. **More effective land use planning at the village level** can be made possible by local training programmes for data collection and assessment, along with provision of appropriate tools and technology. A small investment in training and technology in support of cadastral programmes can alter land use practices by providing the technical infrastructure for **secure land tenure.**

57. Support of **conflict resolution methods**, such as Multiple Goal Programming, can help involve all stakeholders in the resolution of conflicts over competing land use goals. Such conflicts result from differences in private versus public interests, values, and influence; lack of local control over land use and land resources; unequal distribution of resources and authority; lack of effective mechanisms for discussing, evaluating, and resolving conflicts, and lack of effective guidance or authority from decision-making bodies. Resolution of differences over land-use goals is inevitably based on value judgments, and subjective or normative evaluation of alternatives. The consensus and compromise necessary to resolve differences and develop a sustainable land-use plan that is acceptable to all stakeholders requires strong leadership and the guidance of the right authority, both for plan development and plan implementation. Failure to resolve these types of differences has historically led to civil strife.

Box 14: North-South technology transfer in Trieste spawns South-South collaborations around the world

Since 1982 the International Center for Theoretical Physics, along with the Third World Academy of Sciences, in Trieste, Italy, has been sponsoring courses and workshops in Mathematical Ecology. Every two years, leading scientists from the United States and Europe meet with 50 to 60 sponsored participants from developing countries for an intensive 3 to 4 week course on the application of mathematical and computer approaches to issues such as disease epidemiology, water pollution and ecotoxicology, resource management and bioeconomics, and land use planning. Course graduates are now applying these methods at universities and governmental institutions around the world. International workshops modeled on these courses have been organized by course graduates and held in Nigeria, Argentina, and Mexico, with more planned for Asia and throughout the developing world.

58. Improved capability for **policy review and evaluation** by decision-making bodies at all levels is essential for development of an integrated land use plan in support of sustainable development. Essential requirements for effective policy evaluation include **accurate information** on current land conditions and on the potential capability of land to support the various needs of society, including agricultural production, energy sources, mineral resources, clean and abundant water supplies, wildlife and conservation, and recreation and tourism. Provision of the **training and analytical tools** needed to carry out policy review and evaluation can make a major contribution to implementing integrated land management.

D. Direct public investment in resource protection

59. The urgency of stopping unsustainable land uses before they result in permanent degradation of the land's capability to support human populations may often require public involvement in promoting sustainable land uses. The threat to populated areas and productive lands caused by deterioration of distant regions has historically led governments to make major **investments in economically marginal regions** that provide direct and indirect benefits to more populated and economically robust areas. For example, the massive investment in the **infrastructure of dikes and canals** made over centuries by

governments in The Netherlands provides protection to cities and agricultural areas far from the locations where the investments are actually made. Likewise, the Chinese Government has supported **extensive tree-planting programmes** in semi-arid regions for the prevention of wind erosion that causes serious pollution problems in major urban areas to the east. **Agricultural price supports** can allow sufficient input of resources in marginal areas to allow sustainable agricultural practices, rather than continuing land degradation. Such price supports may also be necessary to allow a transition from unsustainable agricultural practices to sustainable methods that will become self-supporting after a period of time. Direct investments in specific land uses that support the economies of marginal areas may often be the **most cost-effective solution** to problems caused by unsustainable land use.

60. Another type of public investment that supports sustainable land use is the **establishment of research institutions** that address specific problems of marginal regions, such as issues related to sustainable agriculture, forestry, mining, and use of other resources. When these institutions are located in the marginal regions themselves, they also serve the important purpose of local education and infrastructure development. This type of direct public investment is particularly important in situations where the short-term market solutions that motivate the private sector do not or cannot effectively address the land use problems. In these situations, it is essential that the central governmental authority have the necessary information and tools for policy evaluation that will allow them to make decisions that will support integrated land use and sustainable development.

E. Agenda for the future

61. Despite the availability of scientific and technological solutions to many of the land-use problems around the globe, most of these problems remain and are, in fact, growing more serious. Many previous approaches to land-use management and planning have failed because they were narrowly focused, and did not address all factors relevant to sustainable development. The Panel therefore wishes to emphasize the importance of a holistic and integrated approach to land-use planning and management as the basis for the successful application of science and technology.

62. Both advanced and traditional technologies have an essential role to play in integrated land-use planning and management. The Panel has identified four practical approaches for supporting technology transfer and capacity-building: (1) intra- and intergovernmental cooperation; (2) private/public partnerships; (3) targeted training and technology support; and (4) direct public investment in resource protection.

63. Each of the above approaches can be used to provide support for a variety of technology transfer and capacity-building programmes. An integrated land-use management programmes should include the following basic components, each of which requires the application of appropriate technologies to meet specific needs:

(a) Information - Accurate information in a useable form is essential for stakeholders at all levels of society (see Section 2.1). For example, television and radio can provide local land users with weather and crop information, while satellites and computer systems provide maps and analyses for government planners.

(b) **Involvement** - The effective participation of all stakeholders, including the poor, women, and minorities, is essential for sustainable land use. For example, communication technologies can foster local, regional, and national dialogues, and interactive evaluation technologies can help develop consensus at all levels of society.

(c) **Empowerment** - The commitment to practise sustainable land uses only occurs when land users have the assurance of receiving the future benefits of these practices. Supporting technologies include navigation satellites that can help define land ownership and tenure boundaries, and access to information that can enable decision-making at the local level.

(d) **Facilitation** - The effective implementation of integrated land management requires a consistent supporting framework of regulations, market structures, and sectoral agencies working cooperatively towards the same goals at regional and national levels. For example, it is widely recognized that public and professional education are essential for sustainable development.

64. Land management problems, needs, and solutions are specific to each country. The Panel recommends that the principles developed in this report be further elaborated to provide specific guidelines for the implementation of technologies that support integrated land management. At the international level, CSD and CSTD may consider establishment of a joint working group, with participation of technology experts and donors, to develop a set of general guidelines to be used by cross-sectoral technology planning groups for identifying specific technological needs and monitoring progress towards integrated land management. These guidelines would be considered by the Commissions at their respective sessions in 1997. Once adopted, these guidelines would provide a framework at the national level for facilitating cooperation among sectoral agencies, NGOs, and donors for the efficient allocation and use of technological resources.

ANNEXES

Annex I

EXAMPLES OF APPLICATION OF SCIENCE AND TECHNOLOGY FOR INTEGRATED LAND MANAGEMENT

Listed below are some examples of the areas where science and technologies can make immediate contributions to integrated land management. These may provide a basis for successful programming and technical assistance projects:

- Remote sensing to create basis for planning and monitoring for the use of land;
- Environmental monitoring;
- Creation of basic Geographical Information Systems (GIS);
- Environmental impact assessment;
- Creation and dissemination of superior breeds and varieties;
- By-product reduction and utilization;
- Reclamation and restoration of land;
- Wildlife management;
- Soil management;
- Efficient use of land resources and waste reduction;
- Information exchange through networking;
- Consensus building;
- Creation of awareness;
- Cadastral mapping and land registration;
- Recycling of water;
- Systems modeling for water supply, irrigation, etc.
- Information collection, storage, retrieval and dissemination;
- Disaster prevention;
- Pest control systems;
- Alternative technologies for energy capture;
- Provision for market information;
- Urban and rural land use and human settlement planning;
- Pollution control.

Annex II

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Annex III

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