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DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS
POPULATION DIVISION

WORLD POPULATION MONITORING 2001

Population, environment and development

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NOTE

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

The designations "developed" and "developing" for countries and "more developed" and "less developed" for regions are intended for statistical convenience and do not necessarily express a judgement about the stage reached by a particular country or area in the development process.

The term "country" as used in the text of the present publication also refers, as appropriate, to territories or areas.

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PREFACE

The present report has been prepared in response to Economic and Social Council resolution 1995/55 of 28 July 1995, in which the Council endorsed the terms of reference and the topic-oriented and prioritized multi-year work programme proposed by the Commission on Population and Development at its twenty-eight session.[1] According to the multi-year work programme, which was to serve as a framework for the assessment of the progress achieved in the implementation of the Programme of Action of the International Conference on Population and Development,[2] a new series of reports on a special set of the themes would be prepared annually. The Commission, in its decisions 1999/1 and 2000/1,[3] decided that the special theme for the year 2001 should be population, environment and development, which is the topic of the present report.

The general trends of rapid population growth, sustained but uneven economic improvement and environmental degradation are generally well accepted. However, how population size and growth, environmental change and development interact on each other is not well established. This report reviews what is known about these interrelationships. The report analyses recent information and policy perspectives on population, environment and development. The topics investigated in this report include: the evolution of population and the environment at major United Nations conferences; temporal trends in population, environment and development; government views and policies concerning population, environment and development; population size and growth, environment and development; migration, population change and the rural environment; health, mortality, fertility and the environment; and population, environment, and development in urban settings. The presentation of these topics is followed by conclusions thereon. Annex I deals with the availability and quality of data; and annex II deals with theories and frameworks for modelling the impact of population growth on the physical environment.

As requested by the Economic and Social Council, the Population Division, Department of Economic and Social Affairs of the United Nations Secretariat, annually prepares the world population monitoring report on the topic of that year's session of the Commission. The full report is accompanied by a summarized version, the "concise report" (E/CN.9/2001/2). Each of these reports is presented and discussed at the Commission and then revised for publication. Presented here is the revised version of the full report on the theme "Population, environment and development".

The report was prepared by the Population Division of the Department of Economic and Social Affairs of the United Nations. The Population Division gratefully acknowledges Professor Richard Bilsborrow of the University of North Carolina for his work on chapter V on migration, population change and the rural environment. The Population Division is also grateful to the United Nations Statistics Division for the preparation of the annex on data availability and data quality. In January 2000, the Population Division organized a one-day seminar on population, environment and development. We would like to thank the participants at that seminar for their useful suggestions on the outline and on issues to be considered for the report, namely, Professor Richard Bilsborrow (University of North Carolina), Dr. Maria Concepcion-Cruz (World Bank), Professor Joel Cohen (Rockefeller University), Professor Tim Dyson (London School of Economics), Dr. Gerhard Heilig (International Institute for Applied Systems Analysis), Professor David Lam (University of Michigan), Dr. Catherine Marie Marquette (Chr. Michelsen Institute) and Professor Luis Rosero-Bixby (University of Costa Rica).

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NOTES

[1] *Official Records of the Economic and Social Council, 1995, Supplement No.7* (E/1995/27), annexes I and II.

[2] *Report of the International Conference on Population and Development, Cairo, 5-13 September 1994* (United Nations publication, Sales No. E.95.XIII.18), chap. I, resolution 1, annex.

[3] See *Official Records of the Economic and Social Council, 1999, Supplement No. 5* (E/1999/25), chap. I, sect. C; and ibid., *2000*, *Supplement No. 5* (E/2000/25), chap. I, sect. B.

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Symbols of United Nations documents are composed of capital letters combined with figures.

Various symbols have been used in the tables throughout this report, as follows:

Two dots (..) indicate that data are not available or are not separately reported.

An em dash (—) indicates that the population is less than 500 persons.

A hyphen (-) indicates that the item is not applicable.

A minus sign (-) before a figure indicates a decrease.

A full stop (.) is used to indicate decimals.

Use of a hyphen (-) between years, for example, 1995-2000, signifies the full period involved, from 1 July of the beginning year to 1 July of the end year.

The following abbreviations have been used in the present report:

AIDS	acquired immunodeficiency syndrome
CELADE	Latin American Demographic Centre
CMV	cytomegaloviruses
DANIDA	Danish International Development Agency
DDT	dichlorodiphenyltrichloroethane
DHF	dengue haemorrhagic fever
ECA	Economic Commission for Africa
ECLAC	Economic Commission for Latin America and the Caribbean
FAO	Food and Agriculture Organization of the United Nations
FSH	follicle-stimulating hormone
GDP	gross domestic product
GHGs	greenhouse gases
HIV	human immunodeficiency virus
ICPD	International Conference on Population and Development
IFAD	International Fund for Agricultural Development
IIASA	International Institute for Applied Systems Analysis
IPCC	Intergovernmental Panel on Climate Change
LPG	liquid propane gas
MAC	*Mycobacterium avium* complex
mha	millions of hectares
NPG	negative population growth
OECD	Organisation for Economic Co-operation and Development
ORS	oral rehydration salts
PAGE	Pilot Analysis of Global Ecosystems
PEDA	environment, socio-economic development and agriculture
PCBs	polychlorinated biphenyls
SPM	suspended particulate matter
SRES	Special Report on Emission Scenarios
UNAIDS	Joint United Nations Programme on Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome (HIV/AIDS)
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
UNFPA	United Nations Population Fund
WHO	World Health Organization

Details and percentages in tables do not necessarily add to totals because of rounding.

Countries and areas are grouped geographically into six major areas: Africa; Asia; Europe; Latin America and the Caribbean; Northern America; and Oceania. Those major areas are further divided geographically into 21 regions. In addition, the regions are classified as belonging, for statistical convenience, to either of two general groups: more developed and less developed regions. The less developed regions include all regions of Africa, Asia (excluding Japan), Latin America and the Caribbean, Melanesia, Micronesia and Polynesia. The more developed regions comprise Northern America, Japan, Europe and Australia/New Zealand.

The group of least developed countries as defined by the United Nations General Assembly in 1998, comprised 48 countries: Afghanistan, Angola, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Cambodia, Cape Verde, the Central African Republic, Chad, the Comoros, the Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, the Gambia, Guinea, Guinea-Bissau, Haiti, Kiribati, the Lao People's Democratic Republic, Lesotho, Liberia, Madagascar, Malawi, Maldives, Mali, Mauritania, Mozambique, Myanmar, Nepal, the Niger, Rwanda, Samoa, Sao Tome and Principe, Sierra Leone, Solomon Islands, Somalia, the Sudan, Togo, Tuvalu, Uganda, the United Republic of Tanzania, Vanuatu, Yemen and Zambia.

INTRODUCTION

The twentieth century has been an unprecedented century of population growth, economic development and environmental change. From 1900 to 2000, world population grew from 1.6 billion to 6.1 billion persons (United Nations, 2001). However, while world population increased close to 4 times, world real gross domestic product (GDP) increased 20 to 40 times (DeLong, 1998), allowing the world not only to sustain a fourfold population increase but also to do so at vastly higher standards of living. Nevertheless, this rapid population growth and economic growth occurred unevenly throughout the world and not all regions have benefited equally from economic growth. Moreover, population growth and economic development occurred simultaneously with increasingly unsustainable utilization of Earth's physical environment.

Discussion of the interrelationships among population, environment and economic development long precedes the writings of Thomas Malthus in the late eighteenth century. Since ancient times, statesmen and philosophers have expressed opinions about such issues as the optimum number of people and disadvantages of excessive population growth (United Nations, 1973). The recurrent theme was the balance between population and natural resources conceptualized as means of subsistence, or, more concretely, food and water. Not all theorists saw population growth in a negative light. In particular, mercantilist ideas in Europe during the seventeenth and eighteenth centuries saw the positive aspects of large and growing populations and favoured policies to encourage marriage and large families. Today, members of the Julian Simon school also emphasize the positive aspects of large and growing populations (Simon, 1981, 1990, 1996).

Deliberations and actions of the United Nations in the area of population, environment and development began at the founding of the Organization. This topic was the focus of an important debate at the first session of the Population Commission (now the Commission on Population and Development) in 1947 and remained a recurrent topic in the work agenda of the Organization, both at the parliamentary and at the technical levels. In the early years of the United Nations, when world population was slightly more than a third of its present size, environmental issues in relation to population and development tended to be framed in terms of natural resources needed to sustain population growth and economic development. In addition, issues of land availability and agricultural production were very prominent. Data on demographic and socio-economic trends in developing countries were exceedingly scanty at the time. The first studies concentrated on the situation of industrialized countries and on the impact of socio-economic development on demographic trends (that is to say, fertility, mortality and migration).

The United Nations Conference on Environment and Development, convened in Rio de Janeiro, Brazil, in 1992, was a milestone in the evolution of an international consensus on the relationships among population, environment and development, based on the concept of sustainable development articulated a few years earlier by the World Commission on Environment and Development. The Commission had defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). The Rio Declaration on Environment and Development (United Nations, 1993, resolution 1, annex I) identified population policies as an integral element of sustainable development. Principle 8 of the Rio Declaration stated "to achieve sustainable development and a higher quality of life for all people, States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies". Chapter 5 of Agenda 21 (ibid., annex II) covered demographic dynamics and sustainability and stated that "the growth of world population and production combined with unsustainable consumption patterns places increasingly severe stress on the life-supporting capacities of our planet" (para. 5.3).

These issues were revisited at the International Conference on Population and Development in Cairo in 1994. Forging a balance among population, sustained economic growth and sustainable development was the central theme of the Cairo Conference. The Programme of Action adopted by the Conference (United Nations, 1995, chap. I, resolution 1, annex) noted "the growing awareness that population, poverty, patterns of production and consumption and the environment are so closely interconnected that none of them can be considered in isolation" (para. 1.5). Population factors were seen as sometimes inhibitors of sustainable development: "demographic factors, combined with poverty and lack of access to resources in some areas, and excessive consumption and wasteful production patterns in others, cause or exacerbate problems of environmental degradation and resource depletion and thus inhibit sustainable development" (para 3.25); and "pressure on the environment may result from rapid population growth, distribution and migration, especially in ecologically vulnerable ecosystems" (para. 3.26). The Programme of Action states that "slower population growth has in many countries bought more time to adjust to future population increases. This has increased those countries' ability to attack poverty, protect and repair the environment, and build the base for future sustainable development. Even the difference of a single decade in the transition to stabilization levels of fertility can have a considerable positive impact on quality of life" (para 3.14). The Conference recognized the "crucial contribution that early stabilization of the

world population would make towards the achievement of sustainable development" (para 1.11).

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I. THE EVOLUTION OF POPULATION AND THE ENVIRONMENT AT MAJOR UNITED NATIONS CONFERENCES

The present chapter focuses on the evolution of the population, environment and development nexus at some of the major intergovernmental conferences held under the aegis of the United Nations during the last three decades—including, where appropriate, their preparatory processes.

A. The early involvement of the Population Commission

As noted in the introduction, the Population Commission addressed the question of population, resources and development at its first session, setting in motion a process that led to a comprehensive review by the Population Division of the findings of studies on the relationships between population trends and economic and social factors. This study, which included a chapter on the subject of population and resources, was presented to the Population Commission at its fifth session in 1950 (United Nations, 1950) and again in a revised form the following year (United Nations, 1951). The study sifted through a considerable amount of information on population and economic development (almost exclusively from the more developed regions). Most of the discussion actually centred on the impact of development on population trends. The reverse relationship—the impact of population on development—was found more difficult to address, leading to the conclusion that whether population growth was economically advantageous or not could not be answered in general terms: it could be answered, if at all, only with reference to a specific situation. At the time, the environment was mainly seen as the set of resources needed to sustain population growth and economic development. In addition, issues of land availability and agricultural production were very prominent.

B. United Nations Conference on the Human Environment (Stockholm, 1972)

In the 1960s there was an increased awareness that global population growth had been reaching unprecedented high levels, a situation that many studies treated as a matter of grave concern. By its resolution 2398 (XXIII) of 3 December 1968, the General Assembly decided to convene a United Nations Conference on the Human Environment. In that resolution, the Assembly noted that "rapidly increasing population and accelerating urbanization" were accentuating the "continuing and accelerating impairment of the quality of the human environment". A subsequent report of the Secretary-General on the problems of the human environment, prepared pursuant to that resolution, cited the "explosive growth of human populations" as first among the portents of a crisis of worldwide scope concerning the relation between man and his environment (United Nations, 1969).

The United Nations Conference on the Human Environment was held in Stockholm in June 1972. It adopted the Declaration of the United Nations Conference on the Human Environment (United Nations, 1973, chap. I) and the Action Plan for the Human Environment (ibid., chap. II), containing 109 specific recommendations for action. The outcome of the Conference constituted the basis for activities of the United Nations system on environmental issues during the 1970s and 1980s. The Declaration affirmed (para. 5) that "the natural growth of population continuously presents problems for the preservation of the environment, and adequate policies and measures should be adopted, as appropriate, to face these problems". However, the Declaration also proclaimed that "of all things in the world, people are the most precious", noting that "it is the people that propel social progress, create social wealth, develop science and technology and, through their hard work, continuously transform the human environment". Further emphasizing this positive note, the Declaration went on to assert that "along with social progress and the advancement of production, science and technology, the capability of man to improve the environment increases with each passing day".

While the concept of "human environment" linked the physical environment to social and economic development, the specifics of the demographic dimension were left for the United Nations World Population Conference, 1974, to address. The Action Plan recommended that the World Population Conference—for which preparations were under way—devote special attention to the questions of population as related to the environment of human settlements (recommendation 11). The Stockholm Conference did not take a position on the global effects of population growth, recognizing that in certain areas the growth of population could frustrate development efforts, while in other areas population densities were too low to permit economic efficiency. The Declaration called for policies that were without prejudice to basic human rights and were deemed appropriate by the Governments concerned to be applied in both cases (principle 16).

C. United Nations World Population Conference (Bucharest, 1974)

The preparations for the United Nations World Population Conference included a two-week symposium on "Population, resources and environment", which was held in Stockholm from 26 September to 5 October 1973. The objective of the Symposium was to review the available scientific knowledge concerning the interrelationships of population, natural resources and environment in order to provide background

for the deliberations of the Conference. The discussions of the Symposium ranged—as the report put it—"far and wide", for three reasons: the interconnectedness of the subject variables; the fact that population was only one of the factors—and not always the most important one—causing resource and environmental problems; and the imprecision of key concepts, compounded by the dearth of empirical data that could be used for prospective analysis or to understand historical processes (United Nations, 1975a, vol. II, annex II).

The debate at the World Population Conference reflected profound divergences in the perception of population-environment interactions, and contained most of the core elements of the future debate on the issue. No consensus on these issues was reached, and population-environment links were not thoroughly treated in the World Population Plan of Action adopted at the Conference (United Nations, 1975b, chap. I).

D. International Conference on Population (Mexico City, 1984)

The preparatory process for the Mexico City Conference included an Expert Group Meeting on Population, Resources, Environment and Development, which was held in Geneva from 25 to 29 April 1983 (United Nations, 1984a). The first item of the agenda called for a general discussion of past and future trends in population, resources, environment and development. The Expert Group emphasized the need for better knowledge of how trends of the various variables interacted and modified each other and particularly about the role of population within the interrelationships. The discussion of food and nutrition centred on the demographic, economic, social, political and institutional aspects of meeting the needs for food and nutrition, while the physical aspects were given greater attention in the subsequent discussions of resources and environment. At the centre of the deliberations were such issues as poverty, the food versus feed controversy, food self-sufficiency and particularly the role of population growth. The discussion on resources and the environment covered the resource base, environmental degradation and non-renewable resources. Attention was centred on the various mechanisms that could expand resource availability as well as those activities that had caused a degradation of the environment. The discussions of social and economic aspects of development involved four interrelated topics: (*a*) income distribution; (*b*) employment; (*c*) health and education; and (*d*) social security.

Although environmental concerns were not particularly prominent in the overall agenda of the International Conference on Population, held in Mexico City in 1984, the Conference recommendations for the further implementation of the World Population Plan of Action (United Nations 1984b, chap. I, sect. B (III and IV)) acknowledged the importance of environmental issues by calling for national development policies and international development strategies based on an integrated approach that would take into account the interrelationships between population, resources, environment and development (recommendation 1). Furthermore, the document, using the language that was to become the cornerstone of the developmental paradigm for the 1990s, stipulated that the formulation of national population goals and policies must take into account the need for long-term environmentally sustainable economic development (ibid., sect. B, para. 8).

The Mexico City recommendations were an important step beyond the language of the World Population Plan of Action, which had merely alluded to resource depletion linked to consumption and economic and population policies in developed countries.

At the Mexico City Conference, environmental issues appeared as the third dimension in the population-development relationship on the global scale:

> "In countries in which there are imbalances between trends in population growth and resources and environmental requirements, Governments are urged, in the context of overall development policies, to adopt and implement specific policies, including population policies, that will contribute to redressing such imbalances . . ." (United Nations, 1984b, chap. I, sect. B (III, recommendation 4)).

E. United Nations Conference on Environment and Development (Rio de Janeiro, 1992)

The United Nations Conference on Environment and Development, held at Rio in 1992, was a milestone in the evolution of an international consensus on the relationships between population and environment, based on the concept of "sustainable development" articulated a few years earlier by the World Commission on Environment and Development. In its report entitled *Our Common Future* (World Commission on Environment and Development, 1987), the Commission had defined sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs"—a definition that was global in its scope and contained at its core a demographic element. Even more explicitly, the World Commission declared in its report that poverty, environmental degradation and population growth were inextricably related and that none of those problems could be successfully addressed in isolation. The report noted that in several regions of the world, rapid population growth had exceeded the available natural resources and was jeopardizing development possibilities. Moreover, the fact that curbs on population growth were necessary made it imperative to integrate population programmes into mainstream development efforts. Although members of the World Commission remained divided on the significance of population growth as a cause of environmental degradation and on concrete policy prescriptions, the prominence given to the issue pushed it up in the international agenda (Rowlands, 1994).

One of the outcomes of the Rio Conference, the Rio Declaration on Environment and Development (United Nations, 1993, resolution 1, annex I), used the concept of sustainable development as a constructive alternative to the dilemma of economic growth versus environmental protection. It also identified population policies as an integral element of sustainable development. Principle 8 of the Rio Declaration stated that "to achieve sustainable development and a higher

quality of life for all people, States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies".

Another outcome of the Conference, Agenda 21 (ibid., annex II), offered a detailed global action programme spelling out the concept of sustainable development at a global scale in terms of specific actions. Chapter 5 of Agenda 21 covered demographic dynamics and sustainability and stated that "the growth of world population and production combined with unsustainable consumption patterns places increasingly severe stress on the life-supporting capacities of our planet. These interactive processes affect the use of land, water, air, energy and other resources" (para. 5.3). It also unambiguously defined population concerns as being intrinsically related to major development and environmental issues and contained explicit policy recommendations as follows:

(*a*) "Policies should be designed to address the consequences of population growth built into population momentum, while at the same time incorporating measures to bring about demographic transition" (para. 5.16);

(*b*) "Full integration of population concerns into national planning, policy and decision-making processes should continue" (para. 5.17);

(*c*) "Integrated sustainable development programmes should closely correlate action on demographic trends and factors with resource management activities and development goals that meet the needs of the people concerned" (para. 5.42).

F. Global Conference on the Sustainable Development of Small Island Developing States (Bridgetown, Barbados, 1994)

Although the Global Conference on the Sustainable Development of Small Islands Developing States had a more targeted focus than the environmental and population conferences reviewed here, its contribution to the international consensus on population and development issues deserves to be highlighted. Population-environment interactions were especially prominent in the agenda of the Conference. The outcome of the Conference, the Programme of Action for the Sustainable Development of Small Island Developing States (United Nations, 1994a, chap. I, resolution 1, annex II) notes several problematic aspects of the impact of population on development and the environment of the small island developing States. In some instances, high population density entails pressure on limited resources and as populations grow, competing demands arise, particularly where land is limited and where commercial development pushes small-scale and subsistence agriculture to marginal lands. At the same time, many such States have small populations in absolute terms, insufficient to generate economies of scale. Moreover, many island developing States experience high levels of emigration, particularly of skilled human resources.

The Conference concluded that high population densities and growth, as well as declining population in some areas, were constraints to achieving sustainable development in many small island developing States. It called for increased attention to be given to the concept of island carrying-capacity and environmental health, especially for fragile and heavily populated environments in urban areas, coastal zones and hillsides. The Conference emphasized the importance of incorporating population issues into the mainstream of decision-making and planning mechanisms of Governments and of adopting appropriate national measures for institutional development to integrate environmental, population and development strategies in national and sectoral development planning.

G. International Conference on Population and Development (Cairo, 1994)

Forging a balance among population, sustained economic growth and sustainable development was the central theme of the International Conference on Population and Development held at Cairo in 1994. Conference preparations included an Expert Group Meeting on Population, Environment and Development, which was held at United Nations Headquarters from 20 to 24 January 1992 (United Nations, 1994b).

The Expert Group Meeting appraised current trends in population and environment, focusing on their implications for sustained economic growth and sustainable development. The discussions concentrated on those areas where population growth and distribution had adverse impacts on the availability and use of key natural resources, such as fresh water, soils and forests, and on the interactions of demographic factors, consumption and production patterns in global issues of increasing international concern, such as climate change and loss of biological diversity. Having reviewed available methodologies and findings of empirical research, the meeting concluded that, in many contexts, detrimental impacts on the environment would best be reduced by a combined strategy of slowing population growth, rationalizing population distribution, alleviating poverty, lessening environmentally dangerous consumption patterns and promoting the application of appropriate technologies and management regimes.

The expert participants stressed the need to develop and promote the application of methodologies that would make it possible to achieve sustained economic growth as well as sustainable development, in particular by replacing fossil fuels with renewable energy resources and providing a more productive use of the increasingly scarce water resources. Since demographic, economic and ecological factors were intrinsically interlinked, development policies should aim at tapping the beneficial potential of that synergism, for instance by encouraging the implementation of ecologically beneficial labour-intensive projects and promoting community participation, especially of women.

The Expert Group Meeting found that although rapid population growth, persistence of poverty and environmental degradation were inextricably interrelated, the magnitude of their reciprocal impacts in different social and ecological settings had not been sufficiently documented. Thus, in order to promote sustainable development, the Expert Group Meeting emphasized the urgent need to strengthen data collection and research efforts in that domain and to test the efficiency of proposed policies and strategies in concrete settings.

In addition to this particular Expert Group Meeting with its extensive treatment of population, environment and development issues, there were other expert group meetings convened in preparation for the Cairo Conference that also touched on those issues from their respective thematic viewpoints.

At the end of the Cairo process, the Programme of Action of the International Conference on Population and Development (United Nations, 1995, chap. I, resolution 1, annex) reflected "the growing awareness that population, poverty, patterns of production and consumption and the environment are so closely interconnected that none of them can be considered in isolation" (para. 1.5). The centrality of population as a developmental issue was manifested in the structure of the Programme of Action, with chapter III ("Interrelationships between population, sustained economic growth and sustainable development") appearing immediately after the chapters containing the preamble (chap. I) and principles (chap. II).

The preamble and other chapters of the Programme of Action recognized the complex nature of population-environment interactions. Thus, population growth was assessed as one of several causes of unsustainability (paras. 1.2 and 3.25), and it was noted that slowing population growth could help countries attack poverty and protect the environment (para. 3.14). On the other hand, sustainable development would make it possible to adjust to the consequences of unavoidable population growth and might also facilitate the demographic transition (paras. 1.8 and 3.15).

The Programme of Action recognized that population factors were sometimes powerful inhibitors of sustainable development, although socio-economic factors were brought out as well. As stated in the Programme of Action, "demographic factors, combined with poverty and lack of access to resources in some areas, and excessive consumption and wasteful production patterns in others, cause or exacerbate problems of environmental degradation and resource depletion and thus inhibit sustainable development" (para. 3.25); and "pressure on the environment may result from rapid population growth, distribution and migration, especially in ecologically vulnerable ecosystems" (para. 3.26). For these reasons, the principles of the Programme of Action included a statement affirming that sustainable development required "that the interrelationships between population, resources, the environment and development should be fully recognized, properly managed and brought into harmonious, dynamic balance" (chap. II, principle 6).

The importance of population factors for sustainable development was highlighted by considering the time dimension. In this regard, the Programme of Action noted the following: "Slower population growth has in many countries bought more time to adjust to future population increases. This has increased those countries' ability to attack poverty, protect and repair the environment, and build the base for future sustainable development. Even the difference of a single decade in the transition to stabilization levels of fertility can have a considerable positive impact on quality of life" (para. 3.14).

The Programme of Action recommended several actions to help achieve integration of population, development and environment. First, it called for development strategies that realistically reflected the short-, medium- and long-term implications of, and consequences for, population dynamics and patterns of production and consumption (para. 3.5). Second, it emphasized measures aimed at the eradication of poverty, with special attention to the areas within or on the edge of fragile ecosystems. Third, it stressed policies to address the ecological implications of inevitable future increases in population numbers as well as changes in population concentration and distribution, particularly in ecologically vulnerable areas and urban agglomerations (para. 3.29 (*e*)).

On a more technical level, the Programme of Action recommended (*a*) the integration of demographic factors into environment impact assessments (para. 3.29 (*a*)); (*b*) the utilization of demographic data to promote sustainable resource management, especially of ecologically fragile ecosystems (para. 3.29 (*c*)); and (*c*) periodic reviews of national and international development strategies with the aim of assessing progress towards integrating population into development and environment programmes (para. 3.6).

H. United Nations Conference on Human Settlements (Habitat II) (Istanbul, 1996)

The United Nations Conference on Human Settlements (Habitat II) was held in Istanbul, Turkey, from 3 to 14 June 1996. Since one of the two major themes of the Conference was "Sustainable human settlements development in an urbanizing world", population, environment and development interrelationships received extensive treatment, particularly as they related to issues of urbanization. As explicitly noted in the Habitat Agenda (United Nations, 1997, chap. I, resolution 1, annex II) adopted at the Conference, Habitat II provided an opportunity to focus on the effect that current patterns of human settlements would have on the ability to achieve the objectives established at recent United Nations conferences (para. 108).

The Conference adopted two principal documents: the Istanbul Declaration on Human Settlements (United Nations, 1997, chap. I, resolution 1, annex I) and the Habitat Agenda. The Istanbul Declaration recognized both unsustainable consumption and production patterns, and unsustainable population changes as being among the factors that needed to be addressed in order to improve the quality of life within human settlements (para. 4). With regard to unsustainable population changes, specific reference was made to changes in structure and distribution, especially the tendency towards excessive population concentration. In the "Commitments" section (chap. III) of the Habitat Agenda, the goal of sustainable human settlements was seen as involving, inter alia, addressing population issues affecting human settlements and fully integrating demographic concerns into human settlements policies. In the "Global plan of action: strategies for implementation" section (chap. IV) of the Agenda, rapid urbanization, the concentration of the urban population in large cities, the sprawl of cities into wider geographical areas and the rapid growth of mega-cities were characterized as being among the most significant transformations of human settlements (para. 99). The document further noted that urban areas would strongly influence the world of the twenty-first century, and urban and rural populations would be increas-

ingly interdependent for their economic, environmental and social well-being. Population growth and migration were identified among the factors influencing that process. A defining perspective of the Conference was expressed in this section: "Urban settlements hold a promise for human development and for protection of the world's natural resources through their ability to support large numbers of people while limiting their impact on the natural environment" (para. 101).

Actions on population issues were among the 10 operational sets of actions adopted by the Conference regarding the major theme of "Sustainable human settlements development in an urbanizing world". Under this theme, the section in the global plan of action entitled "Population and sustainable human settlements development" began with a statement that the quality of life and the activities of all human beings within human settlements were closely interrelated with population change, demographic patterns, including growth, structure and distribution of the population, and development variables such as education, health and nutrition, the levels of use of natural resources, the state of the environment and the pace and quality of economic and social development. Reference was also made to the need to consider population movements within and among countries to ensure the sustainability of human settlements.

An overall review and appraisal of the implementation of the outcome of the United Nations Conference on Human Settlements (Habitat II) took place as a special session of the General Assembly from 6 to 8 June 2001.

I. Nineteenth special session of the General Assembly to review and appraise the implementation of Agenda 21 (United Nations, New York, 1997)

In June 1997, the General Assembly convened the nineteenth special session to review and appraise the implementation of Agenda 21 (commonly referred to as the Earth Summit + 5). A Programme for the Further Implementation of Agenda 21 was adopted (General Assembly resolution S-19/2, annex). In assessing the progress accomplished since the United Nations Conference on Environment and Development, the Programme expressed deep concern that the overall trends with respect to sustainable development had become worse compared with five years earlier (para. 4). Population, however, was one of the areas where the Programme saw a positive development, noting that population growth rates had been declining globally, and that the trend was projected to lead to a stable world population in the middle of the twenty-first century (para. 8). The Programme affirmed: "The impact of the relationship among economic growth, poverty, employment, environment and sustainable development has become a major concern. There is a need to recognize the critical linkages between demographic trends and factors and sustainable development. The current decline in population growth rates must be further promoted through national and international policies that promote economic development, social development, environmental protection, and poverty eradication, particularly the further expansion of basic education, with full and equal access for girls and women, and health care, including reproductive health care, covering both family planning and sexual health, consistent with the report of the International Conference on Population and Development" (para. 30). The second review and appraisal of the implementation of Agenda 21 (Rio + 10) will take place in 2002.

J. Twenty-first special session of the General Assembly for an overall review and appraisal of the implementation of the Programme of Action of the International Conference on Population and Development (United Nations, New York, 1999)

The twenty-first special session of the General Assembly was convened in order to review and appraise the implementation of the Programme of Action of the International Conference on Population and Development—"on the basis of and with full respect for the Programme of Action, and (without) renegotiation of the existing agreements contained therein" (General Assembly resolution 52/188 of 18 December 1997, para. 3). The Assembly at its special session adopted a document entitled "Key actions for the further implementation of the Programme of Action of the International Conference on Population and Development" (Assembly resolution S-21/2, annex). The document noted in its preamble that "while the Programme of Action does not quantify goals for population growth, structure and distribution, it reflects the view that an early stabilization of world population would make a crucial contribution to realizing the overarching objective of sustainable development" (para. 7). The first operational chapter of the document was devoted to "Population and development concerns" and opened with a section on "Population, economic development and the environment". Although the recommendations for action in this area did not focus specifically on the population-environment nexus, there was a call for intensified efforts to equip planners and decision makers with a better understanding of the interrelationships between population and environment (along with poverty, gender inequity and inequality, health, education, financial and human resources and development) (para. 15 (*a*)). The document recommended that Governments draw attention and promote linkages among macroeconomic, environmental and social policies through increased dialogue among finance ministries and other relevant ministries (para. 15 (*b*)).

K. Conclusions

The conceptualization and integration of the environment into the population and development debate at the United Nations have increasingly become more comprehensive and systematic. Traditionally, the discussion focused on per capita availability of selected resources—in particular agricultural land—essentially as an economic basis upon which the population could prosper. Attention has since broadened to encompass the full range of economic activities in a more balanced approach. In addition, current debates reflect greater awareness of the technological and institutional dimensions of economic progress than in the past. General agreement is that economic growth, environmental

sustainability and population growth are interrelated and cannot be addressed in isolation.

In recent years, the concept of sustainable development has provided a commonly agreed framework in which to discuss population and development issues. A notable breakthrough at the intergovernmental level has been the agreement reached at the International Conference on Population and Development, in Cairo, Egypt, in 1994, that the early stabilization of the world population would be a crucial contribution towards the achievement of sustainable development.

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II. TEMPORAL TRENDS IN POPULATION, ENVIRONMENT AND DEVELOPMENT

Human beings have, throughout their history, changed their surroundings—often in ways they neither intended nor desired. Such environmental problems as depletion of soils, overfishing, over-hunting of game, air pollution, and exhaustion and pollution of water supplies have arisen at many times and places. Yet for most of history these problems have had mainly local impacts. What is new today is the vastly greater scale of the impact of human activities on the environment, to the point where the impacts are now global. Table II.1 shows estimates of the degree to which human activities have affected global biogeochemical cycles of carbon, nitrogen, phosphorus, sulphur, water and sediments. According to recent estimates, "between one third and one half of the land surface has been transformed by human action; the carbon dioxide (CO_2) concentration in the atmosphere has increased by nearly 30 per cent since the beginning of the Industrial Revolution; more atmospheric nitrogen is fixed by humanity than by all natural terrestrial sources combined; more than half of all accessible surface fresh water is put to use by humanity; and about one quarter of the bird species on Earth have been driven to extinction . . . All of these changes are ongoing, and in many cases accelerating; many of them were entrained long before their importance was recognized. (And) we are changing Earth more rapidly than we are understanding it" (Vitousek and others, 1997, pp. 494, 498).

The present chapter summarizes long-term global trends in selected key population, development and environmental indicators. Trends highlighted here include population size and growth; economic growth and development; energy use and emissions of CO_2; agriculture, food and land use; fresh water; and forests and biodiversity. Interrelationships among these factors are discussed in a later chapter. More comprehensive reviews of environmental conditions and trends can be found elsewhere (United Nations Environment Programme, 1999; World Resources Institute, 1998).

A. POPULATION TRENDS

The twentieth century has witnessed an extraordinary growth of the world population—from 1.65 billion to 6 billion people, with almost 80 per cent of that increase having occurred since 1950 (figure II.1). Rapid growth was triggered by dramatic reductions in mortality, especially in the less developed regions. The average life expectancy at birth in those regions increased by over 20 years during the second

TABLE II.1. EXAMPLES OF HUMAN INTERVENTION IN THE GLOBAL BIOGEOCHEMICAL CYCLES OF CARBON, NITROGEN, PHOSPHORUS, SULPHUR, WATER AND SEDIMENTS

Element	*Flux*	*Magnitude of flux (millions of metric tons per year)*		*Percentage change due to human activities*
		Natural	*Anthropogenic*	
C	Terrestrial respiration and decay CO_2	61 000		
	Fossil fuel and land use CO_2		8 000	+13
N	Natural biological fixation	130		
	Fixation owing to rice cultivation, combustion of fossil fuels, and production of fertilizer		140	+108
P	Chemical weathering	3		
	Mining		12	+400
S	Natural emissions to atmosphere at Earth's surface	80		
	Fossil fuel and biomass burning emissions		90	+113
O and H (as H_2O)	Precipitation over land	111×10^6		
	Global water usage		18×10^6	+16
Sediments	Long-term pre-industrial river suspended load	1×10^{10}		
	Modern river suspended load		2×10^{10}	+200

Sources: P. Falkowski and others, "The global carbon cycle: a test of our knowledge of Earth as a system", *Science*, vol. 290, 13 October 2000, p. 294; P. Falkowski, personal communication, 19 April 2001.

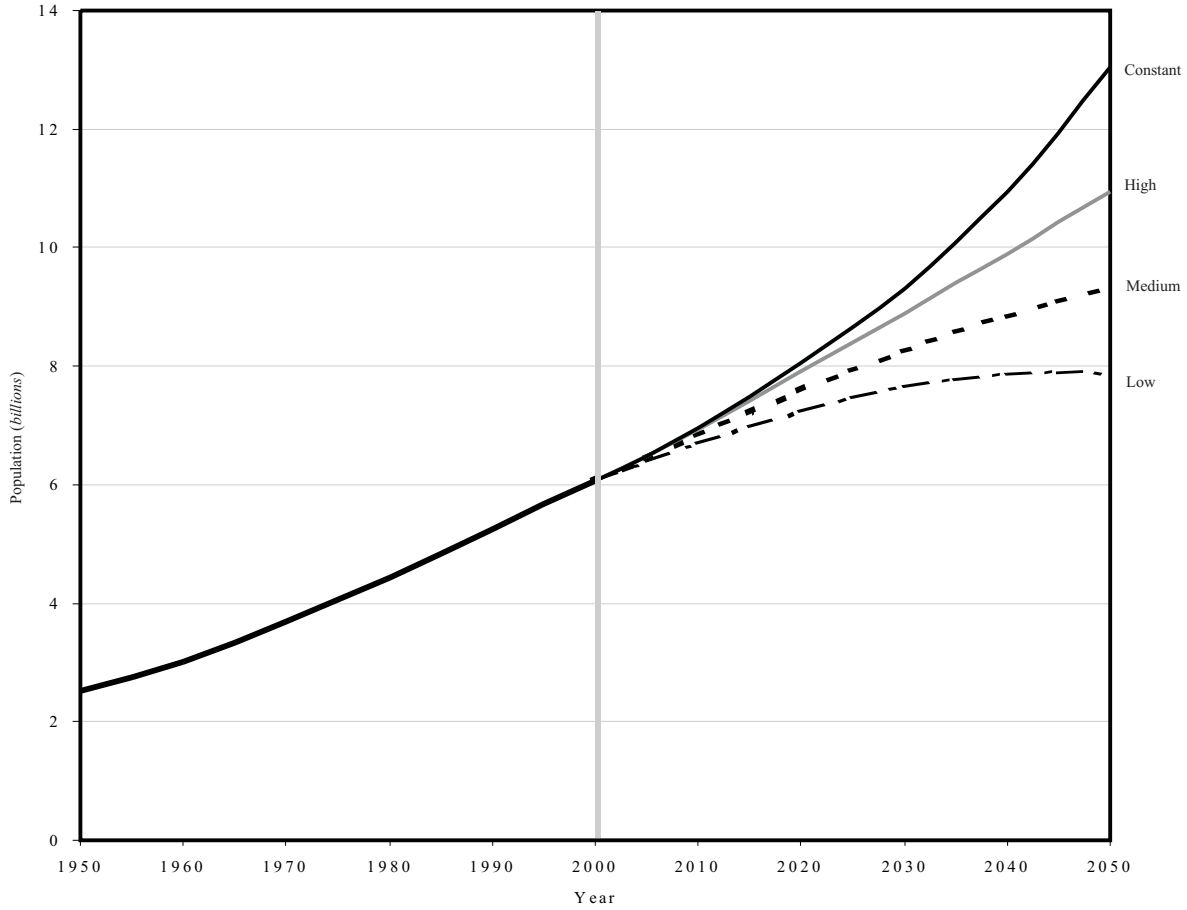
NOTE: Data are for the mid-1900s.

half of the century, from 41 years in 1950-1955 to 64 years in 2000-2005. In this same period, life expectancy increased by about almost 10 years (from 66 to 76 years) in the more developed regions, and nearly 20 years (from 46 to 66 years) at the global level. As a result, world population has increased by nearly 2 1/2 times since 1950, with a peak global rate of growth of 2.04 per cent per year during the late 1960s, and an annual increment of 86 million persons during the late 1980s, the largest increment recorded in history. It took just 12 years (from 1987 to 1999) for the world to add its most recent billion people, the shortest period of time in world history for 1 billion people to be added.

With the declines in fertility in most of the world in the past three decades, however, the global growth rate of population has decreased significantly. Since 1965-1970, the world total fertility rate has declined by 45 per cent from 4.9 births per woman to 2.7 births per woman during 2000-2005. In the less developed regions, the fertility rate dropped from 6.0 to 2.9 births per woman, while in the more developed regions it dropped from 2.4 to a historical low of 1.5. The most recent estimates point towards a growth rate of about 1.2 per cent per year for 2000-2005, and an annual net addition of about 77 million people. Even though fertility has declined to relatively moderate levels in most developing regions, a large and growing number of births are still occurring annually, owing to the continued growth in the number of women of childbearing age, a legacy of past high fertility levels. In 1965-1970, the average number of births per year in the less developed regions was 101 million; today, this number has grown to 120 million.

World population is expected to continue growing. Based on the medium-fertility variant, which assumes replacement-level fertility of 2.1 children per woman, global population is projected to reach 9 billion people in 2043 and 9.3 billion in 2050. However, future population size is sensitive to small but sustained deviations in fertility levels. For example, a low-fertility variant in which fertility reaches about half a child lower than in the medium-fertility variant results in a population that declines to 7.9 billion in 2050. In contrast, a high-fertility scenario in which fertility reaches about a half a child higher than in the medium-fertility variant produces a population of 10.9 billion in 2050 (figure II.1).

Figure II.1. Estimated and projected population of the world according to the different projection variants, 1950-2050



Source: Population Division of the United Nations Secretariat, "World population prospects: the 2000 revision, highlights" (ESA/P/WP.165).

Because the different regions of the world find themselves at different stages of the demographic transition from high to low mortality and fertility, their growth paths differ considerably, resulting in significant shifts in the geographical distribution of world population. In 1950, 68 per cent of the world population resided in the less developed regions. This proportion has grown to 80 per cent at present, and is projected to be 87 per cent in 2050. Of the 77 million people being added to the world each year, 97 per cent live in the less developed regions.

Africa is the region with the highest rates of population growth, while Europe has the lowest rates. According to the medium-fertility variant, Africa's population will increase from 794 million in 2000 to 2.0 billion in 2050, and its share of the world population will pass from 13 to 21 per cent (table II.2). In the same period, the European population is projected to decline from 727 million to 603 million, and its share of the world population to drop from 12 to 6 per cent. So, while the population of Europe was more than double that of Africa in 1950, the population of Africa is expected to more than triple that of Europe in 2050. In the case of China, although the population will increase, its share of the world population will decline from 21 per cent in 2000 to 16 per cent in 2050. The shares of other areas will experience less marked changes over the projection period. As a result of these trends, the world of 2050 is likely to be one in which China and India together will account for about one third of world population. Europe and Northern America taken together will account for about one tenth.

Because of the low levels of fertility experienced by a growing number of countries, particularly in the more developed regions, the role of international migration in influencing population growth has been rising. The 35 million net migrants absorbed by Western market economies between 1970 and 1995, for instance, accounted for 28 per cent of their combined population growth during the period. In contrast, the loss of those 35 million migrants reduced population growth in the rest of the world by less than 2 per cent. Worldwide, the number of persons who have moved to another country has risen to over 125 million migrants today from 75 million in 1965.

Another important population trend is urbanization. Whereas in 1950, 30 per cent of the world population lived in urban areas, by 2000 the proportion of urban-dwellers had risen to 47 per cent and it is expected to reach 60 per cent by 2030. The urban population is projected to equal the rural population by the year 2007. Although urbanization levels have been historically higher in the more developed regions, the gap between them and the less developed regions has narrowed. Between 1950 and 2030, the urban share is expected to increase from 55 to 84 cent in the more developed regions, and from 18 to 56 per cent in the less developed regions. In 2000, 68 per cent of the world's urban population lived in the less developed regions; by 2030, 79 per cent will live in the less developed regions (United Nations, 2000e).

With the increasing levels of urbanization, giant urban agglomerations have become both more numerous and considerably larger in size. The number of mega-cities of 10 million or more persons has grown from 1 to 19 since 1950, and is expected to increase to 23 by 2015. The large majority of large cities are located in the less developed regions. In 2000, 31 of the 41 cities of 5 million or more inhabitants were found in developing countries. The proportion of the population living in these large cities was 6.9 per cent in 2000, and is expected to reach 8.7 per cent by 2015.

As urbanization proceeds, the rural population may continue to increase for a long time, but eventually it stops growing and then typically begins to shrink. In the more developed regions, rural populations have been declining since before 1950 (figure II.2). In the less developed regions, rural population doubled between 1950 and 2000, but at present, in Latin America and the Caribbean, the rural population has essentially stopped growing and is expected to decline in future. In Asia, the rural population is growing at 0.4 per cent annually during 2000-2005, down from over 2 per cent per year in the late 1960s. Only in Africa is the rural population still expanding rapidly. Between 2000 and 2030, the rural population is projected to increase by over 30 per cent in Africa, while it is projected to decrease by 5 per cent in Latin America and the Caribbean and by 3 per cent in Asia (United Nations, 2000e).

TABLE II.2. WORLD POPULATION BY MAJOR AREA, 1950-2050

	Estimated population (millions)			*Percentage distribution*		
Major area	*1950*	*2000*	*2050*	*1950*	*2000*	*2050*
World	2 519	6 057	9 322	100.0	100.0	100.0
Africa	221	794	2 000	8.8	13.1	21.5
Asia	1 399	3 672	5 428	55.5	60.6	58.2
Latin America and the Caribbean	167	519	806	6.6	8.6	8.6
Europe	548	727	603	21.8	12.0	6.5
Northern America	172	314	438	6.8	5.2	4.7
Oceania	13	31	47	0.5	0.5	0.5

Source: Population Division of the United Nations Secretariat, "World population prospects: the 2000 revision, highlights" (ESA/P/WP.165).
NOTE: Information for 2050 is from medium-fertility variant projections.

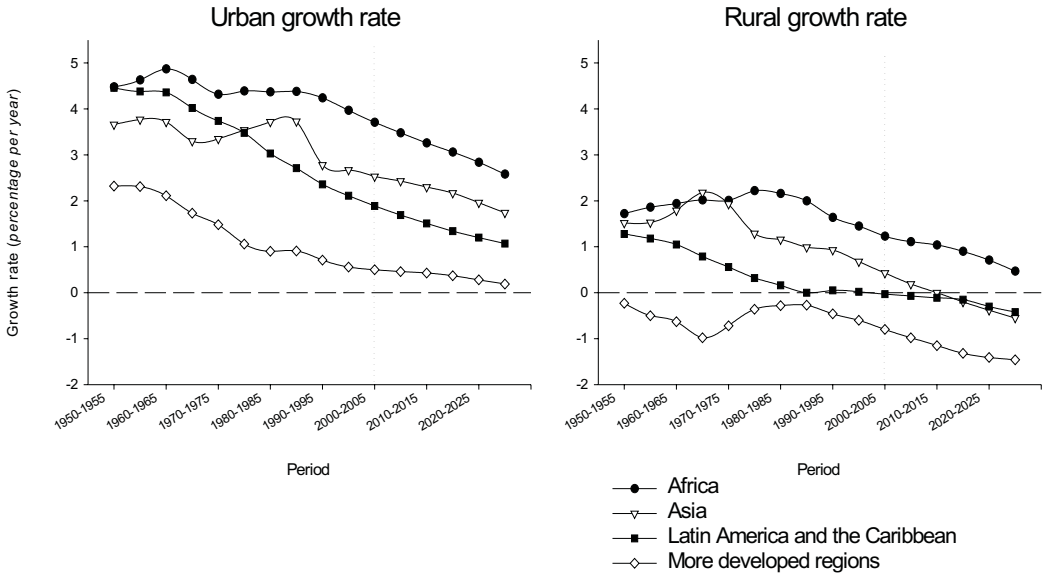
B. Economic growth and poverty

The enormous expansion in the global production of goods and services driven by technological and social and economic changes has allowed the world to sustain both much larger populations and vastly higher standards of living than ever before in history. The two most salient characteristics of global economic growth in the latter half of the twentieth century have been its unprecedented pace and its uneven distribution between countries and regions. Between 1950 and 2000, world gross domestic product (GDP) at constant prices expanded about eightfold (International Monetary Fund, 2000). During the same period, population growth also increased significantly, with world population growing from 2.5 billion inhabitants in 1950 to 6.1 billion at the beginning of the twenty-first century. Although output and population growth both increased during this period, because of the accelerating tempo of technological progress, output growth has increasingly surpassed population growth (figure II.3).

The benefits accruing from the unprecedented growth of the world economy have been uneven. Aggregate data for global output and population conceal the widening disparities in income between regions and countries over time (figure II.4). Although the wealthiest quarter of world population has seen its per capita GDP climb almost sixfold over the century, per capita income for the poorest quarter of the world population grew less than threefold (International Monetary Fund, 2000). A commonly used yardstick of inequality is the Gini coefficient—which can range from 0 (perfect equality) to 1 (complete inequality). Between 1990 and 2000, it rose from 0.4 to 0.5 (International Monetary Fund, 2000). The percentage of the world's population living in absolute poverty (according to the World Bank's criterion of living on less than one United.States dollar per day) declined from about 28 per cent in 1987 to 24 per cent in 1998; however, the absolute number of people classified as poor has not changed much in the past decade and as of 1998 amounted to an estimated 1.2 billion people or nearly one fourth of the population in the developing and transition economies (table II.3). Poverty is most pervasive in sub-Saharan Africa and South Asia, less extensive in East Asia and Latin America and the Caribbean and relatively low in the Middle East and North Africa. That progress to date in combating poverty in Latin America has been limited is due, in part, to the debt crisis of the 1980s. The financial "meltdown" that swept across Asia during 1997 erased some of the gains in poverty reduction in that region, which nevertheless showed substantial progress during the decade of the 1990s. Poverty is related to a wide range of factors, including income, health and education.

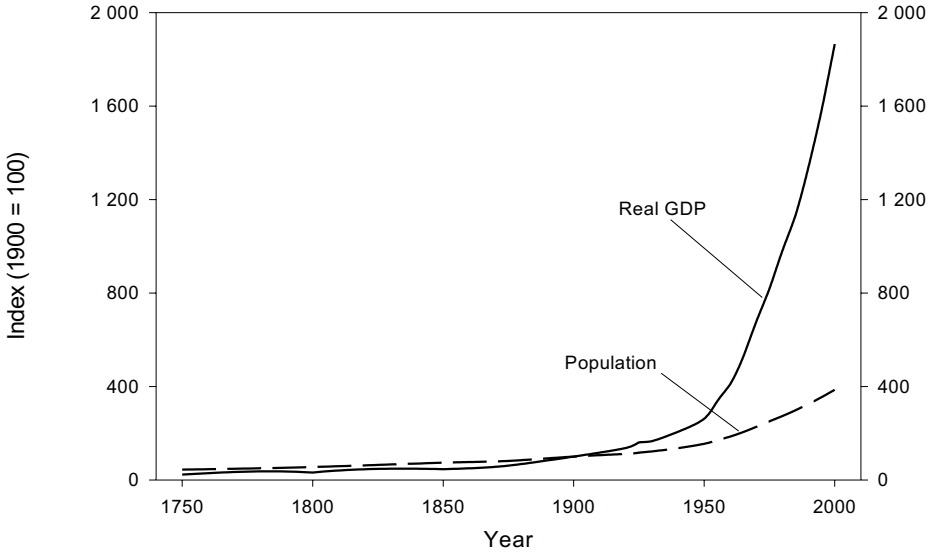
In recent years, development efforts have shifted from the traditional focus on per capita income to a greater stress on improvements in health, education and sanitation as characteristics of successful development. For example, even many low-income countries have achieved substantial improvements in the quality and length of life. These achievements reflect success at providing basic social services such as education and access to safe water and sanitation. These successes have, in turn, contributed to lowering levels of infant and child mortality and illiteracy, and raising life expectancy and school enrolment ratios. In contrast to per capita income, these indicators of living standards display a convergence between high- and low-income countries.

Figure II.2. Growth rates of urban and rural populations, by region, 1950-2030



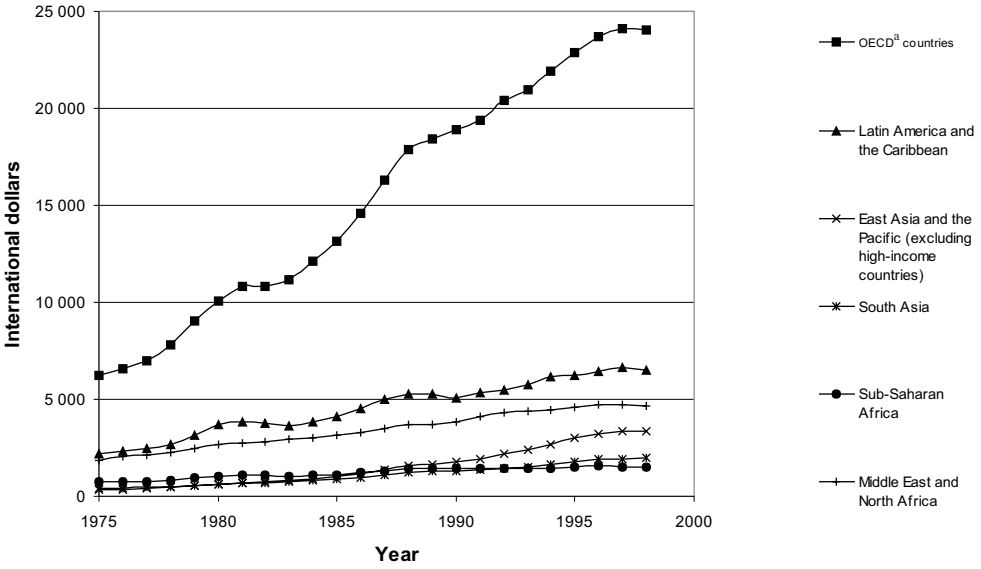
Source: Population Division of the United Nations Secretariat, "World urbanization prospects: the 1999 revision, data tables and highlights" (ESA/P/WP.161).

Figure II.3. World gross domestic product (GDP) and population growth, 1750-2000



Source: International Monetary Fund, *World Economic Outlook 2000* (Washington, D.C., 2000), based on J. Bradford DeLong, *Estimating World GDP, One Million B.C.–Present* (Berkeley, California, Department of Economics, University of California at Berkeley, 1998).

Figure II.4. Per capita income in major world regions, 1975-1998



Source: World Bank, *World Development Indicators 2000*, CD-ROM.
NOTE: Per capita GDP is expressed in international dollars using purchasing power parity (PPP) conversion rates.
[a]Organisation for Economic Co-operation and Development.

TABLE II.3. INCOME POVERTY BY REGION, SELECTED YEARS, 1987-1998

Region	People living on less than $1 a day (millions)			Headcount index (percentage)		
	1987	1993	1998[a]	1987	1993	1998[a]
East Asia and Oceania	418	432	278	26.6	25.2	15.3
Europe and Central Asia	1	18	24	0.2	4.0	5.1
Latin America and the Caribbean	64	71	78	15.3	15.3	15.6
Middle East and Northern Africa	9	5	6	4.3	1.9	1.9
South Asia	474	505	522	44.9	42.4	40.0
Sub-Saharan Africa	217	273	291	46.6	49.7	46.3
TOTAL	1 183	1 304	1 199	28.3	28.1	24.0

Source: World Bank, *World Development Report 2000/2001: Attacking Poverty* (New York, Oxford University Press, 2001), table 1.1.
[a]Estimated.

C. ENERGY CONSUMPTION AND EMISSIONS

The importance of energy and raw materials derives from their dual role of providing the underpinnings for economic activity and human well-being, while at the same time acting as the driving force behind several environmental concerns, including climate change, acid rain and pollution by heavy metals and particulates. Furthermore, additional negative impacts can occur, for example, spills and leakage during the transport of oil and gas, while other energy sources such as hydropower and nuclear power can also have significant environmental impacts.

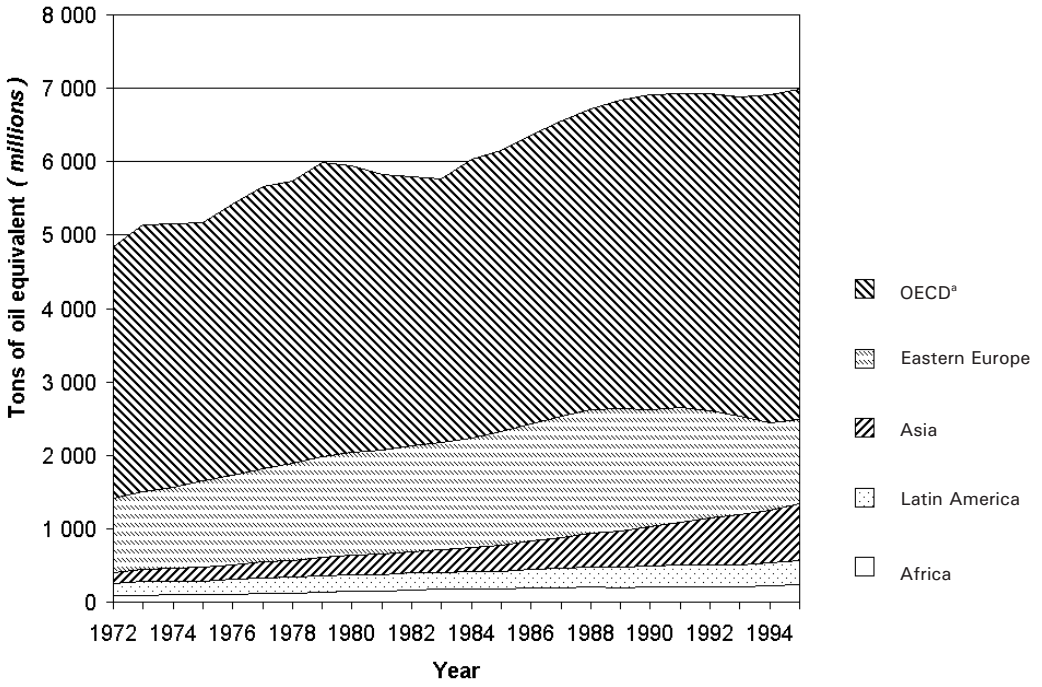
Because energy consumption is a function of economic growth and level of development, energy consumption is distributed unequally in the world. Although their share has fallen slightly in recent years as the rest of the world progresses along the path to development, developed market economics, constituting some one fifth of the world's population, consume almost 60 per cent of the world's primary energy (figure II.5). As a consequence of development and the rapid replacement of traditional energy sources by commercial (mainly fossil) sources, some developing countries, particularly in Asia, have consumption patterns similar to those of developed market economies. Nevertheless, per capita consumption in developing countries as a group remains far behind that of developed market economies.

As a result of economic recession, energy use grew relatively slowly in Organisation for Economic Co-operation and Development (OECD) countries during the early 1990s, especially in Western Europe. More recently, with GDP growing by some 2 to 3 per cent annually, energy consumption has been accelerating, while energy efficiency has been improving by only 1 per cent per year. Relatively low energy prices have dampened the motivation for improving energy efficiency. Only in the successor countries of the former Union of Soviet Socialist Republics and in Eastern Europe has energy consumption fallen, mainly owing to the implementation of restructuring programmes after 1991. Consumption, however, is expected to rebound as economic recovery takes off (United Nations Environment Programme, 1999).

The use of fossil fuels has led to substantial growth in global emissions of CO_2 and the build-up of greenhouse effects, a contributing factor in global warming. It is estimated that since 1751, over 265 billion tons of carbon have been released to the atmosphere, one half of these emissions having occurred since the mid-1970s (Marland and others, 1999). Annual global emissions of CO_2 from the burning of fossil fuels have been steadily rising and have quadrupled since 1950 (figure II.6). The highest per capita CO_2 emissions are found in North America, while Europe trails far behind in second place with per capita emission levels less than one half those in North America (Marland and others, 1999). Continuation of these trends poses serious, though uncertain, risks of climate change, especially global warming, inducing of possible rises in sea levels, flooding of low-lying coastal areas, migration of ecosystems, spread of vector-borne diseases and reductions in agricultural yields in some major producing areas. In addition, industrial and transport-related emissions are undermining the hard-won improvements in the health conditions of urban-dwellers in developing countries.

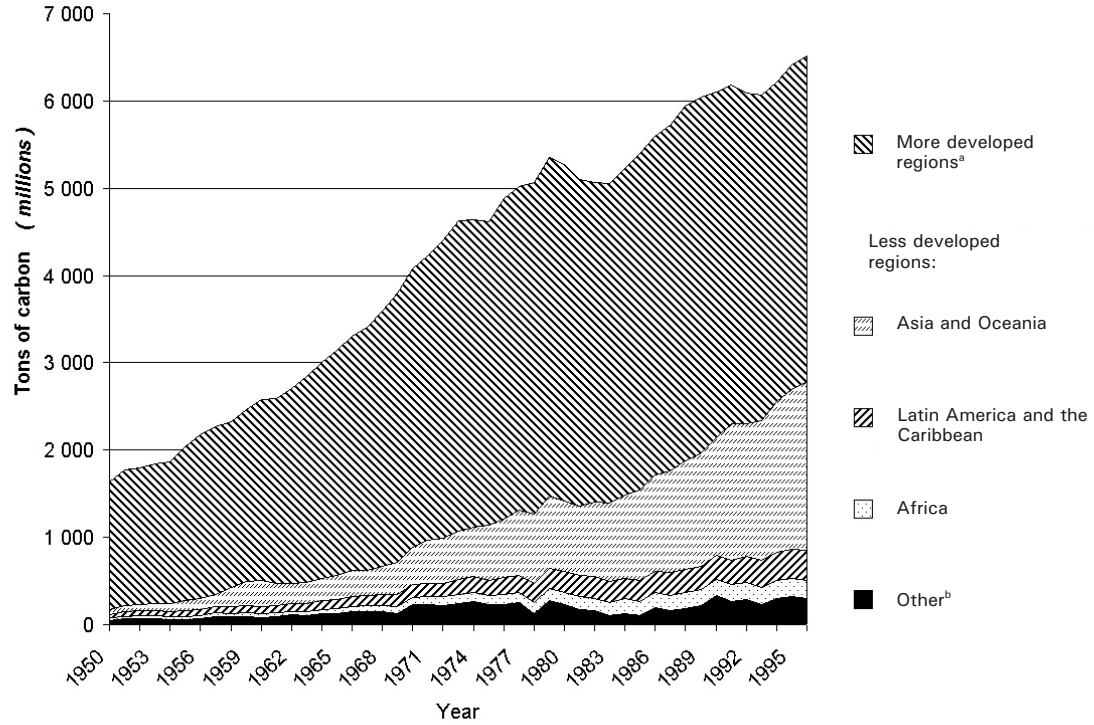
The magnitude of future carbon emissions depends on a number of factors, including global energy demand, the pace of economic development, the introduction of energy-saving technologies and the degree of shift away from fossil fuels. Predicting future trends is difficult because of the need to make assumptions about future economic growth rates, energy prices, the likely adoption of effective energy policies and the development of efficient industrial technologies.[1] Current models suggest that immediate stabilization of atmospheric CO_2 concentrations at present levels can be achieved only if emissions are immediately slashed by some 50 to 70 per cent and further reduced thereafter (United Nations Environment Programme, 1999). Because of the inertia associated with climate systems, even if stabilization of emissions is achieved, global warming could continue for decades and sea levels rise for centuries.

Figure II.5. Primary energy use in major world regions, 1972-1995



Source: International Energy Agency, *Energy Balances of Non-OECD Countries 1996-1997* (Paris, 1999).
[a]Organisation for Economic Co-operation and Development.

Figure II.6. Carbon dioxide (CO2) emissions from fossil fuels and cement production, 1950-1996



Source: Gregg Marland and others, "Global, regional and national annual CO_2 emissions from fossil-fuel burning, hydraulic cement production and gas flaring: 1950-1996". Internet: http://cdiac.eds.ornl.gov/ftp/ndp030/ndp030.html.
[a]Including the former Union of Soviet Socialist Republics.
[b]Emissions from bunker fuels and other emissions for which the country of final use cannot readily be determined.

D. Trends in agriculture, food and land use

The persistence of undernutrition and food insecurity in many areas of the world, and the increasing scarcity and unsustainable utilization of agricultural and other environmental resources related to the process of meeting the food needs of a growing world population have been the dominant issues in the global assessment of food and agriculture prospects.

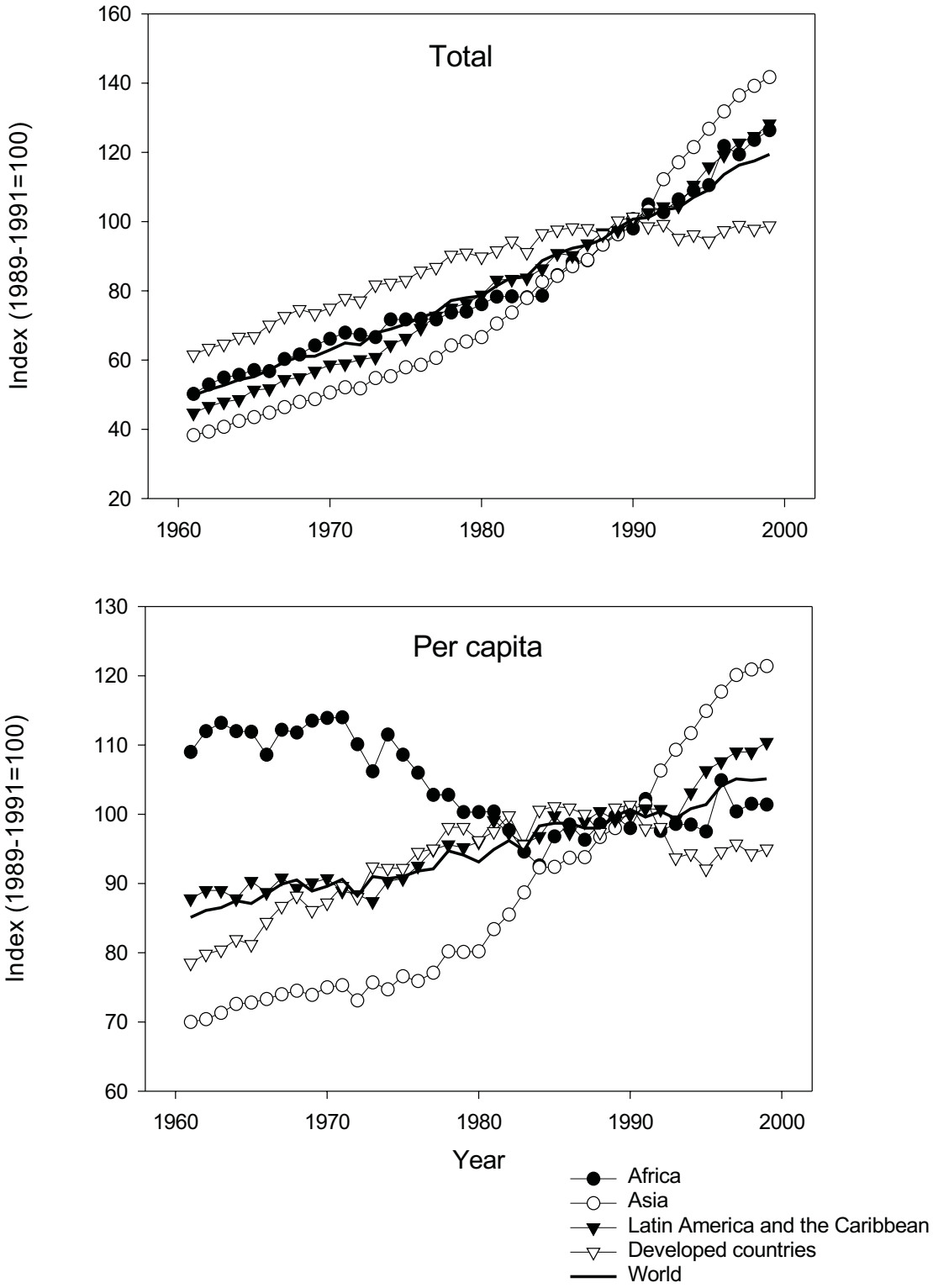
World agricultural production has risen faster than population, and real prices of food have declined.[2] The green revolution that began in the 1960s enabled some developing countries to increase their food production dramatically through the introduction of modern agricultural techniques (figure II.7). Over the period 1961-1998, world per capita food available for direct human consumption increased by 24 per cent, and there is enough being produced for everyone on the planet to be adequately nourished (Food and Agriculture Organization of the United Nations, 2000a). Although the percentage of developing-country population that is undernourished has been halved since 1970, recent estimates (Food and Agriculture Organization of the United Nations, 1999a, 2000c) show that about 790 million people in less developed countries, 8 million in the industrialized countries and 26 million in countries with economies in transition are still undernourished. People have inadequate physical and/or economic access to food as a result of poverty, political instability, economic inefficiency and social inequity. Almost two thirds of the undernourished live in Asia and the Pacific, while about one quarter are in sub-Saharan Africa. The problem is especially severe among the countries of Central, East and Southern Africa, where over 2 in every 5 persons (44 per cent) are undernourished. Progress in combating hunger has been very uneven. Although the aggregate number of undernourished people decreased by about 5 per cent (40 million) during the period 1990-1992 to 1995-1997, a number of countries in sub-Saharan Africa and South Asia and several in Latin America and the Caribbean have experienced serious declines in per capita food availability since the mid-1980s.

More recently, world agricultural growth has been slowing down. The annual growth rate fell from 3.0 per cent in the 1960s to 2.3 per cent in the 1970s and to 2.0 per cent in the period 1980-1992; the rate it was 2.2 per cent during 1994-1998 (World Resources Institute, 1996; Food and Agriculture Organization of the United Nations, 2000d). These developments have given rise to expressions of concern among some observers that production constraints are becoming more severe and may ultimately threaten world food security (for example, Worldwatch Institute, 1998). This progressive slow-down, however, mirrors the similar slowdown in the growth of demand, "which reflects both positive and negative developments in the world food and agriculture scene. The positive ones include the slow-down in world population growth and the fact that, in many countries with fairly high levels of per capita food consumption, the scope for further increases in this variable is smaller than in the past. Negative developments include the totally inadequate growth in per capita incomes and the continued prevalence of severe poverty in many countries with very low levels of nutrition" (Food and Agriculture Organization of the United Nations, 1996). According to the Food and Agriculture Organization of the United Nations (FAO) and the International Food Policy Research Institute (IFPRI), world food production is projected to be able to meet consumption demands for the next one or two decades (Alexandratos, 1995; Dyson, 1996; Food and Agriculture Organization of the United Nations, 2000c; Mitchell and Ingco, 1995). Even for the period up to 2050, recent studies forecast food production is keeping pace with demand, though with qualified confidence and notable conditions.

While at the global level forecasts suggest that future production gains will be sufficient to keep pace with increased population and rising demand, at the regional level they all indicate persistent and in some cases worsening food insecurity in sub-Saharan Africa (United Nations, 1997c; Food and Agriculture Organization of the United Nations, 2000c). FAO projects that by 2015, 576 million people in developing countries (10 per cent of the population) will not have enough to eat (table II.4). Thus, the challenge of feeding a growing world population is a matter not only of producing enough food, but also of making the required food items accessible to all people at all times. While more economically advanced countries may sometimes find it advantageous to import food in exchange for other goods and services, rather than to aim for greater self-sufficiency in food production, "the situation is different in the majority of the low-income countries, where the bulk of the population depends on agriculture" (Food and Agriculture Organization of the United Nations, 1996). As noted by FAO (2000c): "The interaction between food security and food production potential is very much a local problem in poor and agriculturally dependent societies. Many situations exist where production potential is limited (for example, in the semi-arid areas given existing and accessible technology, infrastructure etc.) and a good part of the population depends on such poor agricultural resources for food and more general livelihood. Unless local agriculture is developed and/or other income earning opportunities open up, the food security determined by limited production potential will persist, even in the middle of potential plenty at the world level. The need to develop local agriculture in such situations as the often sine qua non condition for improved food security cannot be overemphasized."

Although land availability is neither the only nor always the most important aspect to be considered for achieving food security, it is still a crucial issue (table II.5). Land currently used in crop production in the developing countries (excluding China) amounts to some 760 million hectares (ha), of which 120 million ha are irrigated (Alexandratos, 1995). These 760 million ha represent only 30 per cent of the total land with rain-fed crop production potential, which is estimated to be 2,570 million ha. However, not all the remaining 1,810 million ha of land with crop production potential is, or should be, considered available for agricultural expansion. Limiting factors in expanding cultivated land area include the scarcity of high-quality agricultural land, competition from alternative land uses, and the risk of environmental degradation of marginal cultivated lands and forests. Much of the land in the 1.8 billion ha "reserve" is of inferior quality compared with that currently in agricultural use. Moreover, a large share of the land not in crop production is concentrated in a small number of countries (27 per

Figure II.7. Agricultural production in major world regions, 1961-1999



Source: FAOSTAT (July 2000).

TABLE II.4. PREVALENCE OF UNDERNOURISHMENT, DEVELOPING COUNTRIES, 1969-2030

	Percentage of population						*Millions of persons*					
	1969-1971	*1979-1981*	*1990-1992*	*1995-1997*	*2015*	*2030*	*1969-1971*	*1979-1981*	*1990-1992*	*1995-1997*	*2015*	*2030*
Developing countries	37	29	20	18	10	6	959	937	828	790	576	401
Sub-Saharan Africa	34	36	34	33	22	15	88	125	162	180	184	165
Near East/North Africa	25	9	8	9	8	6	45	22	25	33	38	35
Latin America and the Caribbean	19	13	13	11	7	5	54	46	59	53	45	32
South Asia	37	38	26	23	10	4	267	337	299	284	165	82
East Asia	43	29	17	13	7	4	504	406	283	240	144	86

Source: Food and Agriculture Organization of the United Nations, *Agriculture: Towards 2015/2030*, Technical Interim Report (Rome, FAO, April 2000).

cent in Brazil, 9 per cent in the Democratic Republic of the Congo and another 36 per cent in 13 other countries), and is not actually available, as it is under forest or located in protected areas (Alexandratos, 1995).

Competition for land is intensifying. Although direct consumption of grain by humans is the most efficient use of available food supplies, more land in developing countries is now used for growing grain feed, fodder and forage for livestock, as dietary preferences change with increasing wealth in favour of meat and dairy products. Development and population growth have also claimed increasing shares of land for housing, industry and infrastructure. Although the data are rough, some estimates point towards some 94 million ha of land of all types being occupied by human settlements and infrastructures in the developing countries (excluding China) (Alexandratos, 1995). Many of the world's largest cities are in fact located on extremely fertile agricultural land. As cities expand they displace farms, cover fertile soils with pavement and contaminate neighbouring soils through airborne deposits and solid waste landfills. Projections place the additional land to be occupied by human settlements in the period to 2030 at about 100 million ha, of which nearly 60 million ha would be land with agricultural potential (Food and Agriculture Organization of the United Nations, 2000c). While this is only a small fraction of total land area, in countries such as China with limited potential for bringing more land into production, even small losses are a cause for concern.

Land degradation affects a much larger area. The state of knowledge in this area is, however, weak. Estimates of loss of productivity due to land degradation vary widely, with some observers finding little effect, and others viewing land degradation as a major threat to food security globally. The problem is clearly serious in some areas where, for instance, extension of farming up steep slopes led to erosion, or where poor irrigation practices led to waterlogging or salinization of soil. Yet on the broader scale there is little correspondence evident between global and regional estimates of the severity of human-induced land degradation and trends in agricultural production (Food and Agricultural Organization of the United Nations, 2000c). The role of overgrazing in causing land degradation and desertification has also been debated. As stated by FAO (2000c): "In the 1970s and 80s it was argued that the Sahara was spreading rapidly southwards as part of an irreversible expansion of the world's deserts. Since then, counter-arguments have been growing in force backed up by strong empirical evidence from remote sensing activities. That is, the desert margins are quite dynamic because of natural climate variation and the issue is more one of localized dryland degradation because of overgrazing, excessive fuel collection, bad tillage practices and inappropriate cropping systems. Nonetheless, there has been some expansion of the deserts and dryland degradation although quantification is not precise".

Long-term global warming and climate change could also threaten as much as one half of the high-quality land resources of some countries through sea-level rise or deterioration in agro-ecological conditions (Alexandratos, 1995). Agriculture now contributes about 30 per cent of total global emissions of greenhouse gases (GHGs). "Tropical forest clearance and land cover change were major factors in the past for CO_2 emissions, but more attention is now being given to methane (CH_4) and nitrous oxide (N_2O), since agriculture is responsible for about 40 and 80 per cent respectively of total global anthropogenic emissions of these GHGs" (Food and Agriculture Organization of the United Nations, 2000c).

Agricultural intensification in recent decades has taken a heavy toll on the environment. Poor cultivation and irrigation techniques and excessive use of pesticides and herbicides have led to widespread soil degradation and water contamination. Salinization of the soil is a serious problem in West Asia and in localized areas in other regions (Food and Agriculture Organization of the United Nations, 2000c).

Each year an additional 20 million ha of agricultural land becomes too degraded for crop production, or is lost to urban sprawl. Yet over the next 30 years the demand for food in developing countries is expected to double. So, new land will certainly be farmed, but much of it will be marginal and therefore even more susceptible to degradation (United Nations, 2000a, para. 284). Advances in agricultural biotechnology may help developing countries by creating drought-, salt- and pest-resistant crop varieties. However, the environmental impact of biotechnology has yet to be fully evaluated and many questions, in particular those related to biosafety, remain to be answered.

While most assessments of prospects for increased food production are cautiously optimistic, this is not the case for

TABLE II.5. LAND AREA AND USE, WORLD AND MAJOR REGIONS, 1986-1998

	Land area[a] (millions of hectares)	Population density (per million hectares), 1998	Domesticated land[b] (percentage), 1998	Land use (millions of hectares)					
				Cropland[c]		Permanent pasture[d]		Other land	
				1996-1998	Percentage change since 1986-1988	1996-1998	Percentage change since 1986-1988	1996-1998	Percentage change since 1986-1988
World	13 048	452	37.8	1 511	1.28	3 424	1.57	8 113	-0.82
Developing[e]	7 586	622	40.4	856	4.96	2 206	1.52	4 524	-1.60
Developed[f]	5 462	216	34.3	655	-3.17	1 218	1.67	3 589	0.17
Africa	2 964	253	36.7	202	7.83	887	-1.05	1 875	-0.28
Asia	3 085	1 162	52.3	557	2.88[g]	1 055	4.28[g]	1 473	-3.36[g]
Europe	2 260	323	21.8	311	-4.00[h]	181	-4.46[h]	1 769	3.70[h]
Latin America and the Caribbean	2 018	250	37.7	159	8.98	602	1.99	1 257	-1.94
Northern America	1 872	163	26.3	225	-4.16	268	-0.26	1 379	0.76
Oceania	849	35	57.5	57	9.10	431	-1.71	361	0.77

Source: Food and Agriculture Organization of the United Nations and Population Division of the United Nations Secretariat.

[a]Total area excluding area under inland water bodies. Data in this category are obtained mostly from the United Nations Statistics Division.

[b]Referring to the sum of cropland and permanent pasture.

[c]Referring to the sum of arable land (land under temporary crops, temporary meadows for mowing or pasture, land under market and kitchens gardens and land temporarily fallow) and permanent crops (land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest, such as cocoa, coffee and rubber).

[d]Land used permanently (five years or more) for herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land).

[e]Including all countries of Latin America and the Caribbean; the countries of Africa except South Africa; the countries of Asia except the countries of the former Union of Soviet Socialist Republics (USSR) (Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan), Japan and Israel; the countries of Oceania except Australia and New Zealand; and the countries of Northern America except the United States of America and Canada.

[f]Including all countries of Europe, the countries of the former USSR in Asia, the United States of America, Canada, Israel, South Africa, Japan, Australia and New Zealand.

[g]Excluding the countries of the former USSR in Asia (Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan).

[h]Excluding the countries of the former USSR in Europe (Belarus, Estonia, Latvia, Lithuania, the Republic of Moldova, the Russian Federation and Ukraine).

marine fisheries, where overfishing has led to a levelling off of total catches, and a decline in populations of many commercially valuable species. During the 1990s, about three quarters of the world's fish supply came from marine fish catcheries (Food and Agriculture Organization of the United Nations, 1998). Fish provided about 15 per cent of the animal protein in the human diet in 1996, or 6 per cent of total dietary protein (Grainger, 1998). During the 1950s and 1960s, world marine fisheries production increased by as much as 6 per cent per year. It roughly doubled between 1950 and 1961 and doubled again in the following two decades. However, in the decade following 1983, the annual rate of increase was only 1.5 per cent, and there was almost no growth between 1994 and 1997. The total supply of fish has continued to grow, but after 1980 this was essentially owing to increasing contribution of aquaculture, which itself is adding to environmental stress in some areas. An assessment by FAO (1998) concludes that "among the major fish stocks for which information is available, an estimated 44 per cent are fully exploited and are therefore producing catches that have reached or are very close to their maximum limit, with no room expected for further expansion. About 16 per cent are overfished and likewise leave no room for expansion; moreover, there is an increasing likelihood that catches might decrease if remedial action is not undertaken to reduce or suppress overfishing. Another 6 per cent appear to be depleted, with a resulting loss in total production . . . and 3 per cent seem to be recovering slowly".

E. WATER[3]

An adequate and dependable supply of fresh water is essential for human health, food production and economic development. Though more than two thirds of the planet is covered with water, only a small fraction, under 0.01 per cent, is readily accessible for direct human use (United Nations, 1997a). Moreover, no more of this renewable fresh water is available today than existed at the dawn of human civilization. As a result, the size of a country's population and the speed at which it grows help determine the onset and severity of water scarcity. Although recent declines in the rate of population growth have improved the outlook for future water availability in many countries, the problems associated with water scarcity will continue to mount as the size of the world's population increases.

Currently humans are using about half the 12,500 cubic kilometres of fresh water that is readily available. Fresh water is distributed unevenly over the globe, and already there are nearly half a billion people, 8 per cent of the world's population, living in countries affected by water stress or serious conditions of water scarcity, while an additional one quarter live in countries experiencing moderate stress. Given current trends, as much as two thirds of the world population in 2025 may be subject to moderate-to-high water stress[4] (United Nations, 1997a). In some regions, groundwater is being depleted much faster than it is being replenished, creating a situation that is clearly unsustainable. The fact that many of

the countries facing water scarcity are low-income countries of Africa and Asia makes adaptation more difficult, since these countries often are not in a favourable position to make costly investments in water-saving technologies for irrigation and water recycling. Population is also increasing rapidly in many of these same countries, especially in Africa.

About 300 major river basins, and many groundwater aquifers, cross national boundaries (United Nations, 1997a). Therefore the need for cooperative efforts will persist and probably increase, particularly in areas facing water shortages, such as the Middle East, North Africa and certain regions in Asia, and wherever pollution in one area is carried downstream across national boundaries.

The United Nations estimates that over 1 billion people lack access to safe drinking water and 2 1/2 billion lack adequate sanitation (United Nations, 2000a, para. 278). These unsafe conditions, especially in rapidly urbanizing areas where drinking water and sewage treatment facilities are often inadequate or non-existent, are estimated to cause a death toll per year of more than 5 million people on average of whom more than half are children. Because of the significant link between water resources and agriculture, forestry, ecosystems and urban and rural development, degrading water quality and the misuse of water resources impose a major threat to the health and development possibilities of the population in large areas of the world (United Nations, 1997d).

F. Forests and biodiversity

The number of plant and animal species inhabiting the planet is not known. Nearly 2 million species have been identified by scientists, but estimates of the number yet to be described have ranged from 10 million to 30 million (United Nations Environment Programme, 1995). Ecosystems of all kinds are under pressure worldwide. Coastal and lowland areas, wetlands, native grasslands, and many types of forests and woodlands have been particularly affected or destroyed. For example, between 1980 and 1995, forests decreased in extent by about 180 million ha, or about 5 per cent of the forested area at the start of the period (Food and Agriculture Organization of the United Nations,1999c); in tropical regions the pace of loss has been greater. Of the 600,000 square kilometres of coral reefs in the world, about 10 per cent have already been eroded beyond recovery (United Nations Environment Programme, 1995). Flowering plants and vertebrate animals have recently become extinct at a rate estimated to be 50 to 100 times the average expected natural rate. Fragile aquatic habitats, including coral reefs and freshwater habitats in rivers, lakes, and wetlands, face an array of assaults ranging from dams to land-based pollution to destructive fishing techniques. Some 58 per cent of the world's reefs and 34 per cent of all fish species may be at risk from human activities (World Resources Institute, 1998).

Over the past 150 years, deforestation has contributed an estimated one third of the atmospheric build-up of CO_2, and approximately 20 per cent of the CO_2 added between 1989 and 1998[5] (Intergovernmental Panel on Climate Change, 2000). It is also a significant driving force behind the loss of species and of critical ecosystem services. Since the beginnings of the spread of agriculture approximately 10,000 years ago, almost half of the forests that once covered Earth have been converted to farms, pastures and other uses, and only one fifth of Earth's original forest remains in large, relatively natural ecosystems (table II.6).[6] Much of the loss of forest has occurred in the past 30 years (World Resources Institute, 1998). Between 1980 and 1995, the extent of the

TABLE II.6. AREA IN ORIGINAL, CURRENT AND FRONTIER FOREST

	Original forest		*Total remaining forest*		*Total frontier forest*	
	Land area (millions of square kilometres)	*Percentage of land area*	*Percentage of land area*	*Percentage of original forest*	*Percentage of original forest*	*Percentage of remaining forest*
World	130	48	26	54	22	40
Africa	30	23	8	34	8	23
Asia	31	49	14	28	6	20
North America	19	58	45	78	34	44
Latin America and the Caribbean	20	57	39	67	40	59
Central America and the Caribbean	3	67	37	55	10	18
South America	18	56	39	70	46	65
Europe	23	73	42	58	21	36
Excluding Russian Federation	6	82	27	32	0.3	1
Oceania[a]	8	17	11	65	22	34

Source: Dirk Bryant and others, *The Last Frontier Forests: Ecosystems and Economies on the Edge* (Washington, D.C., World Resources Institute, 1997).

NOTE: Frontier forests are the world's remaining large intact natural forest ecosystems. These forests are ecosystems and are—on the whole—relatively undisturbed and big enough to maintain all of their biodiversity, including viable populations of the wide-ranging species associated with each forest type.

[a]Australia, New Zealand and Papua New Guinea only.

world's forests increased by 20 million ha in developed countries (a 2.7-point increase in percentage terms), but declined by roughly 200 million ha (9.1 per cent) in developing countries (Food and Agriculture Organization of the United Nations, 1999c).

The forested area, including forest plantations as well as natural forests, occupied about one fourth of the world's land area in 2000. About 55 per cent of the forested land is in developing countries, and 45 per cent in developed countries. Approximately one half of the forests are tropical and subtropical forests and one half are temperate and boreal forests (Food and Agriculture Organization of the United Nations, 1999c). Tropical rainforests are of special interest because of the quantity and the diversity of life they support. Tropical rainforests cover only 7 per cent of Earth's land area, but are estimated to contain at least 50 per cent, and perhaps as much as 90 per cent, of terrestrial species (ibid.).

According to FAO, the pace of deforestation dropped during its last survey period (Food and Agriculture Organization of the United Nations, 2001a, 2001b). Between 1990 and 2000, net forest loss in the developing countries (including natural forest plus forest plantations) was estimated at 10.3 million ha annually, compared with 13.0 million ha per year between 1980 and 1990 (Food and Agriculture Organization of the United Nations, 1990, 2001a). Among the major continental areas, deforestation has lately been proceeding most rapidly in Africa, which lost an estimated 10.5 per cent of its forested area between 1980 and 1995, and Latin America and the Caribbean, which lost 9.7 per cent during that period. In absolute terms, most of forest loss is taking place in South America and in tropical sub-Saharan Africa. The small net gain in forest area in the more developed regions is due to a combination of forest regeneration on land previously farmed and the establishment of forest plantations. Parts of Asia also show small net increases between 1990 and 2000 (table II.7), due to increases in plantations in countries where little natural forest remains. It should be noted that, while there is a consensus that, globally, deforestation has proceeded rapidly during recent decades, estimates often differ regarding the amount and even the direction of change in particular countries over periods of several years' duration, and FAO's conclusion regarding the recent slow-down in rate of forest loss has also been questioned (Matthews and others, 2000; Matthews, 2001). Although data on forest cover have been improving, the recent *Pilot Analysis of Global Ecosystems: Forest Ecosystems* "concludes that the generally poor quality of land cover and land-use information means that the degree and speed of change in forest extent are difficult to determine. Changes in the condition of forest ecosystems are even harder to monitor because good baseline data are largely lacking and indicators of forest condition, applicable to different forest types that may be managed for different purposes, are still controversial" (Matthews and others, 2000). The report makes specific recommendations for improving the quality of information.

The influences of forests and biodiversity are global, reaching far beyond the national borders of any nation, both in space and in time. Therefore international cooperation is essential to better integrate environmental thinking into global, regional and national decision-making processes.

The urgency of these issues has been recognized at the intergovernmental level at the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992, and with follow-up continuing on a variety of fronts, including the 1997 special session of the General Assembly to review and appraise the implementation of Agenda 21, the 1997 Kyoto Protocol (United Nations, 1998) to the United Nations Framework Convention on Climate Change (United Nations, 1994) and beyond. The report of the Secretary-General to the Millennium Assembly of the United Nations (United Nations, 2000a) (A/54/2000) highlights the significance of the preservation of forests, fisheries and biodiversity and calls on all Member States for immediate action.

TABLE II.7. FOREST COVER AND ANNUAL CHANGE IN FOREST COVER, BY REGION, 1990-2000

Region	Forest area (millions of ha) 1990	2000	Annual change in forest area, 1990-2000 (percentage)
World	3 947	3 856	-0.2
More developed regions	1 687	1 700	0.1
Less developed regions	2 259	2 156	-0.5
Least developed countries	589	546	-0.8
Africa	703	650	-0.8
Eastern Africa	188	169	-1.0
Middle Africa	320	310	-0.3
Northern Africa	77	68	-1.3
Southern Africa	32	30	-0.6
Western Africa	85	72	-1.6
Asia	546	542	-0.1
Eastern Asia	190	207	0.9
South-central Asia	103	105	0.2
South-eastern Asia	235	212	-1.0
Western Asia	18	19	0.2
Europe	1 031	1 040	0.1
Eastern Europe	892	897	0.1
Northern Europe	68	69	0.2
Southern Europe	40	42	0.5
Western Europe	32	32	0.2
Latin America and Caribbean	999	953	-0.5
Caribbean	10	9	-1.1
Central America	78	70	-1.2
South America	910	874	-0.4
Northern America	467	471	0.1
Oceania	202	201	0.0

Sources: Food and Agriculture Organization of the United Nations, *Global Forest Resources Assessment 2000*: data as of 21 March 2001, data available online at: http://www.fao.org/forestry/fo/fra/index.jsp; Population Division of the United Nations Secretariat, "World population prospects: the 2000 revision" (ESA/P/WP.165).

NOTE: Forest area includes natural forests and plantations.

The Global Environment Facility was appointed by article 39 of the Convention on Biological Diversity (United Nations Environment Programme, 1992) (see chapter 15 of Agenda 21 (United Nations, 1993, resolution 1, annex II)) to develop operation programmes based on ecosystems (United Nations, 1997b). Their goals include progress in securing global biodiversity objectives and providing a framework for design and implementation of national action plans involving the coordination of international, intersectoral and inter-agency activities. The Intergovernmental Forum on Forests (IFF) in 2000 adopted a set of consensus recommendations for sustainable forest management (United Nations, 2000b, annex). The System of Integrated Environmental and Economic Accounting, which adds natural and resource and pollution accounts to traditional national accounts, is one strategy through which to include environmental issues in national policy formulation.

NOTES

[1]A recent study indicated that eliminating energy-related subsidies in major developing countries could cut global emissions of carbon dioxide (CO_2) by as much as 4.6 per cent (International Energy Agency, 1999). It should be noted that the policy prescription is aimed at developing countries and not the developed countries, which account for some 60 per cent of all CO_2 emissions.

[2]The real international price of wheat fell by 32 per cent between 1955-1959 and 1995-1997; the price of maize fell by 42 per cent and that of rice by 43 per cent (Johnson, 1999).

[3]This section is based primarily on the report of the Secretary-General (E/CN.17/1997/9) entitled "Comprehensive assessment of the freshwater resources of the world", which was prepared by a number of United Nations organizations, with the collaboration of the Stockholm Environment Institute, for the Commission on Sustainable Development at its fifth session in 1997.

[4]The classification of degree of water stress is as follows: (1) low water stress. Countries that use less than 10 per cent of their available fresh water generally do not experience major stresses on the available resources; (2) moderate water stress. Use in the range of 10 to 20 per cent of available water generally indicates that availability is becoming a limiting factor, and significant effort and investments are needed to increase supply and reduce demand; (3) medium-high water stress. When water withdrawals are in the range of 20-40 per cent of the water available, management of both supply and demand will be required to ensure that the uses remain sustainable. There will be a need to resolve competing human uses, and aquatic ecosystems will require special attention to ensure they have adequate water flows. Developing countries, in particular, will need major investments to improve water use efficiency and the portion of gross national product (GNP) allocated to water resources management can become substantial; (4) high water stress. Use of more than 40 per cent of available water indicates serious scarcity, and usually an increasing dependence on desalination and use of groundwater faster than it is replenished. It means there is an urgent need for intensive management of supply and demand. Present use patterns and withdrawals may not be sustainable, and water scarcity can become the limiting factor to economic growth (United Nations, 1997a).

[5]There is a large range of uncertainty around the estimates. From 1850 to 1998, approximately 270 (± 30) gigatons of carbon (Gt C) have been emitted as CO_2 into the atmosphere from fossil fuel burning and cement production, and 136 (± 55) Gt C have been emitted as a result of land-use change, predominantly from forests (Intergovernmental Panel on Climate Change, 2000). Figures in parentheses indicate a 90 per cent confidence interval.

[6]Estimates of how much of the original forest cover has been removed vary widely; both estimates of the original forest cover (which rest chiefly on understanding of what types of vegetation different soils and climatic conditions would support under natural conditions) and estimates of the current forest cover differ significantly. For example, Emily Matthews in 1983 (cited in Cohen, 1999) estimated the pre-agricultural closed forest cover at 4.6 billion ha, while the World Resources Institute study cited in the text estimated a much larger figure, 6.2 billion ha. Estimates of contemporary forest cover also vary: Matthews's 1983 estimate was 3.9 billion ha, as compared with the estimate for 1996 of 3.34 billion ha; FAO's forestry assessment estimated that 3.45 billion ha were forested in 1995 (Food and Agriculture Organization of the United Nations, 1999c).

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III. GOVERNMENT VIEWS AND POLICIES CONCERNING POPULATION, ENVIRONMENT AND DEVELOPMENT

During the 1990s, an increasing number of Governments became seriously concerned about environmental problems, be they of a domestic nature or, less frequently, of a transboundary nature. At the 1992 United Nations Conference on Environment and Development, a consensus was established that population, the environment and development were inextricably linked. This consensus view was reaffirmed at the 1994 International Conference on Population and Development. In addition, reports and statements produced by Governments and non-governmental organizations for the first quinquennial reviews and appraisals of the implementation of Agenda 21 (United Nations, 1993, resolution 1, annex II) and the Programme of Action of the International Conference on Population and Development (United Nations, 1995, chap. I, resolution 1, annex) provide a solid basis to assess how far the various stakeholders have gone in operationalizing the linkages between population, environment and development.

A. Population and environmental policies

Since the convening of the United Nations Conference on Environment and Development in 1992, over 100 countries have adopted national sustainable development strategies or national environmental action plans.[1] These processes have largely focused on setting national environmental priorities, devising the best private-public intervention mixes in relation to those priorities and involving the public. Although policy implementation has been lagging behind policy formulation, as evidenced by the large majority of country reports prepared for the first quinquennial review and appraisal of Agenda 21, national environmental policy instruments provide a unique framework within which to obtain a sense of the salience of population issues in the context of environmental policies. On an operational level, the linkages between population dynamics and the environment are probably best addressed by local environmental management initiatives.

In national environmental strategies and action plans prepared by countries in the more developed regions, little reference is made to demographic dynamics. In contrast, national policy frameworks devised by countries in the less developed regions call for the necessity of preventing poverty-driven environmental degradation in the context of rapid population growth and improving the environmental conditions of the poor. However, there generally is little elaboration. Policies and programmes that address human settlements and land management as well as, to a lesser extent, agriculture and forestry provide further insights. In the less developed regions, public authorities' concern over population dynamics in relation to environmental degradation essentially arises from high population concentration and growth in specific geographical zones. Expanding slum settlements in large cities and frontier migration, in particular, are issues that are often considered critical from an environmental policy viewpoint.

The policy approach taken by the great majority of countries favours integrated urban and rural development programmes that adapt to, rather than intend to modify, population dynamics. Unlike policies adopted in the 1970s and 1980s, there are very few attempts being made to contain urban growth and to relocate population to new, secondary cities. Land management policies and human settlement programmes typically include measures to upgrade infrastructure and services, control the location of new housing and, in general, ensure sound land use. Most such programmes are designed to mitigate the negative effects of an earlier lack of planning.

In reporting on these programmes, several Governments—for example, Bangladesh, Brazil and Thailand—point to the lack of sufficient, accurate and up-to-date data, ranging from basic demographics to land conversion and infrastructure deployment patterns, as a serious impediment to designing better land management and human settlements policies. While continuous improvement in data quality and availability allows an increasing number of countries to include population estimates and projections in their national environmental plans, data and the resources required for their integration at the micro-scale level are rarely available. Also demographics statistics are called upon to illustrate the challenges lying ahead and the sheer magnitude of the work to be accomplished. The Government of Brazil, for instance, estimated that, in 1995, 2 million housing units and the provision of water and sanitation services for 8 million dwellings were needed to cope with infrastructure deficits in the nine main cities, particularly Rio de Janeiro and São Paulo. In addition, the annual demand for urban housing stood at about 1.3 million units. Another example is the Nigerian National Housing Programme, started in 1994, with the objective of renewing existing slum areas while avoiding gentrification of these areas and, in the longer run, preventing conditions leading to the development of new slums. The objective was to build 121,000 housing units for low-, medium- and high-income earners by the year 2000. In April 1997, only 5 per cent of the target had been achieved. By and large, demographic factors are viewed as exogenous rather than policy variables in the context of land management and human settlements.

While few Governments attempt to contain rural to urban migration directly, most have developed measures to correct the urban bias and equalize development opportunities

within the country. Strategies for poverty alleviation in agriculture focus on reforming land tenure systems and ensuring access to land as well as on diversifying agricultural production and promoting sustainable farming practices while avoiding encroachment on environmentally sensitive areas. Increasingly, property regimes are seen as both a cause of, and a solution to, poverty-driven environmental degradation. In Brazil, acknowledgement of the effect of land tenure systems on frontier migration and deforestation prompted the creation of the Ministry for Agrarian Reform in 1996. The Ministry has the responsibility to decide upon the number of families that will be allowed to settle in the frontier each year. The Government also established an Ecological and Economic Zoning project in 1990. The Government of Bolivia adopted a land redistribution policy in 1996 to ensure access of small farmers to land and avoid concentration of property in a few hands. In Ecuador, the Agrarian Development Law adopted in 1996 aims at redistributing and creating a market for land. The issue of frontier migration in South America has also triggered regional initiatives such as the Frontier Development Projects, sponsored by the Organization of American States, involving Brazil, Colombia, Peru and Venezuela. Access to land and human resources development are also key elements of the anti-poverty strategies pursued under the Indian Ninth Five-Year Plan (1997-2002). The measures that are being implemented include: the detection as well as redistribution of ceiling surplus land; the upgrading of land records on a regular basis; tenancy reforms to record the rights of tenants and sharecroppers; the consolidation of holdings; the prevention of the alienation of tribal lands; and access to wastelands and common property resources to the poor on a group basis.

The promotion of sustainable practices in the areas of farming, fishing and forestry is increasingly seen as critical in securing and/or restoring a basis for economic activities, and therefore offering development opportunities to people living in rural areas. Botswana is a pioneering example of such a policy shift. The rural economy in Botswana depends largely on cattle farming. For years, successive policies had ensured the exclusive use of rangeland resources by certain groups of farmers; however, rangeland had been degraded, mostly as a result of overuse and drought. Following the adoption of the National Policy on Agricultural Development in 1991, the country has engaged in training farmers in new dryland farming systems that are more environmentally sound and has encouraged strict soil fertility management.

Environmental policies and programmes are increasingly designed and implemented through participatory processes that involve civil society. Most Governments and donors believe that participatory management through community involvement at the local level is essential to ensuring sustainability and to building local capacity. Taking local knowledge and traditional technologies into account is also increasingly seen as necessary. The promotion of sustainable practices is therefore carried out primarily within the framework of community-based initiatives with international technical and financial assistance. Activities range from awareness-creation to building local capacity in the management of natural resources and support to non-agricultural, supplemental income-generating activities. Local governments in South America and South-eastern and South-central Asia have been relatively proactive in implementing natural resource management projects. In Brazil, for instance, various municipal governments, including those of Rio de Janeiro and São Paulo, have developed community reforestation and rehabilitation projects. Nationwide, the decentralization process promoted during the 1990s has allowed the participation of more than 100 indigenous groups in the Pilot Programme for the Protection of Tropical Forests. In Ecuador, the indigenous population participates in most local agricultural productivity and genetic resources conservation projects. In Nepal, various community forestry projects have been developed by local governments with the assistance of international and bilateral agencies such as the Danish International Development Agency (DANIDA), the International Fund for Agricultural Development (IFAD) and the World Bank, among others. The objective is to develop and manage forest resources through the active participation of the local population. These projects, that emphasize training activities, have significantly contributed to the creation of leasehold and user forest groups, and to the regeneration of large forest areas in the country. The Government of India has issued Guidelines for State Governments to involve village communities and agencies in the implementation of the 1988 National Forest Policy. The policy includes programmes to develop the use of local knowledge and indigenous capacities. The Indonesian Agricultural Policy and the Forestry Action Plan (1992) include actions to promote community participation in forest management.

One important source of information on environment and population policies is the Eighth United Nations Inquiry among Governments on Population and Development carried out by the Population Division of the United Nations Department of Economic and Social Affairs[2] (United Nations, 2001). According to the Inquiry, the impacts of population trends on the amount of fresh water, on water pollution and on the deterioration of the urban environment in both the more developed and the less developed regions of the world, as well as on air pollution in the more developed regions, are among the issues that raise the greatest concern among Governments. However, it is often unclear whether the replies reflect the importance that the Governments attach to an environmental issue regardless of population as an intervening factor or whether the Governments view population as a contributing factor. Some countries refer to national environmental issues while others address global issues.

Countries in the more developed regions and the less developed regions differ significantly with regard to their degree of concern over these issues. In the more developed regions, less than one country in two expresses deep concern over population linkages with air pollution and the deterioration of the urban environment; and one country in three, over linkages between population and the quality and quantity of water resources. In the less developed regions, in contrast, 73 per cent of Governments make reference to population trends in relation to water pollution and 63 per cent in relation to the amount of fresh water. A large majority of countries—65 per cent—also refer to the linkage between population growth and the deterioration of the urban environment. Among the countries that consider the deterioration of the urban envi-

ronment to be a serious problem are those that currently experience the most rapid urban population growth such as Botswana, Burkina Faso and the United Republic of Tanzania, and several with large urban agglomerations such as Bangladesh, China, India, Indonesia, Pakistan, the Philippines and Thailand. However, there are many exceptions to this pattern and the correlation between urban growth and concentration and the views expressed by Governments remain weak. Sixty per cent of countries mention the linkage between rural population growth and density and the degradation of agricultural land and forests. Deforestation is referred to by several countries that experienced high deforestation rates in the 1980s and 1990s such as Indonesia, the Philippines and Thailand, as well as countries that contain large areas of tropical forests such as Brazil and Peru. Most countries in the African Sudano-Sahelian region, the Kalahari desert region (Botswana and Namibia) and Western Asia (Kuwait and Saudi Arabia) express considerable concern over the impact of population trends on desertification.

The information provided within the framework of the Inquiry allows limited documentation of the nature of interventions undertaken to address the population-environment linkages. Not surprisingly, Governments' actions tend to focus on issues of high priority such as the deterioration of the urban environment, water pollution and fresh water supply and air pollution. In the less developed regions, most countries that aim at modifying the impact of population trends on the environment pursue this objective through a policy mix of population-related interventions and other measures and very few countries indicate relying primarily on a modification of population trends. Interventions cited by several countries in Latin America and Asia include measures aimed at improving the physical amenities of urban areas, and developing the management of natural resources as well as achieving a certain level of control over internal migration and settlement in sensitive areas. In the more developed regions, population-environment linkages are essentially dealt with within the framework of non-demographic policies. In the United Kingdom of Great Britain and Northern Ireland and the United States of America, for instance, emphasis is put on promoting agricultural and urban management practices that best suit the regional and local contexts with a view towards achieving more sustainable patterns of development.

B. Public opinion regarding the environment

Political mainstreaming of environmental issues has led Governments both to make commitments enabling civil society participation in environmental policy processes and to encourage firms to develop a sense of corporate social responsibility. Gaining a better understanding of the public's attitudes and expectations vis-à-vis the environment has become an integral part of public policy-making as well as, lately, business strategies. Recently, interest in public opinion on the environment has turned global. Since 1997, the international *Environmental Monitor* survey has been conducted annually by a consortium of pollsters led by Environics International, a Canadian firm. This public opinion survey has been carried out with a random sample of approximately 1,000 adult citizens in as many as 30 countries representing approximately 65 per cent of the world population. In addition to the 1999 *Environmental Monitor* Survey (Environics International, 1999), another two large international surveys were conducted in 1999 that provide additional insights into public perception of environmental issues: the Millennium Survey carried out in 60 countries by Gallup International (1999) and Eurobarometer 51.1, a survey initiated by the European Commission's Directorate General for Environment, Nuclear Safety and Civil Protection (DG XI) in each of the 15 member States of the European Union (EU) (European Commission, 1999). A striking feature of public opinion surveys is the lack of references to demographic dynamics in relation to the environment, in either the questionnaires used or the spontaneous replies of respondents.[3]

Findings from these international surveys, as well as from several national and local surveys, provide a consistent and contrasting picture of how citizens of both developed and developing countries perceive environmental issues, keeping in mind the limits inherent in any interpretation of public opinion polls. First and foremost, survey results point to the environment's being a pressing concern of citizens in both the developed and less developed parts of the world, together with issues such as unemployment/economic hardship, violence and health problems. According to the *Environmental Monitor*, a significant proportion of people in all 27 countries surveyed have at least "a fair amount of concern" about the environment (Environics International, 1999). In the countries of the EU, almost one inhabitant in two (46 per cent), on average, has serious concerns about the environment (European Commission, 1999). Furthermore, comparison with results of past surveys clearly shows that environmental concerns have been rising, particularly in developing countries.[4] In urban India, 27 per cent of respondents to the *Environmental Monitor* volunteered an environment-related response when asked about the most important problems they faced in 1999 as compared with 6 per cent in 1992. Only in Canada and the United States has the level of concern with the environment been somewhat lower than the very high level observed in 1992. The belief that high environmental standards pertain only to the rich country consumers' agenda is therefore not or no longer supported by recent public opinion polls.

Whereas environmental concern is becoming universal, there are significant cross-regional differences in people's assessment of the overall state of their local and national environment. In all countries of the EU, inhabitants express satisfaction with the current state of their environment and have "not much reason to complain" about environmental issues such as air pollution, quality of water, waste disposal, noise and traffic problems. However, they chiefly worry about a serious deterioration of the environment in the future. In contrast, close to 80 per cent of inhabitants of Eastern European countries such as Hungary, Poland, the Russian Federation and Ukraine express major dissatisfaction with the current state of the environment in their countries. In the less developed regions, similar levels of dissatisfaction are observed in many countries such as Armenia, Chile, Colombia, the Dominican Republic, Ecuador, Kazakhstan, Pakistan, Peru and the Republic of Korea. Only in Malaysia and Singapore do

respondents find the environment satisfactory—75 per cent and 91 per cent, respectively, according to the Gallup Millennium Survey.

Clearly, underpinning the public's perception of the environment and policy expectations are worries over the health consequences of water and air pollution. In almost all countries surveyed in the less developed regions, nearly one person in two believes that local pollution has affected their personal health and will harm the health of his or her children. Concerns over the impact of water, air and soil pollution trends on the future health of the population are also driving the opinion in the more developed regions. Also, a striking regional feature, obviously influenced by the aftermath of the Chernobyl catastrophe, is the serious concern expressed by approximately one inhabitant in two in Eastern Europe over the health impact of accidents with nuclear energy. Somewhat surprisingly, large minorities of people consistently express concern, across surveys, over more abstract issues such as climate changes. Indeed, climate change has received a great deal of media attention in the recent past, particularly in the context of the adoption and implementation of the Kyoto Protocol (United Nations, 1997) to the United Nations Framework Convention on Climate Change (United Nations, 1994).

In almost all countries, majorities or near-majorities of citizens look forward to Governments' and businesses' renewed and strengthened action on the very issues that are at the core of their concern: pollution and, to a lesser extent, climate change. This expectation of the public is conveyed with a sense of urgency: action is needed now and policy should be based on deterrence. Enforcement of stronger environmental laws and regulations and, to a lesser extent, strict application of the "polluter pays principle" are widely considered the best way to reduce industrial pollution. In countries of the EU, except Greece, improving public transportation is singled out as the intervention that should receive priority in order to reduce traffic congestion and air pollution in urban areas. Remarkably, actions that pertain to the realm of individuals' or a community's contribution to improving the environment, such as sorting domestic refuse and promoting water-saving practices, are regularly performed by a minority of citizens. Also, preference for more environment- friendly approaches to commodities, such as buying products with a packaging that can be recycled, carries limited weight vis-à-vis non-green attributes (for example, brand names) in consumers' purchasing decisions.

C. Integration of population and environmental policies

Since the 1992 Conference on Environment and Development and the 1994 International Conference on Population and Development, major efforts have been devoted to formulating and implementing new policies in the areas of both population and the environment. However, the integration of population, development and environmental plans has progressed little. Several factors might have contributed to this lack of progress. For example, existing administrative arrangements are not conducive to policy coordination. A majority of countries have a ministry in charge of environmental planning and, at least, one agency responsible for the coordination of population policies and programmes. However, few countries have located the population unit within the ministry of the environment. In a significant number of countries, population issues are the responsibility of the ministry of health. On the other hand, the ministry in charge of population issues does not, in many cases, participate in the national bodies for coordination and follow-up of environmental plans.

Notes

[1]This section is based on the documents prepared by Governments within the framework of the national reporting on the Rio commitments to the Commission on Sustainable Development. Country sheets summarizing national policies in the areas of agriculture, atmosphere, biodiversity, desertification and drought, energy, forests, fresh water, human settlements, land management, mountains, oceans and coastal areas, toxic chemicals, waste and hazardous materials have been prepared by the Division for Sustainable Development of the United Nations Secretariat and are available on the United Nations Sustainable Development web site at agenda21/natlinfo. This web site was accessed between 1 and 30 May 2000.

[2]The Eighth United Nations Inquiry among Governments on Population and Development was transmitted in the form of a questionnaire through the Executive Office of the Secretary-General in November 1997 to States Members of the United Nations and non-member States maintaining permanent observer missions at Headquarters. As of 1 October 1999, 90 replies had been received.

[3]The only exception is a survey conducted by *the polling company*™ for the non-governmental organization Negative Population Growth (NPG) in Florida in 1999. According to this survey, over 70 per cent of respondents "believe Florida's overcrowding and overpopulation is a major problem" (NPG, press release, Washington, D.C., 12 October 1999).

[4]Surveys that can be used for comparison over time include the Gallup International Survey taken on the eve of the United Nations Conference on Environment and Development in 1992 and, to a lesser extent because of significant changes in the questions asked, the five Eurobarometer surveys devoted to the environment carried out in 1982, 1986, 1988, 1992 and 1995.

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IV. POPULATION SIZE AND GROWTH, ENVIRONMENT AND DEVELOPMENT

Interactions among demographic change, the environment and development are complex, varying by the type of resource, the stage of economic, political and social development and the institutional setting. Environmental overuse and degradation take many forms, including air and water pollution, the imprudent use of land, forests, and other renewable natural resources, the reduction of biodiversity and the build-up of wastes, including greenhouse gases and global warming. Some types of environmental degradation are associated with affluence, and others primarily with poverty. Some problems are confined to local areas, while others are regional or even global in scope.

The present chapter considers the ways in which population size, growth and distribution may be related to major environmental issues. One concern in this chapter is to distinguish between issues that require policy attention at the global level and those that may be serious at the local or regional level, but are not thought by most experts to pose an imminent threat to sustainability at the global level. Global threats require analysis and action at the local and national levels, but also are likely to require international cooperation if they are to be resolved successfully.

A. BACKGROUND

For at least 200 years, the impact of population on the environment has been a subject of vigorous and contentious public debate, beginning with Thomas Malthus who in 1798 argued that population growth would be limited by fixed natural resources and extending through to current efforts to dissect the intricate interrelations between population change and the myriad environmental aspects. Demographers, economists, environmentalists and other scientists have attempted to understand and quantify population's effects on the environment (see, for example, Baudot and Moomaw, 1999; O'Neill, MacKellar and Lutz, forthcoming; Worldwatch Institute, 2000; McNeill, 2000).

Concerns about population and the environment have been evolving over time. Demographers' interest in the environment has been part of a much larger body of literature on population growth and development. Beginning in the late 1940s and 1950s, environmental concerns focused almost exclusively on what was felt to be the negative impact of population growth on non-renewable natural resources and food production, echoing Malthus's original concerns (see table IV.1). Virtually no attention was given to environmental side effects. An early effort during this period by the Population Division of the United Nations Secretariat examined population growth in relation to cultivable land, food production, carrying capacity, mineral and energy resources and capital (United Nations, 1951).

In the second wave of environmental concern during the 1960s and 1970s, the focus was widened to incorporate the by-products of production and consumption, such as air and water pollution, waste disposal, pesticides and radioactive waste. Especially in the West, this period was one of heightened concern about effects of rapid population growth, with some accounts predicting near-term collapse of environmental systems and widespread famine (see, for example, Meadows and others, 1972). Towards the other extreme, Julian Simon, starting in the 1970s, argued that moderate population growth was beneficial because it induced technological change, which would spur development and would also provide the means for societies to ameliorate many types of environmental side effects that growth produces. The 1974 United Nations World Population Conference did not adopt conclusions regarding population's environmental impact, but it did recognize population growth, along with social factors and rising per capita consumption, as factors affecting the environment and natural resources and suggested that the supplies and characteristics of natural resources should be considered when formulating population policies.

By the 1980s and into the 1990s, a new dimension was added. This third wave encompassed global environmental changes, including global warming and ozone depletion, and de-emphasized the importance of non-renewable resources. Expressing a view that was to become the cornerstone of the developmental paradigm of the 1990s, the 1984 International Conference on Population urged Governments to formulate population policies in accordance with the need to focus on long-term environmentally sustainable economic development.

An influential report in 1986 by the United States National Academy of Sciences (National Research Council, 1986) concluded that population growth contributed to some types of environmental harm. However, the magnitude of these effects depended on the social institutions that regulated resources and allocated the costs of externalities. In recent years, as part of a fourth wave, additional issues of global concern have received increased attention, including those related to biodiversity, deforestation, migration and new and re-emerging diseases.

The Programme of Action of the International Conference on Population and Development (1994) (United Nations, 1995) recognized both the complex nature of population-environment interactions and that population growth was one of several causes of unsustainability. Slower population growth, it was concluded, could improve the capacity of

TABLE IV.1. EVOLUTION OF ENVIRONMENTAL CONCERNS, 1940S TO THE PRESENT

Wave	*Date*	*General concern*	*Specific issues*	*Document*
First	1940s-1950s	Limited natural resources	Inadequate food production Depletion of non-renewable resources	United Nations report on population and resources (E/CN.9/77)
Second	1960s-1970s	By-products of production and consumption	Air and water pollution Waste disposal Radioactive/chemical contamination	Declaration of the United Nations Conference on the Human Environment World Population Plan of Action of the United Nations World Population Conference
Third	1980s-1990s	Global environmental change	Climate change Acid rain Ozone depletion	Report of the United States National Academy of Sciences Agenda 21 adopted by the United Nations Conference on Environment and Development Recommendations of the International Conference on Population
Fourth	1990s-present	Global environmental change	Biodiversity Genetic engineering Deforestation Water management Migration Emerging and re-emerging diseases Globalization	Programme of Action of the International Conference on Population and Development Resolution S-21/2 on key actions for the further implementation of the Programme of Action adopted by the General Assembly at its twenty-first special session of the General Assembly

Source: Adapted from V. W. Ruttan, "Population growth, environmental change and innovation: implications for sustainable growth in agriculture", in *Population and Land Use in Developing Countries,* C. L. Jolly and B. B. Torrey, eds. (Washington, D.C., National Academy Press, 1993).

countries to combat poverty, while protecting the environment. The consensus is that population, development and environmental policies cannot be fully implemented in isolation and are likely to prove more effective when combined.

B. POPULATION AND RESOURCES

General considerations

Most of the environmental issues of greatest concern today involve resources that are to a greater or lesser degree "common property resources":

> "While most extractive harvesting, processing, and distributional activities can be conducted relatively efficiently through the medium of exchange of private ownership rights, the inevitable residual mass returned to the environment goes heavily into what the economist calls common property resources. The same is true of residual energy. Common property resources are those valuable natural assets that cannot, or can only imperfectly, be reduced to private ownership. Examples are the air mantel, watercourses, complex ecological systems, large landscapes and the electromagnetic spectrum . . . It is obvious what will happen when open and unpriced access to such resources is permitted . . . Unhindered access to such resources leads to overuse, misuse and quality degradation. Market forces, while marvelously efficient in allocating owned resources, work to damage or destroy common property resources" (Kneese, 1977, pp. 27-28).

In the absence of effective social mechanisms to limit and ameliorate the tendency for common property resources to be overused and degraded, population growth will tend to exacerbate such problems. Population growth is rarely the only factor operating, though, for especially during recent decades, population growth has gone hand in hand with massive technological and social change.

Many natural systems can absorb and recover from a low level of exploitation; it is only when the scale of human activity intensifies beyond a certain point that degradation starts to appear. Such problems may then progress rapidly, and they have in some times and places obviously outpaced the ability of societies to develop and implement remedies.

In considering responses to such problems it is important to recognize that social-institutional factors can be as important as, if not more important than, technological ones. The general problem of managing locally scarce or fragile resources is not new. Many examples can be found where traditional societies developed communal rules for managing a scarce resource.[1] Such rules, where successful (and examples of failures can also be found), must solve both the problem of how to maintain the resource and the social problem of ensuring equitable access among society's members. Population growth has the potential to destabilize such communal arrangements, since rules that functioned adequately at a low population density may lead to overexploitation and/or pol-

lution at a higher density. Successful adaptation may be possible—as, for instance, in the transition described by Boserup (1965) from shifting to settled agriculture—but it is important to recognize that changes in the social allocation of resources are likely to be required as part of such adaptation. Even though the overall social as well as environmental benefit to such organizational change may be large, the process is likely to be contentious and politically difficult. Indeed, there are apt to be losers as well as winners in any such process; achieving an equitable transition represents a major social and political challenge at all levels, from local to national—and even international, when we consider problems that have a global impact, such as emissions of greenhouse gases.

One means of examining the underlying relationships between population and the environment is to focus on three features of environmental problems, namely, market failures, policy failures and, especially with regard to environmental problems of developing countries, poverty. The first of these features has already been mentioned. Because of the failure of markets to fully reflect the social costs of environmental resources, environmental spoilage and overuse tend to occur. Moreover, the faster the pace of population growth (an amplifying factor), the more rapid the pace of overuse. Population's role could be attenuated if mechanisms for properly valuing environmental resources were in place, but this is seldom the case in low-income countries where high population growth rates, market distortions or absence of markets, and environmental degradation prevail.

Environmental problems may further be exacerbated by the failure of government policies or interventions, which produce either inefficient outcomes or unintended side effects. These include a long list of policies that disadvantage the rural sector, such as overvalued exchange rates, urban bias in service provision, underinvestment in rural infrastructure and research and development, taxation of farm inputs and constrained farm prices. These policies exacerbate poverty, the third feature of environmental problems, by perpetuating rural poverty and encouraging farm practices that overuse an undervalued resource—the environment. This leads to the poor's being trapped in a "vicious cycle" of worsening interactions between their needs and the environment upon which their survival depends. It appears that the nexus between population growth, poverty and environmental management can reinforce either positive or negative outcomes, depending critically on the policy environment, the institutional setting, the nature of government intervention and access to markets (Boserup, 1965; Heath and Binswanger, 1998; Panayotou, 1994).

Carrying capacity and limits to growth

A major motivation for studying interrelations between population and environmental variables is, of course, the desire to improve our ability to anticipate and deal with emerging problems before they become overwhelming. Experts in fields such as population, agriculture and economics often use their understanding of the causes of past trends to project likely or feasible future trends. Several examples of such projections were cited in chapter III. Most efforts at forecasting trends in population growth, agricultural production or economic growth, along with aspects of the environmental impact of the latter trends, extend in range from several years to 25 or sometimes 50 years into the future. Such periods are much shorter than the timescales of concern to ecologists. Yet beyond the near- or medium-term future, most experts in areas such as agriculture or economics believe that unforeseeable future technological and social changes are likely to play such a major role that attempting longer-term predictions becomes a futile exercise.[2] When experts in such areas do present longer-term projections, these are frequently given a name such as " 'what-if' scenarios" to distinguish them from the shorter-term "projections" that are grounded in professional judgements of likely trends.[3] Such exercises can certainly be valuable, even if they do not provide much insight into what the distant future will actually be like. For instance, they are quite effective at making a convincing case that current trends, if continued long enough, are unsustainable and—a related point—that a relatively small change of course, if taken immediately, might prevent the need for more drastic steps later.

Certainly population trends are a case in point. The long-range projections of population include a constant-fertility scenario, which "shows the absurdity of assuming a continuation of current fertility levels, for such assumption results in a world population of 256 billion persons in 2150" (United Nations, 2000b, introduction, sect. B, third paragraph). Ansley Coale calculated in 1974 that, if then-current population growth rates were to continue, within 6,000 years humanity would form a mass expanding outward from Earth at the speed of light (Coale, 1974). In fact, this nonsensical result would appear eventually with continued exponential growth at any rate, no matter how little above zero. Thus, there are surely limits to growth—but we cannot be confident now where these limits lie.

Despite the inherent problems in doing so, many attempts have been made to estimate the number of people that Earth can support. Joel Cohen (1995) compiled and presented all the numerical estimates he could find of Earth's human carrying capacity. The earliest estimate, by Anton von Leeuwenhoek, dated from 1679; he estimated that Earth could support 13.4 billion people. Most estimates of carrying capacity are based on an assumption that human populations are constrained by a limiting factor, or sometimes a combination of potential limiting factors considered jointly. The most commonly assumed limiting factor is the amount of food that can be grown. In addition, Cohen noted that "almost all of the definitions recognized that ecological concepts of carrying capacity must be extended to allow for the role of technology in enhancing nature's productivity. Most recognized that culturally and individually variable standards of living, including standards of environmental quality, set limits on population size well before the physical requirements for sheer subsistence" (Cohen, 1995, p. 232).

The estimates of Earth's carrying capacity range from under 1 billion to more than 1,000 billion persons. Not only is there an enormous range of values, but there is no tendency of the values to converge over time; indeed, the estimates made since 1950 exhibit greater variability than those made earlier (figure IV.1). This is worth noting, as it might be ex-

pected that, with the improvement in knowledge of Earth's biological and physical systems, there should be an approach to a consensus regarding Earth's carrying capacity. Yet this is not the case. Cohen concludes that, "notwithstanding their cloak of quantification, many of the published estimates of human carrying capacity are probably less dispassionate analyses than they are political instruments, intended to influence actions one way or another" (Cohen, 1995, p. 233). At the same time, it is worth noting that the world's population has already entered into the zone where many of the carrying-capacity estimates are found. Around two thirds of the estimates fall in the range of 4 billion to 16 billion persons, and the median value is about 10 billion, or near the size that will be attained by 2200, according the Population Division's medium-variant scenario (United Nations Population Division, 2000b).

Diversity of environmental issues

The environmental variables considered in relation to population cover a wide spectrum and range from specific resources (land, forest, water, air), to problems concentrated in specific climatic zones, to urban/rural location.

While the environmental problems discussed in this report are largely the result of human activities, they vary in the degree to which they can be linked directly to population size, growth or distribution. For example, increases in some types of pollution are primarily the by-product of rising per capita production and consumption in richer economies, where population has generally been growing slowly. Some types of pollution, such as the release of chlorofluorocarbons, which harm the planet's ozone layer, are linked to particular technologies much more than to either population change or overall economic growth.[4] Even for those environmental problems that are concentrated in countries with rapid population growth, it is not necessarily the case that population increase is the main root cause, or that slowing population growth would make an important contribution to resolving the problem. Each type of problem needs to be considered separately, taking into account the range of conditions that give rise to the problem. Below we consider evidence about the ways in which population size, density and growth may be related to several major types of environmental issues.

Protected areas

There is a special situation with respect to population when the issue is one of preserving a unique, biologically rich, or fragile ecosystem. Such preservation is inherently incompatible with dense human settlement or heavy exploitation of the resources of the protected area. Population growth within and near the preserve can be a factor, among others, placing such areas at risk of degradation. Government regulation is generally needed to exclude or at least limit the number of settlers, animal herders, and logging operations and other uses incompatible with the preservation of the natural ecosystem. However, few such areas are completely uninhabited. Some are the home of indigenous people, and some-

Figure IV.1. Estimates of how many people Earth can support, by date of estimate

Source: Redrawn from Joel E. Cohen, *How Many People Can the Earth Support?* (New York, W. W. Norton and Company, 1995), figure 11.1.

NOTE: Where a range of estimates was given by an author, it is the highest estimate that is shown here.

times established farming communities nearby have traditionally had rights to harvest forest resources. These populations are often very poor and depend on the protected resources for their livelihood. Often it is the women in such communities whose harvesting rights are principally at stake. Increasingly both Governments and non-governmental organizations concerned with conservation have recognized the need to consider the needs of the local people when implementing preservation programmes. Approaches may include, for example, allowing low-impact uses of a forest to continue, involving the local population in income realized from such uses as ecotourism and improving access to education and employment training and to basic social services, including reproductive health. There have been some successes in such programmes, but they are far from universal (Noble and Dirzo, 1997; Stille, 2000; Matiza, 1996; Cruz, 1994). Many Governments have had great difficulty in providing effective protection to areas designated for preservation.

Many of the remaining natural areas with rich or unique ecosystems, or that are important for the continued existence of rare species, have so far survived in a near-natural state primarily because their inaccessibility, their unsuitability for agriculture or their infestation with disease-causing organisms had long limited dense settlement or other heavy exploitation. As extractive technology develops, and as roads are built and diseases brought under control, there is an increasing need for societies and their Governments to make deliberate choices about the number and extent of these areas to be preserved. These issues are now and are likely to remain among the crucial environmental questions confronting Governments of both developed and developing countries.

Food production and its environmental consequences: deforestation, land degradation, stress on water supplies

As noted earlier, much of the theoretical and empirical work related to population and the environment has grown out of Malthusian concerns that production of food would not be able to keep pace with population growth. Increasingly, this question has been joined by concern about the environmental costs of producing that food.

Just to keep pace with population growth, with no improvement of diets, food production needed to nearly double between 1961 and 1998. In fact, the average number of calories per person available for direct human consumption increased by 24 per cent over that period, and the quality of diets (in terms of variety and mix of nutrients) also improved somewhat. Nonetheless, about 80 per cent of the total increase in both total agricultural production and food production over this period is attributable to increased population growth; that is to say, in order to feed the 1998 population at 1961 per capita levels, production needed to have increased by approximately 80 per cent of the increase that had actually occurred. In this sense, population growth has been the main factor in the expansion of demand for food production, and it is likely to remain the predominant factor in increased food requirements between 2000 and 2050[5] (Food and Agriculture Organization of the United Nations, 1996b; Johnson, 1999).

For most of the time since agriculture began, expansion of the area cultivated was the main way of increasing food production. However, in the latter half of the twentieth century, although the area cropped continued to increase, most of the growth in production came about through increased yields and increased cropping frequency, often in conjunction with expansion of irrigation. Worldwide the amount of cropland (land under arable or permanent crops) is estimated to have grown by 12 per cent between 1961 and 1998, while food production (measured by the estimated total number of calories available for direct human consumption) increased by 137 per cent. The average yield for land planted to cereal crops grew by 121 per cent over the period, and the amount of irrigated land nearly doubled (Food and Agriculture Organization of the United Nations, 2000a: 27 July 2000). In the future, most of the increase in food production is also expected to come about through agricultural intensification, although in some areas, primarily in Africa and Latin America, substantially more land is likely to come under cultivation as well (Alexandratos, 1999; Food and Agriculture Organization of the United Nations, 2000b).

Deforestation is the most conspicuous example of environmental change in farming. While the pace at which the remaining forests are disappearing is uncertain, studies across countries and ecological settings reveal a positive relationship between forest destruction and population growth in developing countries (Bilsborrow, 1994; Birdsall, 1994; Palloni, 1992). The strength of these correlations varies substantially and depends on access to and ownership of land, restrictions on foresting and the type of cultivation techniques used.

The types of forest conversion that are most obviously related to population growth are associated with successive shortening of fallow periods under shifting cultivation (as discussed by Boserup) and with harvesting of wood for fuel. Traditional long-fallow shifting cultivation is able to support a stable low population density without net deforestation, since areas that are cleared for cultivation are left fallow long enough for forest to regrow, generally 20-25 years or more (Pingali and Binswanger, 1987). When population density increases, the fallow times shorten so that forest does not regenerate, and eventually, shifting cultivation may give way to permanent farming settlements where land is brought into continuous cultivation. However, if this process is not achieved in a sustainable way, the land may be degraded and eventually be left unfit for further agricultural use.

In a review of land-use changes during the 1980s and early 1990s, Marcoux (2000) concludes that "in Africa, the effects of rural population pressure are very clear. The most prevailing transition has been that from closed forest to short fallow, typical of small-scale subsistence farming". The same study found that the expansion and intensification of shifting cultivation in the hills of South-East Asia are leading to deforestation, although the amount of land affected is much less than in Africa. Intensified shifting cultivation affects some areas in the Amazon region and in Yucatan, but this can account for only a minor proportion of deforestation in Latin America. Rather, in Latin America and some areas of Asia, but to a much lesser degree in Africa, colonization by farmers from other areas is a major factor in land-use changes. In-migration

of farmers from other areas is, in general, less directly related to population pressure than is the intensification of shifting cultivation. Sometimes colonization occurs in response to government policies promoting it, for reasons that may include a perceived overpopulation in the settlers' area of origin, but may also include such factors as a desire to establish better political control over sparsely settled areas. Colonization may also be a function of slow economic progress or limited employment opportunities in the broader economy, and not merely of population growth. Agricultural extensification also occurs when settled farmers expand into neighbouring forested land. In some settings, even if additional land is available, farmers may find it more economically productive to intensify production on already cleared land than to clear new fields; thus, population growth is likely to add to pressures to clear land in some settings, but this depends upon local economic circumstances.

In addition to its effects on expansion of cropland, population growth also increases the exploitation of forests and woodlands for fuelwood. The effect can stretch into the countryside well beyond settlements. Growing towns add to demand, and an increasing amount of forest and woodland is converted into charcoal and transported for use in town. This process may, however, be limited in more affluent settings where people can afford to purchase less bulky and cleaner-burning fuels such as kerosene. Thus the settings in which the causal connection between population growth and deforestation for either farming or fuel-harvesting appears most direct tend to be those characterized by poverty and low levels of development.

There are no reliable statistics showing, for the world as a whole or for major regions, how much of deforestation is attributable to conversion of forest to small-scale farming in response to population growth. In fact, even the amounts of change in cropland and in forest are very imprecisely measured. The best data on changing forest cover come primarily from repeated remote-sensing (mainly satellite) measurements, and it is difficult to relate changing vegetation patterns to their direct causes on the ground. Beyond this, deforestation tends to be a process rather than a one-time event, and the process may be set in motion by different forces than those that operate at a later stage. For instance, in some areas, roads constructed for logging, mining or other purposes open up previously inaccessible areas to immigration of farmers from other areas, and the area is progressively converted from forest to farming (or sometimes, ranching). The World Bank (1992) estimated that roughly 60 per cent of annual clearing in tropical moist forests was due to agricultural settlement. Marcoux (2000) mentions an estimate of about two thirds of deforestation in recent decades being attributable to shifting agriculture. On the other hand, during 1990-1995, according to Food and Agriculture Organization of the United Nations (FAO) estimates, land under temporary and permanent crops grew by under 10 per cent as much as the amount of forest declined (Waggoner and Ausubel, 2000). Bryant and others (1997) estimate that for "frontier forests"—those that remain in a largely natural state—roughly 40 per cent of the area is currently threatened (75 per cent outside of boreal areas), and logging is the main threat for 72 per cent of the threatened area, while mining, roads and other infrastructure threaten 38 per cent; expansion of farming, 20 per cent; and excessive vegetation removal including gathering of firewood, 14 per cent (some areas face more than one threat).

The need to feed a growing population is also placing mounting stress on water supplies in many parts of the world. While only 17 per cent of cropland is irrigated, the irrigated land produces nearly 40 per cent of the world's food (United Nations, 1997). On a global basis, irrigation accounts for more than 70 per cent of fresh water taken from lakes, rivers and underground sources (United Nations Environment Programme, 1999; United Nations, 1997). In addition, run-offs of agricultural pesticides and fertilizer are increasingly serious sources of water pollution in both developed and developing countries. While water is often inefficiently used, largely as a consequence of being underpriced, institutional mechanisms for implementing effective water management policies are often time-consuming, expensive and, in some cases, non-viable options. Population pressures are thus not the only, nor are they necessarily even the primary, cause of ineffective water use and pollution, but they do aggravate the magnitude of ecological damage.

A further set of concerns relates to degradation of agricultural land. Here the role of population growth and density depends heavily upon the social and technological setting. Intensive production to feed a dense population has not invariably led to land degradation. For instance, in some parts of Asia irrigated fields have maintained their productivity for centuries. In other cases, expansion into unsuitably hilly areas and increased cropping frequency have lead to serious erosion and reduced soil fertility (Cruz, 1994). Features of the land tenure system can determine whether farmers have an incentive to make the investments needed to maintain and improve soil quality. Government policies can affect farmers' access to inputs such as fertilizer, and the introduction of different cultivation practices can have a large effect on soil erosion. Most recent assessments conclude that problems of erosion, soil depletion and salinization and waterlogging associated with irrigation do not pose a threat to food production at the global level for the foreseeable future. However, such problems are currently serious at the local and regional levels in many areas. While many of these problems could be reversed using known and tested methods, local institutional constraints, compounded by poverty, often make it difficult to implement needed changes. Soil degradation may increasingly constrain food production in such settings unless corrective measures are adopted (Ruttan, 1999; Food and Agriculture Organization of the United Nations, 1996a; Smil, 2000; Scherr, 1999).

While issues of soil erosion and degradation have mainly local impacts—which may be serious (Ruttan, 1999; Johnson, 1999)—the vulnerability of modern crop varieties and livestock to insects, pathogens and weeds is a global problem. The success of high-yielding grains and other crops developed through modern agricultural research depends in part on control of pests. Over time, the latter tend to evolve resistance to the pesticides and herbicides that were initially effective in controlling them. Resistant pests tend to spread throughout wide areas, and the process is speeded by increased global travel and trade. The appearance of resistant

pests has often led growers to apply higher and higher amounts of increasingly ineffective chemicals, which then damage the surrounding environment and also represent a health risk to farm workers and the local population. There has been some success in developing more sustainable methods of managing pests and weeds, but farmers need access to both training and appropriate inputs in order to succeed with these methods (Food and Agriculture Organization of the United Nations, 1996a). Because crop pests and weeds co-evolve with the strategies used to combat them, there is a continuing need for ongoing research to develop both more resistant crop varieties and better methods of control. Concern has been expressed that an increasing fraction of agricultural research budgets is required just to maintain existing yields (Ruttan, 1999).

In summary, most assessments of the food situation conclude, explicitly or implicitly, that slower growth and earlier stabilization of population size would reduce the pressure to expand agricultural land and would allow more leeway in the pace at which yields will need to be raised in order to improve the adequacy of diets in poor countries. The production of more food has given rise to or aggravated numerous environmental problems, which are likely to constrain food production in some countries and regions. As Preston (1994) notes: "Population growth is not the only factor affecting the rate of resource degradation, and in many contexts it is undoubtedly not the most important factor . . . (There is) a huge array of obstacles to expanded food production and better resource management. These include weak land tenure systems, inadequate credit availability, biased agricultural prices and exchange rates, adverse tax policies, weak agricultural extension services, excessive Government control, and civil wars. But few if any of these problems will be resolved through rapid population growth. They are the context on which this growth will be imposed."

According to most recent assessments, environmental problems will not limit the ability to produce enough food at the global level for the foreseeable future. For instance, the agricultural economist Vernon Ruttan (1999) concludes: "If the world fails to successfully navigate a transition to sustainable growth in agricultural production, the failure will be due more to a failure in the area of institutional innovation than to resource and environmental constraints." A recent FAO assessment concluded that "with regard to poverty alleviation and food security, the inability to achieve environmentally sound and sustainable food production is primarily the result of human inaction and indifference rather than natural or social factors" (Food and Agriculture Organization of the United Nations, 1996a).

The outlook is less positive for ocean fisheries than for food production in general. Marine fisheries are a classic example of a common property resource. Although the conditions leading to overexploitation are reasonably well understood, there has been very limited success so far in attempts to manage fisheries more sustainably. According to a recent FAO assessment, "in the 1980s, it was widely anticipated that fisheries governance would improve substantially in parallel with the establishment of extended national jurisdiction under the United Nations Convention on the Law of the Sea. This was the case for countries that were able and had the will to strengthen their governance. (But) in many countries, governance has continued to languish for a variety of reasons, including a scarcity of the human, institutional and financial resources required to devise and implement management programmes; a lack of understanding, by both Governments and fisheries participants, of the potential benefits that good management can generate; and the reluctance of Governments to make unpopular decisions . . . The countries with the poorest governance are those whose populations face more pressing, fundamental problems such as war, civil disturbances, natural disasters and weak Government" (Food and Agriculture Organization of the United Nations, 1998).

Human population growth is likely to have played a role in increasing demand for fish, but most of the explanation for the rapid global rise in overfishing surely lies elsewhere. Improvements in transportation and processing techniques mean that fresh and frozen fish are accessible to a much more widely distributed population than in the past. Other innovations, such as onboard freezers, have allowed the construction of "factory ships" which can stay at sea with their catches for weeks instead of a few days only (Committee on Ecosystem Management for Sustainable Marine Fisheries, National Research Council, 1999). Fish are also a preferred food, for which demand tends to rise with increasing affluence. Unlike agricultural prices generally, the price of fish has risen, and this too tends to stimulate commercial efforts to harvest more (Food and Agriculture Organization of the United Nations, 1998). If uncontrolled, this trend will tend to continue up to the point where stocks become so depleted that the expense of catching the fish that remain will be greater than the price consumers will be willing to pay.

Non-renewable resources

Starting in the 1940s and 1950s, many observers feared that non-renewable mineral and fuel resources would soon be exhausted. However, since then, other environmental issues have increased in prominence, while concern about imminent shortages of non-renewable resources has receded. During recent decades, new reserves have been discovered, producing the seeming paradox that even though consumption of many minerals has risen, so has the estimated amount of the resource as yet untapped. In addition to newly discovered reserves, innovations in mining and processing technologies have also served to expand the usable resource base, so that ores and fuel deposits that previously had had no economic value became valuable reserves.

Since markets, or social institutions that approximate market processes, mediate the prices of commercially mined minerals and fuels, economists generally expect that the market will signal developing shortages of these commodities through rising prices, which then trigger responses that tend to conserve the remaining supply and also lead to substitution. In the 1990s, known reserves of many natural resources were more abundant and prices lower than they were 20 years previously, despite rising consumption (Livernash and Rodenburg, 1998). Price rises, when they occurred, have as expected prompted substitution of less costly alternative inputs or switching to more efficient processes, although some-

times—as in the case of rising oil prices—the adjustments may be slow and cause hardship.

It remains true that, with continuing depletion, the supply of a finite, non-renewable (and unrecyclable) resource will eventually vanish. Yet given our imperfect foresight, it is very unclear when and with respect to which resources shortages will develop. According to the National Research Council (1986, p. 13), "reflection on the past century's economic history suggests that unanticipated changes in tastes and technology drastically shifted the configuration of 'essential' resources". As the Council notes, slower population growth and stabilization of population at a smaller size may well put off the time when this occurs, although it is unclear that this would have any effect on the number of people who would, through time, eventually live at a given level of resource depletion. Adoption of more efficient, resource-sparing technologies would also delay resource exhaustion, of course, and "the fact that exhaustible resource consumption is highest in economies with high income levels . . . means that the trends in demand for resources in developed countries may be much more important in determining the rate of global resource use than the trends in developing countries" (ibid., p. 15).

Industrial pollution

Pollution of air and pollution of water are the principal environmental threats facing developed countries and a growing number of developing countries. Although the supply of materials used in industry and by households in developed economies is usually mediated through markets or, in some cases, controlled by governmental allocation, the by-products of mineral extraction, production and consumption have tended to fall on the common property resources of the air and water and to contaminate the land.

In order to decompose the impact of population and other factors on the environment, an accounting identity known as I = PAT has frequently been employed. A discussion of the I = PAT framework is presented in section C below.

Impact of the environment on population

The discussion so far has focused on the effects of demographic variables on the environment. A causal relationship can also be found in the opposite direction, with environmental change impinging on demographic outcomes, including health, mortality and migration. Safe drinking water, sanitation, atmospheric pollution, deforestation, desertification, depletion of the ozone level and climate change are actually or potentially major determinants of health. Despite dramatic improvements in the provision of freshwater supplies and basic sanitation in the last two decades, especially in underserved rural areas of developing regions, provision has not kept pace with growing needs. It is estimated that at least 1.1 billion people still lack access to safe drinking water, while almost 2.5 billion have not been served by adequate sanitation facilities (United Nations, 2000a, table 1). Another daunting challenge is that posed by the speed of urbanization in developing countries, which is straining the ability to maintain existing infrastructure, let alone extend services to the growing number of urban-dwellers. Between 2005 and 2025, the urban population of developing countries is expected to grow by some 2.4 per cent annually (United Nations, 2000c). The sustainability of urban development is jeopardized by the swelling demand both for water and sanitation, and for waste treatment facilities, which are already under enormous strains. The inability to properly treat urban waste will have serious consequences for the health status of urban populations.

The environmental hazards confronting developing regions—unsafe water, inadequate sanitation, indoor smoke from cooking fires and outdoor from coal burning—are different from and more immediately life-threatening than those associated with the affluence of developed countries such as greenhouse gas emissions, depletion of the stratospheric ozone layer, photochemical smog, acid rain and hazardous waste, issues that impinge on the welfare of current and future generations. A further threat is posed by the potentially deleterious impact of global climate change, including changes in the distribution of vector-borne diseases due to temperature changes. Assessments also suggest that tropical diseases have the potential to grow to epidemic proportions following modifications in patterns of land use to augment agricultural production. For example, a study of frontier expansion in the Brazilian Amazon concluded that colonization projects in the region made the risk of malaria transmission more likely. The success of these projects was seriously undermined by the significant fall in productivity from settlers contracting the disease (Castro and Singer, 2000). Poor environmental quality is linked to diarrhoeal diseases, respiratory infections and a variety of parasitic diseases, as well as cardiovascular diseases and cancer (World Health Organization, 1997).

C. Relating population and environment: the I = PAT framework

The demographic impact identity I = PAT expresses the environmental impact (I) of population (P), affluence (A) and technology (T) in a multiplicative perspective—the environmental impact of population is seen as amplifying the effects of affluence and technology in direct proportion to population size. The I = PAT identity was first introduced by Paul Ehrlich and John Holdren (1971) in the early 1970s as an instrument to assess the influence of population growth on the rising pollution levels in the United States. A variety of forms of the I = PAT identity have been used since then to analyse a wide range of issues, such as automobile pollution (Commoner, 1991), fertilizer use (Harrison, 1992), energy (Pearce, 1991) and air quality (Cramer, 1998). The environmental impact is usually taken as either utilization of a natural resource or emission of a pollutant. Population is normally represented as total population size. Affluence, in general, is represented by a measure of consumption (or output) per person, while technology is expressed as the environmental impact per unit of that economic consumption or output. The formula treats each factor as multiplying the environmental impact of the others. Most applications in fact focus on *changes* in I, P, A and T over a period of time rather than on the levels of the terms at a particular time. In this perspective, changes in P, A and T are viewed as the driving forces for changes in environmental impact.

The I = PAT formula implies that the situations in which population growth is likely to emerge as the dominant driving force for increased pollution or degradation are ones in which population growth is relatively rapid, but living standards and technology are stagnant or changing only slowly. In fact, though, the formula has most often been applied to pollution problems that are most commonly associated with affluent societies where economic and technological change has been extremely rapid during the twentieth century. In such cases it can be anticipated that the role of population growth may emerge from the analysis as smaller than that of changes in affluence and technology.

Many researchers have accepted the I = PAT formula as a useful tool for discussing and attempting to quantify, at least roughly, the relative importance of the driving variables. At the same time, however, this method has been criticized for reducing complex phenomena to quantifiable terms which provide little insight into the causal relationships between population dynamics and environmental outcomes at the local level or within critical regional ecosystems. It ignores or obscures, for instance, the possibility that increasing population size or density might themselves induce technological changes (à la Boserup) or that increased affluence might itself provide a force that drives population and technological change. On the other hand, it is typical of situations involving overuse and degradation of common property resources—as is usually the case with regard to environmental pollution—that damage-limiting feedback effects do not operate effectively, or do not begin to do so until considerable damage has already occurred. In such circumstances, any factor that tends to increase the output of the goods and services that generate pollution as a by-product will tend to increase the total burden of pollution. To the extent that increase in population size increases total demand for such goods, it is therefore reasonable to regard it as having an amplifying effect on the other factors that also contribute to pollution.

In order to lessen the problem of excessive generality, some studies have separated the demographic impact into components specific to different sectors such as households, urban or rural areas, industrial, residential etc., while others have incorporated induced effects and population characteristics into the model. For instance, Liddle (2000) showed the importance of accounting for factors such as public investment and age structure for attaining more accurate estimates of environmental impact. A model developed by O'Neill, MacKellar and Lutz (forthcoming) partitioned the impact of population on carbon dioxide (CO_2) into two terms: changes in numbers of households and changes in number of persons per household. This model allowed for the observed tendency of household size to decrease as population growth has slowed, as well as for the fact that energy use and hence CO_2 emissions tend to be lower if the average household size is large than if the same number of people live in a greater number of small households. Taking projected decreases in persons per household into account produced projections of global emissions 25 per cent higher by 2100 than when only trends in total population size were considered.

More recently, it has become usual to convert multiplicative I = PAT models of historical or projected trends to additive ones, expressed as follows in terms of the growth rate of each element:

$$r_I = r_p + r_A + r_T$$

where r_x is the exponential growth rate of variable x.

Growth rate decompositions, however, present a number of inherent limitations (see O'Neill, MacKellar and Lutz, forthcoming). In the first place, it is the absolute amount of a specific outcome (for example, pollutant emissions) that damages the environment, not its annual growth rate. Yet, examining growth rates is arguably relevant to understanding the sources of past and likely future change in environmental factors, so long as attention to growth rates does not become a substitute for attention to the scale of the problem. Another problem is "heterogeneity bias": because some environmental outcomes (per capita greenhouse gas emissions, for instance) are lowest where population growth is highest, decompositions at the global level overstate the contribution of population growth. The bias can be very serious. For example, Lutz (1992, cited in Preston, 1994) calculated that, considering only global averages, and holding CO_2 emissions constant at their then-current level, population growth alone would be projected to increase global CO_2 emissions by 86 per cent in 60 years. However, if the calculations were done separately for each region (with regional CO_2 emissions held constant) and then added up, the effect of population growth would be to increase global emissions by only 20 per cent. In general, higher per capita gross national product (GNP) is associated with both lower population growth, and lower levels of pollution, as richer countries tend to use less polluting techniques (World Bank, 1992). Because of this, applications of the I = PAT framework at the global level can produce seriously misleading results.

One way suggested by Preston (1996) of incorporating these interactions into the analysis is to express the equation in terms of variances rather than means. He argued that "this change also moves the assessment in the direction of causal analysis, which is principally directed towards understanding the sources of variation in outcomes" (p. 13). By applying the formula for calculating the variance of a sum (in this case, the sum of three growth rates), the I = PAT identity becomes:

$$\sigma^2_I = \sigma^2_P + \sigma^2_A + \sigma^2_T + 2COV_{PA} + 2COV_{PT} + 2COV_{AT}$$

where σ^2 represents the individual variance of each variable, and the COV terms represent the covariance between each pair of variables.

Preston applied this formula to five different environmental hazards: CO_2 emissions (for nine global regions); and carbon monoxide emissions, nitrogen oxide (NO_x) emissions, pesticide use in agriculture, and nitrogen fertilizer usage in agriculture (for Organisation for Economic Co-operation and Development (OECD) countries only). In table IV.1, Preston's results are shown for three of the variables he analysed, and new calculations have been added in the case of CO_2 and nitrogen fertilizer usage, based on updated data with a much broader coverage of countries.

For example, the first row of table IV.2 shows results for a variance-covariance decomposition of changes in CO_2 emissions from commercial energy use for the period 1980-1996, for 108 countries covering both more and less developed re-

gions. The variance in average annual percentage growth rates of CO_2 emissions has a value of 11.61, while that of average annual rates of population change, at 1.18, is only 10 per cent of the variance of CO_2 growth. Population growth by itself can account for only a small portion of the international variation in growth of CO_2 emissions. The covariance between population growth and "affluence" is negative—countries with more rapid population growth have in recent years experienced slower growth in GNP per capita—while that between population growth and the technology term is positive. If all three of the terms involving population are attributed to population change, then only about 5 per cent of the total variance of growth in CO_2 emissions is attributable to population growth (1.18 - 2.06 + 1.50 = 0.062, which is 5 per cent of the total variance, 11.61). For the remaining rows of the table, results regarding the relative contribution of population growth are similar: the variance in population change amounts to between 1 and 10 per cent of the variance in growth of each environmental hazard, and the three terms involving population, when summed, amount to 10 per cent or less of the variance in the growth of the environmental hazard. In all cases, the technology term—representing emissions per unit of the affluence or output term—stands out as the most important. Except in the cases of pesticide use in OECD countries and fertilizer use in more developed countries, the affluence and technology terms are negatively associated. This is consistent with other research showing that as national affluence increases, less polluting technologies tend to be adopted. (Unfortunately, this effect is not in general strong enough to completely cancel out the "affluence" effect—richer countries still generally have higher levels of per capita outputs of various types of pollution.)

In addition to its application to analysing changes in pollution over the recent past, the I = PAT formula has also been employed in projections, to show the implications of alternative assumptions about future trends—for example, the projections by O'Neill, MacKellar and Lutz (forthcoming) and by Bongaarts (1992) of CO_2 emissions. In general, these studies show that, particularly in the near-term future, alternative plausible assumptions about the course of the "affluence" and, especially, "technology" factors have a much larger impact on projected emissions trends than do alternative assumptions about population trends. However, they also suggest that the greater the concern with long-range futures, the more important should be population policies in the array of strategies for enhancing the environmental condition. In the case of greenhouse gas emissions, for instance, a common conclusion is that policies to accelerate demographic transition would reduce emissions significantly only in the long run (after the second half of this century); in the near to medium term, policies impinging on per capita emissions would have a far greater effect on emission reduction.

Yet, as Preston (1994, p. 16) observes, analyses such as these may not provide the best way of specifying the problem for policy purposes. "The calculations take no account of the costs of implementing various policies. Even if population growth were playing a minor role in producing a particular problem, population policy may provide one of the most cost-effective ways of addressing it." The issues have very rarely been discussed with this in mind, however. In one illustrative analysis based on estimates of the lifetime addition to CO_2 emissions contributed by each person, the cost of preventing an (unwanted) birth through a government-subsidized family planning programme and the cost of reducing emissions through a carbon tax, Nancy Birdsall (1994) estimated that over a human lifetime it would cost less than half as much to reduce emissions indirectly through support of family planning as through implementation of a car-

TABLE IV.2. ANALYSIS OF THE INTERNATIONAL VARIANCE IN GROWTH RATES OF DIFFERENT FORMS OF ENVIRONMENTAL HAZARDS

Hazard	*Units*	*(I)* σ^2_I	=	*(P)* σ^2_P	+	*(A)* σ^2_A	+	*(T)* σ^2_T	+	*2 × covariances* *PA*	+	*PT*	+	*AT*
CO_2 emissions,[a] 1980-1996														
Total	108 countries	11.61		1.18		4.99[b]		8.53		-2.06		1.50		-2.54
More developed countries	27 countries	3.58		0.18		1.23[b]		2.57		0.05		0.13		-0.58
Less developed countries	81 countries	12.22		0.67		6.07[b]		9.55		-1.92		0.12		-2.27
Carbon monoxide emissions, 1970-1987	15 OECD countries	8.83		0.13		1.04[c]		11.70		-0.04		-0.52		-3.48
Nitrogen oxide emissions, 1970-1987	16 OECD countries	4.89		0.11		1.60[c]		7.65		0.06		-0.12		-4.40
Pesticide use in agriculture, 1975-1986	10 OECD countries	10.98		0.07		1.13[d]		8.96		-0.28		-0.60		1.72
Fertilizer consumption, 1980-1996														
Total	125 countries	33.60		1.09		5.94[e]		27.56		-0.20		2.35		-3.14
More developed countries	26 countries	16.73		0.19		3.43[e]		9.22		0.34		0.00		3.55
Less developed countries	99 countries	31.13		0.57		6.64[e]		28.99		-0.20		-0.28		-4.59

Sources: Carbon monoxide emissions, nitrogen oxide emissions and pesticide use in agriculture from Preston (1994); CO_2 emissions and fertilizer consumption calculated from World Bank (1999), CD-ROM.

[a] CO_2 emissions from commercial energy use.

[b] Indicator: GNP per capita.

[c] Indicator: vehicle kilometres per capita.

[d] Indicator: agricultural production per capita.

[e] Indicator: cereal production per capita (dry grain only).

bon tax.[6] And, given the high levels of unwanted fertility and "unmet need" for family planning, the potential impact of lower population growth through better access to family planning services could be large. Based on surveys conducted in a large number of developing countries, Bongaarts (1994) estimated that in the early 1990s, approximately one in four births in the developing world (excluding China) was unwanted.

D. Conclusions

Concerns about population and the environment have been evolving over time. Beginning in the late 1940s and 1950s, environmental concerns focused almost exclusively on what was felt to be the negative impact of population growth on non-renewable natural resources and food production, echoing Malthus's original concerns. Virtually no attention was given to environmental side effects. During the 1960s and 1970s, the focus was widened to incorporate the by-products of production and consumption, such as air and water pollution, waste disposal, pesticides and radioactive waste. By the 1980s and into the 1990s, a new dimension was added, encompassing global environmental changes, including acid rain, global warming and ozone depletion, biodiversity, deforestation, migration and new and re-emerging diseases

Many of the environmental issues of greatest concern today involve resources that are to a greater or lesser degree "common property resources". Economic theory predicts, and much experiential evidence demonstrates, that unhindered access to such resources leads to overuse, misuse, and quality degradation. In the absence of effective social mechanisms to limit and ameliorate the tendency for common property resources to be overused and degraded, population growth will tend to exacerbate such problems. Population growth is rarely the only factor operating, though, for especially during recent decades, population growth has gone hand in hand with massive technological and social change.

While all the environmental problems discussed above are largely or entirely the result of human activities, they vary in the degree to which they can be linked directly to population size, growth or distribution. It is generally not possible to partition "blame" for environmental problems among the various contributing factors, except in a very rough manner.

In considering responses to environmental problems, it is important to recognize that social-institutional factors can be as important as, if not more important than, technological ones. Even though the overall social as well as environmental benefit to such organizational change may be large, the process is likely to be contentious and politically difficult. Indeed, there are apt to be losers as well as winners in any such process; achieving an equitable transition represents a major social and political challenge at all levels, from local to national—and even international, when we consider problems that have a global impact, such as emissions of greenhouse gases.

Population growth is the main force driving increases in agricultural demand. While most recent expert assessments are cautiously optimistic about the ability of global food production to keep up with demand for the foreseeable future (that is to say, until approximately 2030 or 2050), it is important to note that these assessments are predicated upon the expectation that population growth rates will continue to decline. At the same time, food insecurity, associated with poverty, is projected to persist for hundreds of millions of people. A host of environmental side effects derive from farming, and these pose serious threats to sustainability of food production in some areas. However, FAO has concluded that "with regard to poverty alleviation and food security, the inability to achieve environmentally sound and sustainable food production is primarily the result of human inaction and indifference rather than natural or social factors" (Food and Agriculture Organization of the United Nations, 1996a).

The need to feed a growing population is placing mounting stress on water supplies in many parts of the world. On a global basis, irrigation accounts for more than 70 per cent of fresh water taken from lakes, rivers and underground sources. While water is often inefficiently used, it can be very difficult to implement effective water management policies, especially in poor areas. Population pressures are thus not the only, nor even necessarily the primary, cause of ineffective water use and pollution, but they do aggravate the magnitude of ecological damage.

Population growth, through its effects on the expansion of cropland and the harvesting of wood for fuel, is also an important factor contributing to deforestation and is thought to be the predominant factor in some areas. Commercial logging and other factors predominate in other areas. In general, global and regional data in this area are quite weak, though improving. There have, however, been many local area studies relating to population and land use, and these can help diagnose problems and point to solutions at the local level (see Marquette and Bilsborrow, 1999).

Pollution of air and pollution of water are the principal environmental threats facing developed countries and a growing number of developing countries. High rates of emission of CO_2 and other greenhouse gases are associated with high levels of development, and this is also true of many types of pollution with a local or regional, rather than a global, impact. In general, population growth appears to be much less important as a driving force of such problems than are economic growth and technology. Nevertheless, other things being equal, continued increase in population plays a role by increasing aggregate economic demand and hence the volume of pollution-causing production.

Although recent decades have witnessed significant environmental degradation, the nature and causes of environmental problems, as well as the need for appropriate environmental management, are being increasingly recognized. Environmental use and poverty reduction are integrally linked with demographic, economic and political change. While rapid population growth can exacerbate problems associated with poor environmental quality and poverty, policies that promote a more equitable income growth, empower the poor with education and health and provide incentives for sound environmental management can break this "vicious cycle". In such a setting, population policies can be an important element for promoting socio-economic development, while fostering long-term environmental progress.

Even for those environmental issues for which population change appears to be a relatively minor factor by comparison with recent trends in per capita consumption or in pollution-causing technologies, over the longer term the effect of alternative paths of population growth will assume more importance. As noted by Preston (1994): "The widely recognized momentum of population growth cuts both ways. While it reduces the apparent advantages of lower fertility in the short run, it may increase them in the long run. The fact that population growth is a ponderous process means that whatever happens today has multiplier effects in each successive generation. In a very real sense, today's births are tomorrow's momentum. The more concerned we are with long-term futures, the more important are population policies in the array of strategies for enhancing the human condition."

NOTES

[1]For instance, a variety of traditional collective forest management arrangements are discussed in a special issue of the FAO journal *Unasylva* (Food and Agriculture Organization of the United Nations, 1995).

[2]For example Ridker (1979), reviewing projections of consumption of selected resources and pollution for the 50-year period 1975-2025, noted that for longer periods, beyond 2050, "simple extrapolation would indicate that a change in population growth assumptions makes a significant difference . . . (but) that fact is irrelevant since nothing useful can be said about what might happen to population growth rates, tastes, technology, or any other factor that might influence the situation that far into the future".

[3]The term "scenario" is in fact employed for the projections of population up to 2150 (see figure II.2), as well as for the modelling of factors that may affect climate change and other environmental factors by the Intergovernmental Panel on Climate Change (2000), the Stockholm Environmental Institute (Raskin and others, 1998) and the World Resources Institute–Santa Fe Institute–Brookings Institution "2050 Project" (Hammond, 1998).

[4]Commoner (1991) makes a similar observation with respect to several other polluting technologies in both more and less developed countries.

[5]Over the longer run, the type of diet that people will choose will also have a substantial impact on the amount of food that needs to be produced. In particular, a meat-rich diet requires more resources to produce than a cereal-based diet. Experience shows that as populations become more affluent, they tend to choose diets that include more meat and rich foods, and to produce such diets an increasing fraction of the cereal and root crops grown are used as feed rather than directly consumed by people. However, in most countries dietary patterns are slow to change, and it is not clear how persistent cultural differences in food choices will prove to be. Over the period 1961-1998, the proportion of cereal grains used as animal feed grew from 34 to 36 per cent, and the estimated amount of land used as permanent pasture grew by 9 per cent (Food and Agriculture Organization of the United Nations, 2000a: August). These changes, while important, accounted for a much smaller amount of the total increase in agricultural production than did the increase in the total number of people to be fed.

[6]Obviously, all the statistics involved in such a calculation are very imprecise. Birdsall estimated the cost of averting a birth through family planning programmes at $220, which, combined with estimates of lifetime carbon emissions per person, implies that the cost of reducing carbon emissions by one ton through family planning would be $4. A wide range of estimates has been offered for the size of the carbon tax that would be required to reduce emissions by a given amount. Birdsall's estimate of $20 per ton of carbon to reduce emissions by 10 per cent is well within the range.

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V. MIGRATION, POPULATION CHANGE AND THE RURAL ENVIRONMENT

Population change, particularly that induced by migration, has had an important impact on the rural environment. Most forested land, which includes tropical rainforests, and subtropical and temperate forests, as well as the non-forested agricultural lands and drylands from which humankind derives most of its food and sustenance, is located in rural areas. Most of the world's gene pool is concentrated in rural environments, with the tropical rainforests and coral reefs having the highest densities per unit area, although other biota, such as highland forests, wetlands, savannah and deserts, also contain unique floral and faunal biodiversity. All of these areas are threatened to varying degrees by the growth and intrusions of human populations and by the exploitation to which they are subject in order to satisfy perceived human needs. Despite two centuries of rapid urbanization, the majority of the world's population still lives in rural areas, and for at least two more decades most population of the developing world will continue to be rural.

This present chapter considers the interrelations between rural population growth, migration and the rural environment, focusing on changes experienced since 1950. It reviews past trends of rural population growth and their effects on increasing population densities with respect to agricultural land. It discusses a general framework useful in conceptualizing the interrelations between rural population growth, migration and changes in the rural environment, highlighting the importance of human-induced deforestation. Several case studies are then examined to establish the extent to which migration to the agricultural frontier has affected the rural environment, particularly in terms of deforestation and destruction of vegetation in dryland areas. Lastly, the role of environmental factors in inducing migration is discussed.

A. THE SIZE AND GROWTH OF THE RURAL POPULATION

The twentieth century witnessed a profound shift of the world population from rural to urban areas. Thus, whereas 66 per cent of the world population lived in rural areas in 1960, by the turn of the millennium that proportion had declined to 53 per cent. Because urbanization began earlier or was faster in the more developed regions and in Latin America, by 2000 only a quarter of their population lived in rural areas. In contrast, the population of Africa and Asia was still nearly two thirds rural by 2000 (table V.1). Despite the reduction of the proportion rural, the rapid increase of the world population during 1960-2000 involved a significant increase of the rural population, from 2 billion in 1960 to 3.2 billion in 2000. This increase was entirely due to the growth in the less developed regions, since the rural population of the more developed regions had declined during the period. Particularly large gains occurred in Asia, whose rural population rose from 1.3 billion to 2.3 billion during 1960-2000, and in Africa, where the rural population increased from 225 million to 487 million. Over the next 30 years, virtually no growth is expected in the rural population of the world, and even that of the less developed regions will increase by less than 100 million (United

TABLE V.1. RURAL POPULATION, RATE OF GROWTH AND RURAL DENSITY IN TERMS OF LAND USED FOR ARABLE AND PERMANENT CROPS, 1960-2030

	Percentage of the population in rural areas			*Rural population (millions)*			*Rate of growth of the rural population (percentage)*		*Land in arable and permanent crops (millions of hectares)*		*Persons per hectare of land in arable and permanent crops*	
Major area	*1960*	*2000*	*2030*	*1960*	*2000*	*2030*	*1960-2000*	*2000-2030*	*1961*	*1998*	*1961*	*1998*
World	66.4	53.0	39.7	2 005	3 210	3 223	1.18	0.01	1 346	1 512	1.51	2.10
Less developed regions	78.4	60.1	43.8	1 652	2 925	3 023	1.43	0.11	676	855	2.49	3.37
More developed regions	38.6	24.0	16.5	353	285	200	-0.54	-1.19	670	656	0.52	0.44
Africa	81.5	62.1	45.5	225	487	640	1.93	0.91	155	202	1.48	2.34
Asia	79.2	63.3	46.6	1 348	2 331	2 272	1.37	-0.09	484	556	2.84	4.13
Europe	42.0	25.2	17.4	254	184	120	-0.81	-1.42	345	311	0.73	0.60
Latin America and the Caribbean	50.7	24.7	16.8	111	128	122	0.37	-0.18	102	159	1.09	0.80
Northern America	30.1	22.8	15.6	61	71	58	0.35	-0.65	226	225	0.27	0.31
Oceania	33.6	29.8	25.6	5	9	11	1.35	0.51	35	59	0.15	0.15

Sources: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, "World urbanization prospects: the 1999 revision", data tables and highlights (ESA/P/WP.161), March 2000; and Food and Agriculture Organization of the United Nations, statistical databases: land use, http://apps.fao.org/page/collections, 1 July 2000.

Nations, 2000b). The continued shift of population from rural to urban areas through the expansion of the urbanized territory and the flow of migrants from rural to urban areas together with the overall decline of population growth will lead to reductions of the rural population in all major areas except Africa and Oceania.

Rural population growth has been particularly rapid in the regions of Africa and in Melanesia and Micronesia (table V.2), surpassing in most cases 1.8 per cent per year during 1960-2000. Although a reduction in rates of rural population growth is expected in all regions, 10 of the 21 regions constituting the world are expected to maintain positive rates of growth during 2000-2030. As a consequence, substantial increases in the rural population are likely in Eastern Africa, Middle Africa, Western Africa, Melanesia and Micronesia. The highest rates of rural population growth are expected in Middle Africa, which includes countries and geographical areas characterized by high population density and civil conflict. Similarly, most countries of Eastern Africa, which is also expected to have high rural population growth, already have seriously degraded rural environments (including large semi-arid areas with little agricultural potential) and difficulties in feeding their populations (Food and Agriculture Organization of the United Nations, 1996; Cleaver and Schreiber, 1994; Higgins and others, 1982). Both South-central and Western Asia are expected to experience modest growth of the rural population, but already have high rural population densities relative to arable land. Lastly, Central America, including Mexico, is the only region of Latin America expected to experience an increase of the rural population; this region includes several densely populated countries that have had difficulty producing sufficient food and other agricultural output to achieve sustained economic growth in recent decades (Leonard, 1987).

Most of the rural population of the world is concentrated in a few countries. The 35 countries listed in table V.3 account jointly for 85 per cent of the world's rural population in 2000. Three (China, India and Indonesia) have more than 100 million people living in rural areas and by 2030 Bangladesh and Pakistan will have also passed that threshold. Of the 10 countries with the largest rural populations in 2000, most will continue to experience rural population growth (the exceptions being China, Indonesia, Thailand and the United States of America). However, these populous countries will not experience the fastest rates of rural population growth. Countries with smaller rural populations, such as Uganda and Yemen, are expected to see their rural population grow at more than 2 per cent per year; and rural growth will likely also exceed 1.5 per cent per year in Afghanistan, the Democratic Republic of the Congo and Ethiopia. Countries that experience high rates of rural population growth are more likely to face problems of environmental degradation in rural areas. The data in table V.3 for these 34 countries show that the rise in rural population density (measured as persons per hectare of land in arable and permanent crops) during 1960-2000 was directly linked to the rate of rural population growth. Although most developing countries with large rural populations experienced a rise in the land area in arable and permanent crops, rural population growth was so rapid that it outstripped the increases in agricultural land. Consequently, in countries

TABLE V.2. RURAL POPULATION AND RURAL GROWTH RATE BY MAJOR AREA AND REGION, 1960-2030

Major area or region	*Rural population (millions)*			*Rural rate of growth (average annual percentage)*	
	1960	*2000*	*2030*	*1960-2000*	*2000-2030*
World	2 005.2	3 210.0	3 222.6	1.18	0.01
More developed regions	353.3	285.0	199.7	-0.54	-1.19
Less developed regions	1 651.9	2 925.0	3 022.9	1.43	0.11
Africa	225.4	487.3	640.2	1.93	0.91
Eastern Africa	76.4	182.4	259.9	2.18	1.18
Middle Africa	26.1	61.8	96.1	2.15	1.47
Northern Africa	46.8	85.3	88.6	1.50	0.13
Southern Africa	11.4	24.3	22.1	1.89	-0.31
Western Africa	64.6	133.5	173.6	1.81	0.88
Asia	1 348.4	2 330.7	2 271.8	1.37	-0.09
Eastern Asia	613.0	913.5	776.3	1.00	-0.54
South-central Asia	507.6	1 035.3	1 116.7	1.78	0.25
South-eastern Asia	185.0	325.9	313.4	1.42	-0.13
Western Asia	42.8	56.1	65.5	0.67	0.52
Europe	254.0	184.0	120.4	-0.81	-1.42
Eastern Europe	132.1	88.4	55.9	-1.00	-1.52
Northern Europe	20.1	15.3	11.1	-0.68	-1.08
Southern Europe	59.7	48.4	31.2	-0.52	-1.47
Western Europe	42.2	32.0	22.2	-0.69	-1.22
Latin America and the Caribbean	110.7	128.3	121.5	0.37	-0.18
Caribbean	12.2	14.1	13.0	0.37	-0.28
Central America	26.3	44.3	47.5	1.30	0.23
South America	72.2	69.9	61.0	-0.08	-0.45
Northern America	61.4	70.6	58.1	0.35	-0.65
Oceania	5.3	9.1	10.5	1.35	0.51
Australia/ New Zealand	2.6	3.4	3.2	0.74	-0.20
Melanesia	2.4	4.9	6.4	1.86	0.89
Micronesia	0.1	0.3	0.4	1.98	1.06
Polynesia	0.2	0.4	0.4	1.25	0.57

Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, "World urbanization prospects: the 1999 revision", data tables and highlights (ESA/P/WP.161), March 2000.

such as the Democratic Republic of the Congo, Ethiopia, Kenya and Yemen, rural population density more than doubled, while it rose by over 70 per cent in Bangladesh, India, Myanmar, Nigeria, Pakistan and Viet Nam. By 1998, rural population density surpassed 6 persons per hectare in Bangladesh, China, Egypt, Nepal, Sri Lanka, Viet Nam and Yemen, and was over 4 persons per hectare in another seven developing countries (table V.3). If there was no further increase in the land in arable and permanent crops in the next 30 years, most of these countries would experience a further rise in

TABLE V.3. RURAL POPULATION AND RURAL GROWTH RATE OF COUNTRIES ACCOUNTING FOR 85 PER CENT OF THE WORLD'S RURAL POPULATION, ORDERED ACCORDING TO THE NUMBER OF PERSONS PER HECTARE OF LAND IN ARABLE AND PERMANENT CROPS IN 2000

Country	Rural population (millions)			Persons per hectare of land in arable and permanent crops			Rural growth rate (percentage)	
	1960	2000	2030	1961	1998	2030	1960-2000	2000-2030
Bangladesh	48.8	97.5	105.2	5.6	11.5	12.6	1.73	0.25
Egypt	17.3	37.5	40.3	6.8	11.0	12.2	1.94	0.24
Viet Nam	29.6	64.1	74.9	5.0	8.6	10.3	1.93	0.52
Yemen	4.8	13.6	25.8	3.6	7.9	16.0	2.63	2.12
Sri Lanka	8.1	14.4	14.1	5.4	7.5	7.4	1.43	-0.08
Nepal	9.0	21.1	29.7	5.0	6.8	10.0	2.14	1.14
China	552.2	867.6	743.9	5.3	6.4	5.5	1.13	-0.51
Japan	35.3	26.9	18.0	5.8	5.5	3.7	-0.68	-1.34
United Republic of Tanzania	9.7	22.5	28.2	3.7	4.8	6.1	2.10	0.75
Ethiopia and Eritrea	22.6	54.7	87.3	2.0	4.7	7.9	2.21	1.56
Kenya	7.7	20.1	20.2	2.0	4.4	4.5	2.40	0.02
Democratic Republic of the Congo	11.9	36.0	59.8	1.7	4.4	7.6	2.77	1.69
Pakistan	38.9	98.5	123.7	2.4	4.3	5.6	2.32	0.76
India	362.9	725.4	749.3	2.3	4.2	4.4	1.73	0.11
Indonesia	82.2	125.3	103.6	3.2	4.1	3.3	1.05	-0.63
Myanmar	17.6	33.0	32.0	1.8	3.2	3.2	1.58	-0.10
Philippines	19.2	31.4	29.9	2.9	3.1	3.0	1.23	-0.17
Uzbekistan	5.7	15.4	18.5	..	3.0	3.8	2.50	0.62
Uganda	6.2	18.7	34.7	1.6	2.6	5.1	2.75	2.06
Thailand	23.1	48.1	45.1	2.1	2.3	2.2	1.84	-0.22
Afghanistan	9.9	17.7	29.4	1.3	2.1	3.7	1.46	1.69
Nigeria	32.3	62.5	72.0	1.1	2.0	2.3	1.65	0.47
Italy	20.4	18.9	11.8	1.3	1.7	1.1	-0.19	-1.57
Iran (Islamic Republic of)	14.2	26.0	25.2	0.9	1.4	1.3	1.51	-0.11
South Africa	9.3	20.0	17.0	0.7	1.2	1.1	1.92	-0.55
Sudan	10.0	18.8	20.7	0.9	1.1	1.2	1.58	0.32
Poland	15.4	13.4	9.0	1.0	0.9	0.6	-0.36	-1.32
Mexico	18.2	25.3	24.4	0.8	0.9	0.9	0.83	-0.12
France	17.2	14.4	10.3	0.8	0.7	0.5	-0.44	-1.11
Turkey	19.3	16.4	11.6	0.8	0.6	0.4	-0.41	-1.16
Brazil	40.1	31.8	25.0	1.4	0.5	0.4	-0.57	-0.80
Ukraine	22.7	16.1	10.4	..	0.5	0.3	-0.86	-1.45
United States of America	55.9	63.4	51.7	0.3	0.4	0.3	0.32	-0.68
Russian Federation	55.5	32.8	20.0	..	0.3	0.2	-1.32	-1.65

Sources: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, "World urbanization prospects: the 1999 revision", data tables and highlights (ESA/P/WP.161), March 2000; and Food and Agriculture Organization of the United Nations; statistical databases: land use, http://apps.fao.org/page/collections, 1 July 2000.

rural population density, which might lead to further increased pressures on rural environments.

However, it is unlikely that the amount of land devoted to arable and permanent crops will remain constant. Between 1961 and 1998, this area increased by over 50 per cent in Latin America and Oceania, by 30 per cent in Africa and by 15 per cent in Asia (see table V.1). In the future, at least two mutually countervailing forces will continue to lead to changes in arable land: the absorption of agricultural land by expanding urban areas and the extension of agricultural land through the colonization of the agricultural frontier. Both processes involve the redistribution of population over a country's territory, usually brought about by migration. Rural-urban migration is one of the components of growth of the urban population, a growth that generally leads to the geographical expansion of cities. Because of the importance of urbanization, rural-urban migration has dominated the academic literature and policy discussions. However, in countries where most of the population still lives in rural areas, rural-rural migration tends to be more common (table V.4). Data allowing a global assessment of the magnitude of the different types of migration flows within countries are not available, but for 11 of 14 developing countries (including some of the most populous, such as Brazil, India and Pakistan) rural-rural migration was larger than rural-urban migration (data refer mostly to the 1980s).[1] This fact should be borne in mind in the discussion below on the role of rural-rural migration in the analysis of linkages between popula-

tion and the rural environment since it is through (out-) migration that the population of a rural area may respond to pressures stemming from a deteriorating environment, and it is via (in-) migration that human populations may exert rising pressure on environments in rural areas of destination. These points are developed further below.

B. Conceptualizing the linkages between population, migration and the rural environment

To analyse the impact of population on the rural environment, it is useful to identify key measures of rural environmental degradation, which at minimum must include deforestation, soil desiccation, and other measures of soil degradation.[2] However, other forms of degradation are also directly associated with the destruction of vegetation (habitat), including microclimate changes in the immediate area, global warming (deforestation is estimated to contribute 15-30 per cent to global warming) and loss of biodiversity (55 per cent of all living species are estimated to live in the tropical rainforests). Although soil degradation is difficult to document, a global assessment of the extent of human-induced soil degradation in the 1980s found that 20 per cent of all the vegetated land in the developing world had been degraded (Oldeman, van Engelen and Pulles, 1990). Deforestation was found to be a major cause of soil degradation, accounting for 40 per cent in Asia and South America, 22 per cent in Central America, and 14 per cent in Africa. On a global scale, the World Bank (1991) also attributed 60 per cent of recent deforestation in the developing world to the advance of the agricultural frontier, 20 per cent to logging operations (including mining and petroleum) and 20 per cent to fuelwood use. The importance of these three factors varied across regions and from one country to another, but demographic factors have had a bearing on deforestation caused by the advance of the agricultural frontier and that associated with fuelwood use (Food and Agriculture Organization of the United Nations, 2000).

Since the first hunter-gatherers depleted game in their immediate vicinity, humans have resorted to migration as a mechanism for reconciling human wants to available resources. Migration has also been a critical factor in the advance of the agricultural frontier throughout history, but as the frontier becomes settled, the natural increase of the settler populations also becomes important in terms of the impact of population growth on deforestation and land degradation. Analysing the linkages between population, migration and the rural environment is complex because population pressure and environmental deterioration may both induce out-migration as well as be consequences of migration in areas of destination. Thus, environmental change may both induce migration and be the consequence of it. While separating the two is somewhat artificial, it is useful in conceptualizing the processes involved. To examine first the effects that environmental factors may have on migration, recall that migration is mainly determined by perceived differences in socio-economic conditions between places. The factors that propel a person to leave his or her place of origin are often referred

TABLE V.4. MIGRANTS BY TYPE OF FLOW, ACCORDING TO URBAN OR RURAL ORIGIN AND DESTINATION

			Percentage			
Country	*Census year*	*Type of data*	*Rural-urban*	*Urban-urban*	*Rural-rural*	*Urban-rural*
Africa						
Botswana	1988	Place of birth	60.0	8.0	29.0	3.0
Côte d'Ivoire	1986	Previous residence	14.8	44.2	20.3	20.7
Egypt	1976	Inter-state	26.0	55.2	12.0	6.8
Ghana	1988	Previous residence	4.6	48.5	9.5	37.3
Asia						
India	1971	Place of birth	14.6	10.4	69.1	5.9
India	1981	Place of birth	16.7	11.9	65.4	6.1
Malaysia	1970	Residence in 1965	8.8	20.0	38.8	32.4
Pakistan	1973	Residence in 1965	17.3	38.8	32.6	11.4
Philippines	1973	Residence in 1965	39.3	25.2	19.7	15.8
Republic of Korea	1966	Residence in 1961	36.6	32.0	21.2	10.2
Republic of Korea	1975	Residence in 1970	43.5	28.7	14.0	13.8
Republic of Korea	1995	Residence in 1990	12.8	85.7	1.5	7.0
Thailand	1980	Residence in 1975	15.4	18.5	56.0	10.2
Latin America and the Caribbean						
Brazil	1970	Place of birth (inter-district)	17.9	50.4	25.7	6.0
Brazil	1970	Place of birth (inter-state)	17.4	50.4	26.5	5.6
Ecuador	1982	Residence in 1977	16.0	46.0	18.0	21.0
Honduras	1983	Residence in 1978	26.0	32.0	28.2	13.9
Peru	1986	Previous residence	11.6	51.6	13.6	23.2

Sources: See United Nations (2000a), except for Botswana, Côte d'Ivoire, Ghana, Ecuador and Peru, for which see original sources in Bilsborrow (1992), based on population census data in the World Bank Living Standards Measurement Survey (except Peru, for which see World Bank Living Standards Measurement Survey).

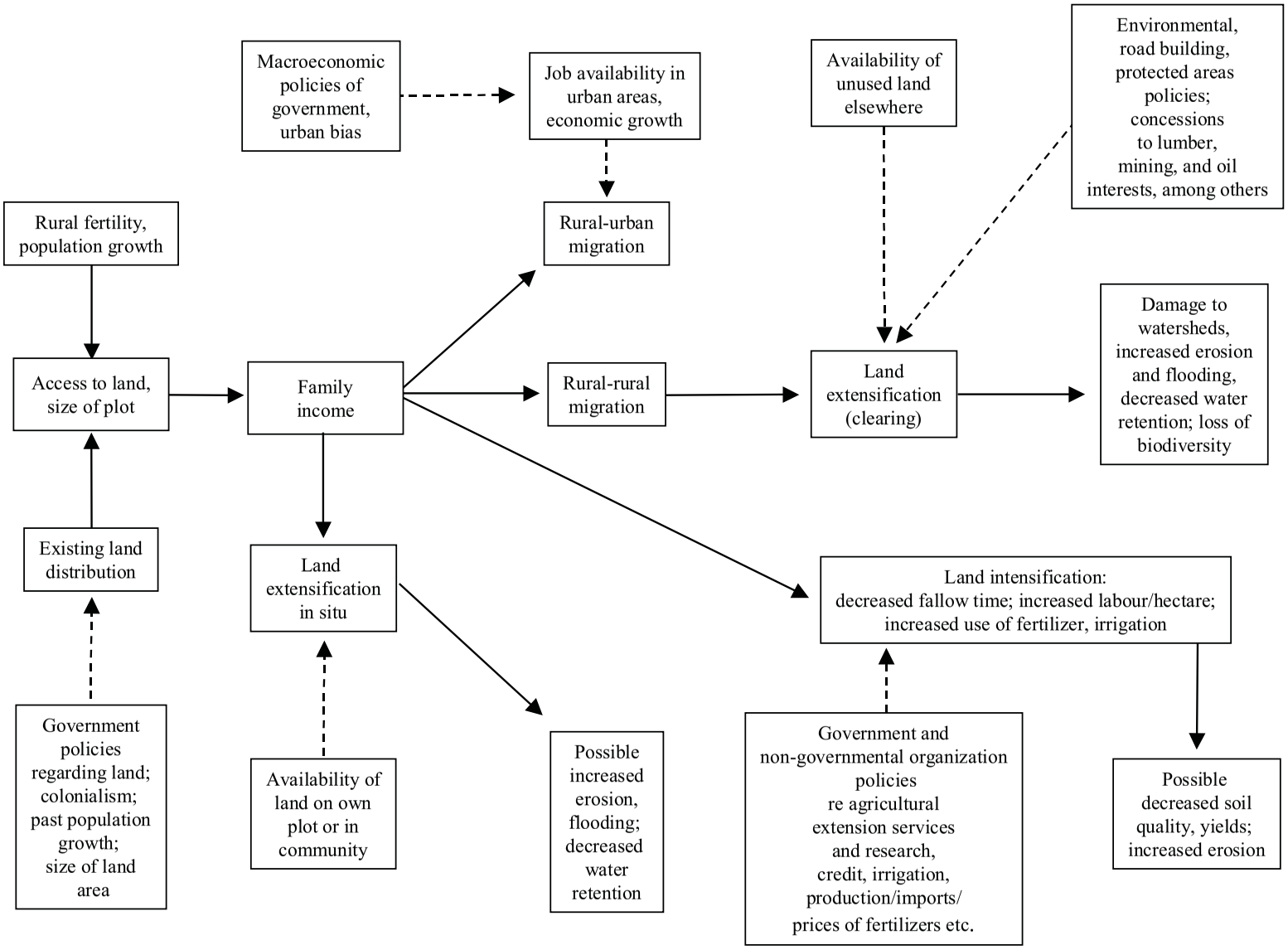
to as "push" factors, while those that attract a person to a particular destination are "pull" factors. Natural disasters, such as earthquakes, volcanic eruptions, hurricanes and cyclones, as well as disasters induced by human activity, such as floods resulting from deforestation of watersheds or soil degradation stemming from improper land-use practices, are also push factors that may result in migration. Environmental pull factors include the attraction of land or a more pleasant natural setting or climate. The environment can exert an influence on the decision to migrate by affecting factors at the household or community level. Thus, in rural areas of origin, since the amount and quality of land available to the household determine its income-earning opportunities, degradation of soil will tend to create pressures on living standards that induce a response. Such degradation may result from the household's own intensive use of the land (without compensating nutrient restoration) or from a natural disaster in the community (such as a flood, drought or hurricane). The latter will tend to reduce temporarily or permanently agricultural prospects in the community and hence off-farm employment opportunities. Environmental factors, such as air and water pollution, can also make the community of origin less desirable in non-economic terms. However, studies of the causes of migration based on interviews of migrants or potential migrants have generally not asked about environmental factors. In most studies, migrants or potential migrants from rural areas report that they have moved or intend to move because of poor economic prospects in the place of origin, but possible linkages between those poor prospects and environmental changes have not been explored. When environmental degradation is the cause of low agricultural wages or crop yields, it may become an underlying or "root" cause of migration.

Beyond this, the role of environmental factors in migration decisions may be seen in the context of theories focusing on the effects of population growth on increasing population density in rural areas (see Malthus, 1960; Boserup, 1965; Davis, 1963; Bilsborrow, 1987). In rural areas, higher density usually manifests itself in small agricultural plot sizes, which result from a combination of population growth and land fragmentation through partible inheritance among large families and agrarian policies regarding land tenure that facilitate a highly inequitable land distribution (figure V.1). When plot sizes become too small to support a family, households respond by clearing more land and bringing it into cultivation, by intensifying the use of existing land, or by diversifying sources of income, through off-farm employment of family members, whether in a local town or elsewhere through out-migration of family members to places where they can earn enough to send remittances to the household of origin. Davis hypothesizes that the more one response occurs, the less pressure there is for other responses to occur. At the same time, the responses are "multiphasic" rather than mutually exclusive: migrant remittances may provide the household with the capital needed to acquire more land or to buy the modern inputs necessary to intensify the use of land (for example, fertilizer, hybrid seeds etc.). In countries that are still mostly rural, the most common type of migration that rural families resort to is rural-rural migration, especially if land is available or agricultural employment opportunities exist elsewhere in the country. Sometimes rural-rural migration takes place internationally, when agricultural workers obtain employment abroad. Otherwise, migration to urban areas by selected members of the family is a common strategy to obtain access to cash income.

Figure V.1 illustrates the environmental implications of various responses. Thus rural-rural migration involves the relocation of whole households to areas where land is available, which has tended to have significant environmental implications in recent decades, since it is increasingly to marginal, fragile areas made accessible through extensions of road networks.[3] Depending on the type of biome in the area of destination, the permanent relocation of families can lead to the clearing of forests or other vegetation to establish croplands or pastures, a process that can produce serious damage to watersheds, reduce water retention and replenishment of underground aquifers, increase surface run-off, flooding, and siltation of dams downstream, and contribute to soil erosion and decreased soil fertility. While many of these consequences can be controlled or moderated, most developing countries lack the necessary resources and technology to do so. The dotted lines in figure V.1 indicate the crucial roles played by contextual factors—natural resource endowments of a country and its institutions and policies at both the national and local levels—that determine the most likely types of responses. The next section will examine the types of linkages documented in particular countries, noting the key roles played by such contextual factors.[4]

An important question is whether the poor are especially involved in the process of circular causation in which they are forced to overexploit the land in order to survive, degrading it in the process, until declining yields force them to move in search of new land on the agricultural frontier, where the cycle begins anew with further environmental damage in the form of deforestation. The short answer is that the poorest of the poor rarely migrate because they lack the means to move and often lack information about better alternatives or the knowledge about how to access them. In addition, environmental factors appear less important than economic factors in inducing migration, and the migration of poor colonists to frontier areas with fragile ecosystems would be much less common if the construction of roads by logging or mining companies, some of which are multinational corporations catering to global markets, had not taken place. Moreover, the majority of the land clearing in recent decades has been for pasture and has often been carried out by commercial agricultural enterprises catering to international markets and to the growing urban populations whose food tastes are changing. Leonard and others (1989) noted that the poorest 20 per cent of the population in the developing countries live on "low potential" lands, that is to say, marginal agricultural lands with inadequate or unreliable rainfall, low soil fertility or steep slopes. In most countries, even those that have had some land redistribution, the better-off have corralled the better lands (Cruz and others, 1992; Cruz, 1997; Stonich and DeWalt, 1996). Thus, three quarters of the poorest 20 per cent in Latin America live on marginal lands, compared with 57 per cent in Asia and 51 per cent in Africa. In other words, rural poverty is caused not only by lack of land but also by lack of access to good land. The poor have little access to technology, fertilizer or credit

Figure V.1. Linkages between rural population growth, migration and the rural environment



for land improvements (Barbier, 1997), and little incentive to not "mine" natural resources to survive. Furthermore, since the poor are relegated to marginal lands, this makes it more likely that those lands will become degraded when used,[5] forcing them to migrate to other marginal areas to begin the process of degradation again. Hence, poor migrant families become implicated in the deforestation that ensues, even though the underlying causes include their lack of access to land or their having poor-quality land, as well as global market forces that drive Governments, multinational corporations, agro-business and large ranching interests to open up frontier areas.

The discussion so far has considered situations of growing rural populations and increasing population density. When the rural population starts to decline, however, densities will decrease. But the problems observed today stem not only from overall population density but also from inequities in the distribution of land. Although reductions in rural populations have the potential to increase average land per person, if the distribution of land among poor families does not improve, the risk of environmental degradation through land clearing and degradation will continue. Nevertheless, slower growth of the rural population provides opportunities for better land management, including reforestation and the use of technology to ensure soil preservation.

C. Impacts of migration on the rural environment in developing countries

The studies summarized in the present section indicate the diversity of impacts of migration on the rural environment of places characterized by distinct types of ecosystems. Such impacts are probably the most investigated topic on the linkages between migration and the environment. While there have been important advances, this body of research has usually been based on inadequate demographic and environmental data, difficulties in matching them for geographical areas (Clarke and Rhind, 1992; Liverman and others, 1998) and lack of quantitative analysis. The findings indicate that the nature of the impacts vary according to the context and depend on such factors as natural resource endowments, local infrastructure and government policy. This review starts by focusing on the impact of migrant colonists to the rainforest frontier.

Settler migration to rainforest areas and the subsequent destruction of that habitat have been a source of growing concern. Because of their growing numbers and their access to more effective technology to clear the land, migrant colonists have been the direct agents of a significant proportion of the tropical deforestation occurring in the developing world. In Brazil, a country that has 35 per cent of the world's rainforests, the extension of the agricultural frontier has been responsible for the largest annual volume of forests lost, although many other countries, with smaller initial forest stocks, have been experiencing higher annual rates of deforestation. Although the Brazilian Amazon region had long been sparsely settled by indigenous tribes and parts of it had been exploited during the various decades of the rubber boom of a century ago, most of it was not settled and cleared "permanently" until roads began to be constructed in the 1960s (for example, BR-364 to Rondônia and the Transamazon Highway). In the context of high rates of population and industrial growth, national policy at the time promoted a westward expansion to tap the vast wealth of the Amazon, assert Brazilian sovereignty in border areas and provide a release valve for peasants who had insufficient land and lived in densely populated areas (especially those in the drought-stricken north-east). Although several government-sponsored programmes that provided free land and food for six months were instituted to attract migrant settlers, they were soon overrun by spontaneous settlers (Henriques, 1983; Hecht and Cockburn, 1990). Tax incentives for cattle added to a speculative land boom. While the first plots offered to settlers were 240 hectares (ha), their size fell to 100 ha in Rondônia in the 1970s and to 50 ha in the 1990s. The poor soils, transportation difficulties in marketing, title delays and lack of credit for all but the big ranchers led many of the original settlers to experience declining yields, to sell out and to either migrate further into the rainforest and begin the clearing process anew or migrate to the boom towns of the region. Ranchers, benefiting from generous tax subsidies, often bought out the small farmers, sometimes forcefully removing them from the land (Hecht, 1985; Hecht and Cockburn, 1990; Schmink and Wood, 1993). The conversion of abandoned lands to pasture—a far more extensive use of land than for crops—contributed to further deforestation, even as the rural population declined in the Brazilian Amazon as a whole. While rural population pressures thus declined as proximate causes of deforestation, the process of rural-rural migration continues to be an important factor driving it. Because of the high visibility of the expansionist policies of the Government of Brazil in the Amazon and of the relatively low population density of the country as a whole, some have argued that population pressure has played no role in the deforestation of the region. Such an argument, however, disregards the importance that sustained high fertility in the north-east of Brazil had in increasing population density in that area, leading to the maintenance or increase of rural poverty especially in a context of extreme inequality in land ownership, and providing some impetus for the early migration to the Amazon once the region was made accessible. High population growth in the areas of origin, as well as migration, is therefore among the factors that have contributed to deforestation, even though other factors, such as tax incentives and inflation-induced land speculation, have been at least as important; and as fertility dramatically declined in Brazil between the 1970s and 1990s, population pressures have become minor. Indeed, in the 1990s, concern about the rapid pace of land conversion in Brazil led the Government to eliminate the tax subsidies to cattle ranchers and to adopt a policy of declaring large areas as protected or as belonging to indigenous populations and therefore as being off-limits to colonization.

Similar processes of migration to the rainforest frontier accompanied by large-scale forest clearing have been documented in other countries. In Guatemala, migration into the northern Petén resulted in the clearing of half the forests in the region during 1950-1985. As in Brazil, high population growth in the Guatemalan Altiplano, where the institutional context favoured an extreme inequality in landholdings and the increasing fragmentation of smaller holdings, had led to

growing rural unemployment and underemployment due to insufficient growth in labour demand on partially idle large landholdings and to rising rural poverty, which together motivated out-migration from rural areas to both the capital city and the Petén, the country's last agricultural frontier (Bilsborrow and Stupp, 1997; Sader and others, 1997). In Panama, migration to the forest frontier, mainly to establish cattle farms, led to deforestation along new roads, a process which is now occurring also near the Colombian border in the Darién gap (Heckandon and McKay, 1984; Joly, 1989). In Costa Rica, migrants to the canton of Sarapiquí have colonized forest areas and cleared them to plant cash crops or grow cattle. As a consequence, the population of Sarapiquí grew fourfold between 1963 and 1983, while the forest cover decreased from 70 to 30 per cent, and pasture increased from 24 to 57 per cent of the land area (Schelhas, 1996). In southern Honduras, the Government has promoted cattle ranching and plantations of cotton and sugar cane, both products for export, which have been developed on good lowland areas by large commercial landowners and have forced smallholders to migrate to adjoining mountain slopes to establish new farms. These migrant farmers have cleared the mountain slopes, producing increased soil erosion and flooding downstream and, because of low yields, are barely managing to eke out a living (Stonich, 1989; DeWalt, 1985; DeWalt and Stonich, 1999; see also Humphries (1998) on northern Honduras).

In Ecuador, migration to the northern Amazon and the accompanying massive deforestation by agricultural colonists began in the early 1970s with the construction of roads by petroleum companies to lay oil pipelines. Those roads facilitated an influx of migrant colonists, 75 per cent of whom had originated in the highlands (Pichón, 1997; Pichón and Bilsborrow, 1999). Population in the Amazon region grew at annual rates of 8 per cent in 1974-1982 and 6 per cent in 1982-1990, more than double the national average, while deforestation proceeded at a rate of 1.8 per cent per year, the highest among all Amazon-basin countries. A survey of colonists living on over 400 representative plots in 1990 found that, on average, 44 per cent of the 40 to 50 ha constituting each plot had been deforested. Since the colonists had been living, on average, 10 years on those plots, the mean rate of clearance was over 2 ha per year. Since the Amazon region that straddles southern Colombia, Ecuador and Peru is one of the world's richest areas in terms of biodiversity, the deforestation that had occurred represents a devastating loss.[6] In 1999, a follow-up survey of the same plots found that many of them had been subdivided among adult sons and that the population living on them had increased from 2,700 to about 5,000 persons. In addition, average deforestation had increased to 57 per cent of the area of each plot (Pan and Bilsborrow, 2000; Murphy, 2000). The survey data permit an analysis of the factors that led people to leave the highland region and settle in the forest frontier. First, the Government's policy of according priority to the extraction and export of petroleum facilitated the building of roads linking the Amazon region to other parts of Ecuador and making access possible. Second, the high concentration of landless or virtually landless families in the highlands region, which had been the product of high fertility and of extreme inequality in the distribution of landholdings, provided a pool of persons ready to migrate in search of land; that is to say, both population pressure on existing agricultural land and the poor distribution of that land were necessary factors in generating the transfer of population that would be responsible for much of the deforestation on the Amazon basin of Ecuador.

In virtually all cases where environmental degradation has been caused by forest clearing by migrant colonists in Latin America, the colonists are low-income families migrating in search of land. However, the land they obtain in the forested area usually does not permit them to rise above the poverty level so that, despite the environmental loss suffered by the country, the extent of poverty may not decrease (see Murphy, Bilsborrow and Pichón, 1997, on Ecuador). However, it must be underscored that there are other agents causing deforestation. In the Amazon region, the clearing of forests for pasture by commercial landholders has been more prevalent than their clearing by families in order to plant crops. Thus, Wood and others (1996), based on a cross-sectional statistical study of 279 *municipios* (municipalities) in the Brazilian Amazon, found rates of deforestation linked to levels of in-migration, but the effects of large farms and ranches were much greater.

Findings similar to those for Latin America exist for other continents. Indonesia, the world's fourth most populous country and the third in terms of tropical forest stock, has been experiencing the second highest annual volume of forest loss (Food and Agriculture Organization of the United Nations, 1997). Since the time of colonization by the Dutch, the great disparity in population density between Java-Bali and the rest of Indonesia (the "Outer Islands") has been of concern, with density in the former being roughly 800 persons per square kilometre compared with 4 to 80 persons per square kilometre in the Outer Islands.[7] With three quarters of the land in Java already in agricultural and other uses, little land remaining in forests, a mean plot size of 0.25 ha (barely enough to support a family, and suffering from erosion: see Barbier (1990)), high rural poverty (estimated at over 40 per cent in 1984 by the World Bank) and 40 per cent of the rural population landless, the Government of Indonesia initiated in the early 1970s a "transmigration programme", the largest directed but mainly voluntary colonization programme of the twentieth century. Migration under the programme peaked in the 1980s and continued at lower levels during the 1990s. About 2 million sponsored migrants had been resettled from Java to Sumatra and Sulawesi by 1990. Most were poor, half landless and three quarters reported themselves as being better off after migration. To help families get started, the Government cleared 1 to 2 ha per family and provided seeds, farming tools and food for the first 18 months. However, sites were not appraised before the families moved and half of them proved inadequate because of poor soils or because they were already occupied (Whitten, 1987). Moreover, the transmigration programme was so well publicized that it produced at least twice as many spontaneous migrants as those sponsored by the programme and their impact on the forests was usually greater because they were not subject to government monitoring. Yet, although this spontaneous migration greatly magnified the environmental impact, the fact that 70 per cent of the sites occupied had been cleared or logged previously reduced that impact. Overall, forests losses were esti-

mated at 2,400 square kilometres per year during the 1970s and 1980s, amounting to about 60 per cent of total deforestation in Indonesia during the period. In the 1990s, despite the adoption of national environmental policies, the creation of national parks and the virtual suspension of the organized transmigration programme, illegal logging, road construction and spontaneous migration continue to produce substantial deforestation (Wells and others, 1999).

In northern Thailand, substantial deforestation by migrant colonists was reported by Panayotou and Sungsuwan (1994), and in the southern hill region of Nepal, migrant colonists settled after a successful dichlorodiphenyltrichloroethane (DDT) campaign to reduce malaria and the clearing of forests ensued (Shrestha, 1990). In the Philippines, the lowlands came to be increasingly under large landholdings devoted to cash crops such as sugar cane and to cattle grazing, so that the growing rural population could find new land only on the increasingly steep adjoining mountain slopes where forests were cleared to establish agricultural plots. The deforestation that resulted caused substantial erosion and flooding (Cruz, 1997). It has also been widely reported that the greater frequency of floods and the damage caused by them in Bangladesh in the 1990s is the result of extensive forest clearing upriver in the watersheds of India and Nepal.

Rural-rural migration also figures prominently in a number of studies on Africa. Netting, Stone and Stone (1989) described the changes between the 1950s and 1980s experienced by the Koyfar of the Jos plateau, Nigeria. In response to expanding market opportunities—and not induced by population pressures or assisted by government policy—they expanded food production (namely, of yams) by migrating to the fertile Benue plains and changing from shifting cultivation in forest clearings to permanently, intensively tilled and fertilized family farms in areas cleared of forests. They took advantage of good, available lands, expanding markets, and cultural factors (individualism, the work ethic) to achieve economic progress, albeit with environmental consequences. In another case study, similar to that of Honduras, the spread of cash crops (especially coffee and cotton) stimulated by government policy in several regions of the United Republic of Tanzania led to substantial rural-rural migration to the Usangu plains accompanied by depletion of vegetation. The human population of the plains rose fivefold between 1948 and 1988 and the number of cattle doubled. However, the ecological deterioration was also partly due to insecure land tenure and the absence of social institutions for regulating resource access and use (Charnley, 1997). Charnley introduced the concept of a "cascade effect" to refer to cases such as this, in which environmental displacement of populations leads to their migration elsewhere where they create even worse environmental problems. She postulates that the latter are more complex and difficult to solve so that environmental problems should be solved in their source areas.

Deforestation can also be caused by populations seeking fuelwood to meet their energy needs. The poor are especially dependent on fuelwood, as are certain migrant groups, such as displaced persons and refugees. In situations of conflict or major natural disasters, large numbers of rural-dwellers are often forced to move and seek refuge in other parts of their own country (displaced persons) or in another country (refugees). In Africa, Central America and Asia, large populations of displaced persons or refugees have had to live in makeshift camps for long periods. Deforestation has resulted from the use of nearby forests for fuelwood, and there has also been depletion of surface water and underground water deposits (Sessay and Mohamed, 1997).

Population growth due to both natural growth and in-migration has also been linked to vegetation loss in dryland areas, with most of the work being on sub-Saharan Africa. However, an example of the impact of migrants on dryland areas in Latin America is that of colonists settling in ejidos around the Calakmul Biosphere Reserve in the Yucatan Peninsula, Mexico. Environmental degradation has resulted from the use of crops and technologies inappropriate for the area (Ericson, Freudenberger and Boege, 1999). There have been many studies on dryland areas in Africa, where the debate continues about whether the damage to the vegetation of the Sahel in recent decades is mainly human-induced and linked to in-migration or part of a natural cycle (Faulkingham and Thorbahn, 1975; Granger, 1982; Postel, 1997). Nevertheless, there is little doubt that pastoralists and the animal herds they depend on have both increased substantially in recent decades and have had to seek additional grazing lands. In some areas in the northern Sahel, the decline of vegetation has forced nomads and pastoralists to take their animals further south where they are increasingly competing for land with sedentary rural populations and increasing pressures on resources. The resulting conflicts have led Governments to attempt to settle pastoralist populations, a strategy that has met with mixed success.

The Sudan, albeit with a population density less than 10 persons per square kilometre, is nevertheless close to overpopulation because most of its territory is arid or semi-arid. The Gezira irrigation project, the world's largest agricultural irrigation scheme, has displaced pastoralists from their traditional seasonal grazing range, while the draining of wetlands to create other irrigation schemes has attracted migrants to the east. The Sudan has lost three quarters of its original forests, mostly since 1950. While some deforestation is due to the extensive use of fuelwood for cooking, the arrival of refugees and other migrants to previously unexploited land has played an important role as well (Ibrahim, 1987; Little, 1987; Bilsborrow and DeLargy, 1991).

The case studies reviewed above indicate that migration to marginal and fragile areas can result in deforestation and other forms of environmental degradation. However, factors other than migration are often the main precipitating factors, including the actions of Governments, national and multinational corporations (logging and mining enterprises) and large-scale ranchers responding to national and international demands for fine wood, other forest products, beef and other agricultural products. The roads and infrastructure these actors construct have frequently facilitated the arrival of migrants. Indeed, Governments have altered areas to attract migrants, for instance, by constructing dams for irrigation in the eastern Sudan, northern Mexico, northern India, central China and coastal Peru (though other populations are often displaced).

The discussion here is not complete without considering the environmental impacts of out-migration in rural areas of

origin. The effects may be positive owing to reduced pressures on resources, possibly facilitating natural reforestation, though there has been little research on this topic. For example, in the Camacho valley of Bolivia out-migration led to less intensive grazing and improvement of the environment (Preston, 1998). In Indonesia, the transmigration programme had as an explicit goal the easing of demographic pressures in areas of origin, including the reduction of pressures on forests and water supplies in upland areas; and yet, although more than 2 million people had been moved by the transmigration programme, the population of Java-Bali still rose by 10 million owing to natural increase. Consequently, the environmental benefits from the reduction of population pressure must have been less than anticipated. In several other contexts, the environmental consequences of out-migration have in fact been found to be negative. Thus, in the Peruvian Andes out-migration led to a depletion of the labour supply which made it hard to maintain the terraces, and resulted in increased soil erosion (Collins, 1986). A similar outcome was observed in an island community of Kenya in Lake Victoria (Conelly, 1994). In Gabon, near the Gamba Complex of Protected Areas, the out-migration of young persons searching for employment in cities and in the oil sector is reported to have disrupted community-based conservation projects (Freudenberger and others, 1999).

The discussion is incomplete here without some consideration of the impacts of migration on resources in the present developed countries. In fact, the effects were quite dramatic, such as the westward movement of the agricultural frontier in the United States of America during the nineteenth century, resulting in extensive deforestation. However, except for Alaska—mostly protected now through national parks and national forests—this frontier is now closed, as it has been for the European countries and Japan since even earlier. As noted in section A, the rural population is declining throughout the developed world, and at the same time the area in (secondary) forest has been stable or rising. Out-migration from rural areas in these countries has almost invariably been to urban destinations rather than to rainforest frontiers as in many tropical countries.

D. Effects of environmental change on out-migration from rural areas

The effects of the environment on migration have been less investigated than those of migrants on the environment but are becoming of increasing interest (Kane, 1995). Throughout human history, first hunter-gatherers and then shifting cultivators have customarily moved once they depleted their natural supply of food or the fertility of the soil in their area of cultivation. Although this custom of mobility in response to humanly induced environmental degradation still exists among small populations of hunter-gatherers and shifting cultivators, from the Kung Bushmen of the Kalahari Desert in southern Africa to the Yanomani and many other ethnic groups of the Amazon basin, the populations involved are small. Today, interest in environmentally induced migration has mostly focused on the issue of "environmental refugees", that is to say international migrants compelled by environmental conditions to seek temporary asylum in another (usually neighbouring) country; on "displaced persons", who are people forced to migrate within their country by environmental disasters; and on other persons who migrate from rural areas within their own country at least partly for reasons of environmental deterioration.

There are two kinds of factors that may cause such severe deterioration of the environment as to impel people to leave—a major natural disaster (earthquake, flood, volcano explosion etc.) or a gradual, cumulative deterioration in the productivity or livability of a place.[8] Most of the time, major natural disasters produce internally displaced persons, but sometimes—because of their magnitude, the poverty of the country involved and its inability to provide assistance, and closeness to an international border—people cross that border seeking refuge and are accepted as refugees.[9]

Although it has been reported that sudden environmental disasters or cumulative degradation is important in the internal displacement of an estimated current stock of 6.5 million persons, the precise role of environmental factors is hard to establish, especially where political, civil, religious or ethnic conflicts are also part of the cause for the movement involved (Lonergan, 1998). Lonergan describes with acuity how a number of studies have greatly exaggerated both the numbers of persons affected and the role of environmental factors as the "root cause" of both international migration and refugee movements, on the one hand, and of internally displaced persons, on the other, in order to promote the widespread use of the concept of "environmental refugees". Some of these studies even report numbers higher than the total number of refugees and displaced persons. As Lonergan notes, while there is growing interest in studying the specific role of environmental factors in generating both international and internal migration, little empirical evidence is available. Numerous examples have been presented to substantiate a link between environmental degradation and internal migration in developing countries, such as Bangladesh, El Salvador, Haiti, and countries in the Sahel and elsewhere, but in each case a number of other social, economic and political problems were also at play. Efforts to disentangle the various factors have been scant and largely unsuccessful. For instance, a study supported by the National Heritage Society (1987) on the relevance of environmental factors in international migration from Mexico to the United States found they were weakly related to migration but did not rely on good indicators of environmental factors. Lonergan concludes that "the key factor is that certain populations are becoming more vulnerable to environmental change because of other factors, primarily poverty and resource inequality . . ." (p. 11). It is therefore more crucial than ever to disentangle the relationships between the environment, migration and poverty, especially in environmental "hot spots" where populations are highly vulnerable, such as countries that already have large numbers of internally displaced persons and where severe problems of rural poverty, agricultural neglect and declining soil fertility are already evident.

Regarding the possible effects of cumulative processes of environmental degradation on internal migration in developing countries, the Dominican Republic provides an interesting case study (Zweifler, Gold and Thomas, 1994). Air photo time-series were linked to survey data to examine the processes influencing land-use change in a hill community

called Las Ayumas. Settled at the turn of the century, Las Auyumas had been a vibrant albeit poor frontier community until 1940. Rice, plantains, maize, beans and other crops were raised in food gardens known as *conucos*, but by the early 1940s settlers had cleared almost all of the original forests and soil fertility began to decline. Farmers responded first by reducing the cultivation of nutrient-demanding crops such as peanuts, tobacco and rice, and switching to less demanding perennials such as pasture and coffee. After 1945, the village became more incorporated into the market economy, which spurred crop intensification. A boom in coffee prices led to an expansion of the land area in coffee to 40 per cent of the total by 1959. At that time, forests still covered 23 per cent of the village's land area, but by 1968 this figure fell to 7 per cent. Over that period, the local urban centre, Santiago, grew rapidly, attracting young adult labour away from the village. The out-migration of much of the young male population led to a greater dependence on land uses that demanded low labour inputs and were more tolerant of depleted soils, such as coffee and pasture. From 1968 to 1983, the area in coffee expanded again, reaching 63 per cent of the total land in use, while food gardens shrank. Cassava, bananas and sweet potatoes, crops that can tolerate degraded soils, replaced the earlier staples from *conucos*. The gradual decline in soil fertility over time thus led to both out-migration and changes in land use in favour of crops with lower demands on labour and soil nutrients.

It is likely that similar processes of adaptation, including migration, have been occurring and continue to occur widely in the developing world even though the underlying, long-term process of environmental degradation (declining soil fertility) is rarely ferreted out in survey questionnaires. Thus, in both Brazil and Ecuador, major waves of migrants to the Amazon originated in areas characterized by recurrent droughts (from north-east Brazil and the southern Ecuadorian Sierra province of Loja), which may be related to deforestation, the clearing of vegetation and nutrient-depleting agricultural practices in areas of origin. In Guatemala, the virtually complete deforestation of the Altiplano led to high soil erosion, which may have reduced soil fertility (Leonard, 1987). While nutrients can be restored to soils, soil erosion cannot be compensated except in the very long run; and most farmers in developing countries cannot afford the cost of fertilizers to replenish nutrients, so populations will continue to migrate away from areas where soil fertility is depleted.

Finally, in developed countries as well, environmental deterioration has often led to out-migration from rural areas. Sometimes the environmental changes have been due to natural causes, while at other times they have been induced by human practices. An example of the former is the effect of climate change (less precipitation and declining soil moisture as a result) on agricultural prospects and therefore on stimulating out-migration from the Great Plains of the United States during the twentieth century, beginning with the "dust bowl" era of the 1930s (Gutmann and others, 1996). Apart from the effects of nuclear and industrial accidents, toxic and solid waste dumps, and severe air or water pollution, human practices have often induced gradual, steady, severe deterioration of rural environments. A striking example is the shrinking by half of the area of the large, inland Aral Sea in Central Asia due to excessive withdrawals of water for irrigating cotton fields from the two rivers feeding the lake. This has forced out-migration from the area (see Postel, 1996, and references cited therein).

E. Conclusion

A review of recent literature on population growth, migration and the rural environment has provided numerous examples of instances in which migration of farmers to the agricultural frontier has resulted in tropical deforestation or the desiccation of land in dryland areas. The case studies also indicate the crucial role that natural resource endowments, institutions, local and national policy and (in some cases) international markets and cultural factors have played in mediating the responses of farmers to declining yields resulting from overexploitation of the land in areas of origin, as well as determining whether migration to the agricultural frontier occurs. Access to agricultural land in areas of origin or to inputs that facilitate the intensification of land use and increase yields tends to reduce out-migration. However, in countries of origin where the environment is degraded and population density is high, out-migration is likely, to unused lands if any remain, or to urban areas. In regions of destination, care needs to be taken to protect areas of particular ecological value while at the same time encouraging agricultural land-use practices that are more sustainable and appropriate for the climate and soils than has been the case to date. High natural increase among populations already settled in frontier areas is also generally adding to demographic pressures on the environment.[10] Given that many of the areas being settled are characterized by extraordinary biodiversity and that tropical forests also play a crucial role in world climate patterns and in preventing global warming, it is in the interest of the international community to address the root causes of the migration that leads to deforestation. Since most of the migrants involved are poor, a major challenge is thus to find ways of combating rural poverty in areas of origin while at the same time promoting a more sustainable use of the rural environment.

Notes

[1]Only India and the Republic of Korea had data allowing the analysis of trends over time. During 1966-1995, the Republic of Korea evolved from a low-income to a middle-income economy and experienced a rapid rate of urbanization. Consequently, by 1995 the country was mostly urban, and rural-urban, urban-urban and rural-rural migration had become less significant than they had been in the 1960s.

[2]The reliability of environmental measures is subject to considerable debate. Thus, the estimates of the World Bank and those of FAO of deforestation in Indonesia in the 1980s differed by a factor of 3 (Bilsborrow, 1992), and a recent paper has questioned the high rates of deforestation of FAO in seven countries of Western Africa by pointing out that the estimates of forest cover for the base year (1900 or 1950) were too high (Leach and Fairhead, 2000). The growing availability of satellite imagery promises to provide a better basis for more accurate estimates in the future, but substantial data processing and analysis are needed to derive those estimates.

[3]The effects of roads on facilitating in-migration to fragile ecosystems have been documented in a number of studies. See Rudel (1983), Rudel and Richards (1990), Chomitz and Gray (1995), Brown and Pearce (1994), and case studies reviewed in section C.

[4]Because of differences in land availability, responses to increasing rural populations in recent decades have differed from one continent to another, with more land extensification and rural-rural and rural-urban migration in Latin America and Africa and more intensification of agriculture in Asia (Bilsborrow and Carr, 2000).

[5]Repetto (1986) describes a sixfold increase in sedimentation in a West Java watershed since 1911 caused mainly by the expansion of human settlements up steeper mountain slopes as forests were cleared to create more farmland in response to population pressure and poverty. The most severe erosion was found on subsistence upland holdings of less than 0.4 ha.

[6]Myers (1988) has called this region one of the 11 world's ecological "hot spots".

[7]The Netherlanders recognized early in the twentieth century the desirability of redistributing population and promoted this.

[8]Man-made disasters, such as those in Chernobyl in Ukraine and Bhopal in India, and major development projects, such as the Three Gorges Dam in China, may also lead to population displacement, but are not explicitly considered here.

[9]In such cases, host countries grant refugee status on a prima facie or group basis for humanitarian reasons since the persons involved usually do not meet the standards set by the Geneva Convention relating to the Status of Refugees regarding a "well-founded fear of being persecuted" in their own country (chap. I, article 1 A (2)).

[10]Fertility levels of populations along the agricultural frontier are generally quite high. An important exception is Brazil, where total fertility levels on most of the Amazonian frontier are between 3 and 4 births per woman in her lifetime.

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VI. HEALTH, MORTALITY, FERTILITY AND THE ENVIRONMENT

Health concerns underlie much of the increase in discussions about the consequences of environmental degradation. The present chapter reviews the evidence from various studies on the impact of environmental factors on health and mortality. The impact of environmental factors on fertility is also reviewed. However, the emphasis is on reproductive health, rather than fertility per se, because the existing evidence suggests that although human fecundity may be declining, a perceptible effect on fertility levels is not apparent. Although recent discussion has focused on the threats posed by modern processes and patterns of production and consumption, this chapter discusses both modern and traditional health threats because the latter continue to play an important role in developing countries.

Environmental threats to health have been classified into two categories: "modern hazards", which are associated with development that occurs without adequate environment-health safeguards; and "traditional hazards", which are generally associated with the lack of development (World Health Organization, 1997). Modern environmental hazards include water pollution from populated areas, urban air pollution, poor control of solid and hazardous waste materials, chemical and radiation hazards, deforestation and other problems related to ecological and climate change and stratospheric ozone depletion. Traditional environmental health hazards include poor control of disease vectors, poor sanitation, contamination of food and drinking water, indoor and outdoor air pollution from fires and particulate matter, poor waste disposal and natural disasters. Emerging and re-emerging infectious diseases have also been classified as modern environmental hazards (World Health Organization, 1997) because of their close association with outcomes of economic development. In this chapter, however, emerging and re-emerging diseases are discussed separately.

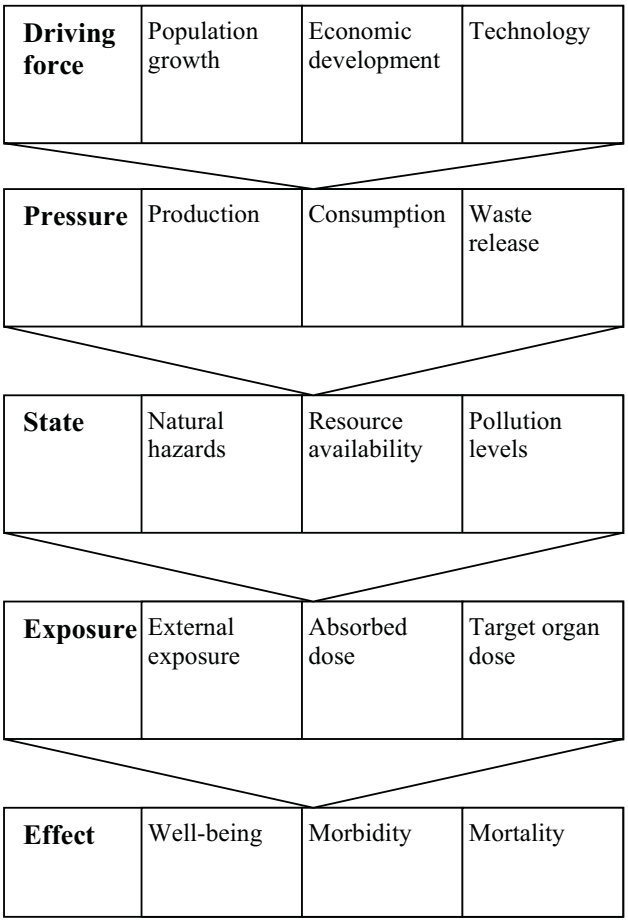
A number of factors confound efforts to assess the impact of environmental factors on fertility, health and mortality. As suggested in figure VI.1, the relationship between health and the environment is complex, being governed by population, economic development and advances in technology. Production and consumption patterns as well as exposure factors also play important roles. Morbidity and mortality from environmental factors rarely occur suddenly. This is especially true for modern environmental threats that may begin to exhibit their effects long after exposure. Further, socio-economic factors, such as education and income, which dictate where people live and work and their ability to choose or control the quality of their environment, are important determinants of health outcomes. The degree to which hazardous substances are absorbed and the part of the body that is exposed also determine health outcomes. Further, even if levels of pollution in a particular neighbourhood are known to be related to particular health problems, pollution may not be diffused equally over an area and the effects on health would similarly be different across individuals (Kolsky and Blumenthal, 1995).

A. MODERN ENVIRONMENTAL THREATS

Both less developed and more developed regions face modern environmental health threats. However, the balance between traditional and modern risks depends on the stage of economic development, the structure of the particular economy and the nature and efficacy of environmental policies (World Bank, 1992). Because of the high levels of industrialization in more developed regions and the elimination of most traditional health threats, the bulk of environmental health threats in developed countries result from modern environmental pollutants. In the less developed regions, modern environmental hazards play a smaller, though increasing role. However, urban air pollution associated with inadequately regulated motor vehicle emissions and with newly emerging industries is rapidly gaining importance. In particular, health hazards are increasing in sweatshops and other developing-country workplaces where toxic chemicals and dust, poor lighting, inadequate ventilation and space, and inadequate protection of workers from machinery and noise are becoming more common. Industrial chemical accidents, such as those in Bhopal, India, where the accidental release of methyl isocyanate in 1984 led to over 3,000 deaths, are becoming more common in developing countries. Similarly, natural gas explosions in Mexico City in 1984, explosions in Guadalajara that resulted in the release of hexane, a strong irritant that causes light-headedness, irritated eyes, nausea and headache, suggest that developing countries are by no means free from the effects of modern environmental health hazards. Cities in developing countries, especially, are facing increasing environmental pollution from vehicle emissions, and from industries and domestic heating sources at a level that exceeds the capacity to disperse and dilute emissions to non-harmful exposure levels (United Nations, 1995).

The evidence on the health effects of specific modern environmental health threats is scattered and is often supported largely by data from experimental situations that do not adequately represent the levels of exposure in actual populations. However, there is considerable evidence to suggest that negative health consequences can result from exposure to a number of modern environmental pollutants. Among these are chemicals such as aluminium, arsenic, asbestos, cadmium, excessive fluoride, lead, nitrates, polychlorinated biphenyls (PCBs) and sulphur dioxide. In addition, exposure to ionizing radiation from nuclear power stations or from natural sources has been associated with negative health consequences (Corvalán and Kjellström, 1995).

Figure VI.1. Health and environment cause-effect framework



Source: World Health Organization, *Health and Environment in Sustainable Development* (Geneva, 1997).

Some of the most persistent modern environmental threats to health arise from the degradation of the air quality, especially in urban contexts where transportation, energy generation and energy-intensive industrial operations are concentrated, thus heavily polluting the outdoor air (World Health Organization, 1997). Air pollutants, including gases such as nitrogen dioxide and sulphur dioxide, which are emitted from various production processes, have been shown to have negative effects on health. Sulphur dioxide, for example, which is a common contaminant of urban air, can impair the lung's defences and act as a bronchoconstrictor, thus causing asthma or other acute respiratory distress (Katsuoyanni and others, 1997). Asthma is thus largely an urban problem and incidence and severity appear to also be related to high levels of ozone, suspended particulate matter and nitrogen dioxide (Linn and Gong, 1999).

A major health threat in both developed and developing countries arises from air pollution by suspended particulate matter (SPM), which is estimated to account for about 3 million deaths each year (World Health Organization, 1997). SPM consists of a mixture of fine and coarse particles, which are generated from combustion and mechanical processes, and the constituents of SPM may vary from time to time and across contexts (Godleski and others, 2000). The smallest molecules of SPM—typically found in smoke from diesel engines, burning, cigarette smoke and some types of industrial activity—are the most dangerous to health because they can reach deep into the respiratory system (De Souza, 1999). Persons with pre-existing disease are most susceptible to the effects of small increases in particulate air pollution (Utell and Samet, 1993). It should be noted that, although particulate pollution in developed countries is largely a result of modern environmental pollutants, traditional sources such as smoke from indoor fires contribute a large share of the SPM in developing countries. The health and mortality impact of SPM thus varies, depending on the major pollutants involved.

Lead, which is known to be associated with reduced intelligence, impaired mental development, reduced birth weight and disturbances of the nervous system (Pocock, Smith and Baghurst, 1994; World Health Organization, 1997), is often a constituent of SPM. Lead also occurs naturally in soil and is also present in a number of products such as household plumbing fixtures, batteries, insecticides, paints and dyes and can contaminate food or water that comes into direct contact with these products. The inhalation of fumes from the combustion of leaded gasoline remains an important source of low-level persistent exposure in developing countries where leaded gasoline is still in use. Aluminium, which can be released into the air as a result of industrial processes, is also known to be toxic to the neurological system of humans, causing tremor, impaired balance, reduced recall memory and slow speed of cognitive functions (Kilburn, 1999; Akila and others, 1999; McLaughlin and others, 1962).

Pollutants that occur are also present in water and food sources. Chemical contamination of food can occur either because of the natural occurrence of the contaminant in soil or from pollution from industrial or other human activities. Contamination of food by lead, mercury, cadmium and PCBs are usually a result of industrial activity. Industrial development and the increased use of fertilizers in agriculture have also resulted in leaching of various chemicals into groundwater and ultimately into food sources. Many surface and groundwater sources are contaminated with nitrates, nutrients, radioactive substances and heavy metals (World Health Organization, 1997). The presence of PCBs, dioxins and hexachlorobenzene in lakes and rivers contaminates fish from these sources, and results in negative effects on human health (Gilbertson and others, 2000). A strong association between high nitrate ingestion and recurrent respiratory tract infection has been reported (Gupta and others, 2000). Dietary intake of cadmium, lead, mercury, PCBs and pesticides has been found to exceed acceptable daily intakes in a number of developed countries, with consumption by infants and children being particularly in excess of these acceptable limits (Baht and Moy, 1997). Because many of these chemicals also cross the placental barrier, there are health risks to the unborn child when pregnant women ingest contaminated

food and water. Arsenic in drinking water is also a continuing global health threat. Arsenic is found naturally in high concentrations in drinking water in parts of Argentina, Bangladesh, Canada, Chile, Japan, Mexico, the Philippines and the United States of America and can cause adverse health effects such as neuropathy and cardiovascular disease, and skin and internal cancers including those of the liver, lung, kidney and bladder. In districts in West Bengal, India, and in Bangladesh, where levels of arsenic pollution well above the World Health Organization–recommended maximum level have been found, a high prevalence of arsenic skin lesions has been noted (Chowdhury and others, 2000).

There have been suggestions in recent research that modern environmental pollutants are also responsible for reductions in human fecundity and reproductive health (Auger and others, 1995; Carlsen and others, 1992; Ewing and Mattison, 1987; Irvine and others, 1996; Sharpe and others, 1995). Modern chemicals are believed to be causing disruption in the endocrine system, increasing serum levels of testosterone, decreasing the level of follicle-stimulating hormone (FSH), causing congenital malformations of the male genital tract, lowering sperm counts, and increasing the incidence of reproductive cancers in both males and females (Osterlind, 1986; Sharpe and Skakkabaek, 1993). Chemicals thought to be responsible for these changes include naturally occurring steroid hormones and synthetic hormones, organic and inorganic pesticides, PCBs and dioxins (Swan and others, 1997). Maternal exposure to PCBs has been found to account for poorer neonatal and early childhood health (Swain, 1991). Consumption of PCB-contaminated fish may impair fertility, and consumption of such fish by pregnant women has been found to be associated with irreversible growth retardation and subtle behaviour change in newborns (Gilbertson and others, 2000). In a study of all singleton births registered by the Czech national birth register for 67 districts, the link between maternal exposures to sulphur dioxide, total suspended particulates and nitrous oxides was assessed (Bobak, 2000). The study found that although there was no effect on intrauterine growth retardation, exposure to these modern environmental hazards resulted in low birth weight and prematurity and that these differences were not attenuated by controls for socio-economic status.

Chemical agents that have been used to enhance ovulation have also been linked to negative reproductive health consequences, including reduced viability of pregnancy, a higher incidence of spontaneous abortions, and increased risks of breast, ovarian and uterine cancer (Tucker 1996; Venn and others, 1999). The specific risk factor appears to be the stimulation of the ovaries using follicle-stimulating hormones (FSH) or the use of gonadotropin-releasing hormones (GnRH) and related drugs. Rossing and others (1994), for example, suggest that women with long-term exposure to ovulation-inducing drugs may have higher risks of developing ovarian tumours.

Even if environmental factors have had a negative effect on fecundity and reproductive health, there is little evidence that overall levels of fertility have been affected. Using data on time to pregnancy among Swedish women, Hogberg and Wulff (1994) found no evidence of a secular decline in the cumulative incidence of pregnancy within a year of trying to conceive. In Belarus and Ukraine, where studies have shown that the period immediately following the Chernobyl nuclear accident was characterized by a sharp drop in fertility, it appears that factors other than impairment of fecundity played an important role. In particular, the emigration of reproductive-age women, especially those who were pregnant, increases in the number of abortions and delayed fertility for fear of the side effects of the Chernobyl disaster played important roles in the fertility decline (Rybakovsky, 1994). Given the complexity of the relationship between the environment and health factors, there may be many factors at work and better research methods and longer time-series data are required to document this association more conclusively.

Modern environmental pollutants appear to be most hazardous to the young, especially those under age 5. Adolescence is also subject to high risks because of the maturation of a number of organs, including the reproductive, respiratory, skeletal, immune and central nervous systems, which are subject to the toxic effects of environmental chemicals (Golub, 2000). Various studies have shown that infants and young children are up to 10 times as sensitive as adults to the effects of radiation and that there is no threshold level below which exposure of the thyroid to radiation is not risky (Braverstock, 1993). Studies conducted following the Chernobyl nuclear accident in 1986 have demonstrated elevated incidence of thyroid cancer among children. Increases in paediatric thyroid cancer cases in Belarus and Ukraine (Kazakov and others, 1992), for example, appear to be strongly related to the Chernobyl accident and the radioactive gases and particulates that were released into the atmosphere. Although it is difficult to separate the effects of the nuclear accident from extraneous influences on mortality and health, there is sufficient evidence to corroborate susceptibility of the human thyroid gland to radiation-induced cancer (Braverstock, 1993; Souchkevitch, 1996). Elderly persons are also more likely to suffer high mortality from cardiovascular disease when high levels of suspended particulate matter exist in the environment (Duanping and others, 1999). Lifestyle factors, especially whether an individual is a smoker or is exposed to environmental tobacco smoke, also appear to modify the health consequence of chemical pollutants. Nicotine and tar inhaled from smoking appear to interact synergistically with other chemical exposures, to produce a large negative effect on health (Kjellström and Rosenstock, 1990). Xu and Wang (1998), for example, found from a study on the pulmonary effects of smoking and air pollution that long-term exposure to high levels of particulate matter and sulphur dioxide in Beijing was associated with significantly reduced pulmonary function and the associations were significantly stronger among those who smoked.

B. Traditional environmental threats

Although most of the diseases associated with traditional environmental factors are no longer of major significance in developed countries, diseases such as the bubonic plague, smallpox, respiratory tuberculosis, measles, whooping cough, scarlet fever and diphtheria caused considerable morbidity and mortality in Europe before the beginning of the twentieth century. Between 1348 and 1352, the bubonic plague, whose spread is associated with rat infestation and

poor and crowded housing conditions, is estimated to have killed one third to one half of the populations of many European countries (McNeil, 1976). In North America, the toll of mortality from bacterial pneumonia at the beginning of the twentieth century was similar to the levels found in some parts of the less developed world today. The reduction in the role of traditional environmental pollutants as sources of mortality and morbidity in the more developed regions resulted from a number of factors. These include improvements in sanitation, community water supply, housing and indoor air quality (Preston and van de Walle, 1978; Preston and Haines, 1991a, 1991b; World Health Organization, 1999; Berman, 1991). In conjunction with these changes which reduced exposure to infectious disease pathogens, immunization programmes have helped to protect vulnerable populations, especially children, against the most common killer environment-related diseases. Despite successful control efforts, small epidemics caused by environmental bacteria and by animal and insect vectors continue to occur sporadically in developed countries. During the late 1980s, outbreaks of *Haemophilus influenzae* Type b (Hib) occurred widely among children in the United States (Cochi, O'Mara and Preblud, 1988). Various vector-borne diseases, including shigella, giardiasis and rotovirus infection, also continue to occur, usually in sub-populations that exhibit low levels of hygiene, or in pre-school and day-care centres (Wharton and others, 1990; Pickering and others, 1981). Untreated groundwater and inadequate disinfection of groundwater continue to cause disease outbreaks in the United States (Craun, 1992). Surveillance data for 18 European countries found 778 outbreaks of water-borne disease in 19 countries and 2.5 million cases of gastrointestinal and other diseases related to water quality (Bartram and Thyssen, 1999; Lack, 1999). During the 1990s, the political, social and economic changes in Central and Eastern Europe and the newly independent States resulted in a deterioration in the health status of many countries in the region, leading to a surge in the number of cases of communicable diseases. The region was responsible for about 80 per cent of the world's reported cases of diphtheria in the period 1990-1994 (World Health Organization, 1996a). Reasons adduced to explain the diphtheria epidemic in the newly independent States include low vaccination coverage of children, and a large population of susceptible migrants after the dissolution of the former Union of Soviet Socialist Republics (USSR) which resulted in the rapid spread of *Corynebacterum diphtheriae* (World Health Organization, 1996b).

In less developed regions, diseases that are associated with poor sanitation, faecal contamination of water and food, contaminated indoor and outdoor air, and infections via insect or animal vectors continue to cause significant mortality and morbidity. Most cases of pneumonia, otitis media and sinusitis in children in developing countries are believed to be due to aspiration of nasopharyngeal secretions (Shann and others, 1984; Moxon and Wilson, 1991; Shann, 1999), which are more easily transferred under crowded living conditions and poor sanitation. Deaths due to poor water supply, sanitation and personal and domestic hygiene alone accounted for 5.3 per cent of global deaths and 9.4 per cent of all premature deaths in 1990 (Murray and Lopez, 1996). Further, malaria caused 1.1 million deaths globally in 1998, with all deaths occurring in low-income countries (World Health Organization, 1999). Malaria is governed by environmental factors such as rainfall, humidity and temperature, all of which affect the distribution, seasonality and intensity of transmission of *Plasmodium falciparum* by the *anopheles gambiae* vector, which exists only in frost-free regions (Snow and others, 1999).

Table VI.1 presents estimates for 1990 of the global distribution of deaths from all causes, and from infectious and parasitic diseases, and respiratory infections and respiratory diseases—two groups of causes that are, perhaps, most closely linked to traditional environmental causes. Numbers of deaths are also provided for specific diseases within these groups that are known to be related to traditional environmental factors. These groups of diseases are considered here because it is estimated that roughly 60 per cent of the global burden of disease from acute respiratory infections, 90 per cent from diarrhoeal diseases, 50 per cent from chronic respiratory diseases, and 90 per cent from malaria can be avoided by simple environmental interventions (World Health Organization, 1997).

Globally, almost one in five deaths is caused by infectious and parasitic diseases, with the major contributors to mortality being diarrhoeal diseases and the childhood cluster diseases including pertussis, poliomyelitis, diphtheria, measles and tetanus. Diarrhoeal diseases, which are transmitted primarily through faecal contamination of food and water, accounted for 2.2 million deaths in low-income countries but for only about 7,000 deaths in high-income countries in 1998 (World Health Organization, 1999). Mortality from these causes is highest in sub-Saharan Africa, where 40 per cent of deaths are due to infectious and parasitic diseases. Malaria alone is estimated to account for 10 per cent of total mortality in sub-Saharan Africa. Respiratory diseases, many of which arise from the contamination of the air by infective agents, also result in considerable mortality. Table VI.2 also shows that infectious diseases, as a group, account for about one quarter of disability in the world, with less developed regions bearing the heaviest burden. The tropical cluster of diseases, which comprises trypanosomiasis, Chagas' disease, schistosomiasis, leishmaniasis, lymphatic filariasis and onchocerciasis, are all transmitted by vectors that benefit from tropical conditions such as high humidity and temperature. These diseases account for low levels of mortality worldwide, but for a high level of disability, principally in India and sub-Saharan Africa (see tables VI.1 and VI.2). Intestinal nematode infections also cause little mortality worldwide. However, in China and in other Asia and the Pacific, they cause about as much disability as bacterial meningitis, hepatitis B and hepatitis C combined.

The level of mortality and disability associated with traditional environmental health hazards is often much higher than that attributed to the disease directly. Many food-borne diseases, for example, can lead to serious and chronic sequelae and affect the cardiovascular, renal, respiratory or immune systems and food-borne infections are also one of the most important underlying factors in malnutrition, in rheumatic disease and, indirectly, in respiratory tuberculosis (Bunning and others, 1997; Käferstein, 1997). There is evi-

TABLE VI.1. DISTRIBUTION OF DEATHS DUE TO CAUSES ASSOCIATED WITH ENVIRONMENTAL PATHOGENS, 1990
(*Thousands of deaths*)

Cause of death	*World*	*EME*	*FSE*	*IND*	*CHN*	*OAI*	*SSA*	*LAC*	*NASWA*
All causes	50 467	7 121	3 791	9 371	8 885	5 534	8 202	3 009	4 553
Infectious and parasitic diseases	9 329	111	52	2 647	544	1 176	3 456	473	871
Tuberculosis	1 960	15	23	752	278	320	386	78	109
Sexually transmitted diseases excluding HIV	230	1	—	68	1	45	89	12	14
HIV	312	41	1	1	93	—	239	29	1
Diarrhoeal diseases	2 946	3	4	922	53	397	950	153	424
Childhood cluster diseases	1 985	1	1	513	41	227	863	91	236
Bacterial meningitis	180	5	6	44	34	24	26	14	18
Hepatitis B and hepatitis C	108	4	2	17	1	19	15	4	13
Malaria	856	—	—	26	—	77	732	14	7
Tropical cluster diseases	125	—	—	35	1	3	62	20	4
Dengue	21	—	—	12	1	7	1	—	—
Intestinal nematode infections	22	—	—	3	7	7	2	2	1
Other infectious and parasitic diseases	585	42	15	253	39	50	92	53	44
Respiratory infections and respiratory diseases	7 315	618	272	1 496	2 004	700	1 233	297	697
Lower-respiratory infections	4 299	272	113	1 195	467	543	1 006	178	525
Upper-respiratory infections	43	3	1	12	5	6	10	2	5
Otitis media	28	—	—	12	2	3	7	0	3
Chronic obstructive pulmonary disease	2 211	245	80	140	1 432	77	102	61	74
Asthma	137	22	8	20	35	18	13	12	9
Other respiratory diseases	587	76	70	106	63	54	95	44	79

Source: C. J. L. Murray and A. D. Lopez, eds. *The Global Burden of Disease: A Comprehensive Assessment of Mortality and Disability from Diseases, Injuries, and Risk Factors in 1990 and Projected to 2020* (Cambridge, Massachusetts, Harvard School of Public Health on behalf of World Health Organization and World Bank, 1996), annex tables 6a to 6i.

NOTE: Regions: *EME* = established market economies; *FSE* = former socialist economies of Europe; *IND* = India; *CHN* = China; *OAI* = other Asia and Pacific; *SSA* = sub-Saharan Africa; *LAC* = Latin America and the Caribbean; *NASWA* = Northern Africa and South-central and Western Asia.

dence that the immune system can be negatively affected by exposure to biological pathogens in the environment. *Helicobacter pylori* (*H. pylori*), for example, is a waterborne infection that has been linked to the development of gastric ulcer and gastric cancer (Hosking and others, 1994; Hansson and others, 1996; Parsonnet, 1996). The improvement of the water supply and the reduction in exposure to *H. pylori* are believed to have accounted for the marked reduction in deaths due to gastric cancer in the United States since the 1930s (Manton, Stallard and Corder, 1999).

Traditional environmental factors pose a potent threat to the health of children and adults alike. However, there are differentials across population groups in their effects. Children under age 5 suffer the highest mortality and bear the heaviest burden of diseases caused by poor sanitation, crowded living quarters and contamination of food and water. Seventy per cent of deaths from acute respiratory infections, most of which are related to environmental factors, occur before the first birthday and one quarter of the deaths among children under age 5 are estimated to be due to diarrhoea (World Health Organization, 1995). Vaccine preventable diseases such as measles, neonatal tetanus, poliomyelitis, diphtheria and pertussis alone account for almost 15 per cent of the total disease burden of the age group 0-4 (Murray and Lopez, 1996). Data from various demographic and health surveys suggest that a high proportion of children under age 5 frequently suffer from diarrhoea, fever or respiratory illness (see table VI.3) and the rates of illness appear to be highest in the least developed countries. In Africa, where malaria is estimated to account for over 200 million episodes of clinical disease (Snow and others, 1999), children suffer the heaviest toll, although morbidity and mortality among adults over age 15 is also high. There is evidence, in particular, that pregnant women are at higher risks of developing complications from malaria and from contaminated food and water sources (Käferstein, 1997). Women and young girls are also more likely to suffer the consequences of poor indoor air pollution. This is because of their traditional role in the preparation of food and their exposure to particulates and to smoke from the burning of coal, fuelwood, animal dung and other sources of fuel (World Health Organization, 1997).

Most morbidity and mortality due to traditional environmental causes can be prevented with simple interventions such as vaccination, the use of prophylactics, and treatment options such as oral rehydration therapy and appropriate use of antibiotics (World Health Organization, 1999). However, various factors make control of these diseases difficult, especially in developing countries. Large segments of the popula-

TABLE VI.2. DISTRIBUTION OF DISABILITY-ADJUSTED LIFE YEARS (DALYS) FROM SELECTED CAUSES ASSOCIATED WITH ENVIRONMENTAL PATHOGENS, 1990

(*Thousands*)

Disease category	*World*	*EME*	*FSE*	*IND*	*CHN*	*OAI*	*SSA*	*LAC*	*NASWA*
All causes	1 379 238	98 794	62 200	287 739	208 407	177 671	295 294	98 285	150 849
Infectious and parasitic diseases	316 050	2 750	1 659	83 146	15 622	39 588	125 495	17 311	30 479
Tuberculosis	38 426	118	378	13 763	4 155	5 501	10 184	1 778	2 549
Sexually transmitted diseases excluding HIV	18 684	404	382	5 566	107	4 011	6 191	1 220	804
HIV	11 172	1 267	41	236	3	118	8 370	1 090	47
Diarrhoeal diseases	99 633	230	235	29 480	3 685	13 711	32 126	5 371	14 795
Childhood cluster diseases	71 173	41	39	18 328	2 254	8 084	30 445	3 377	8 605
Bacterial meningitis	6 242	181	228	1 506	1 281	847	996	501	701
Hepatitis B and hepatitis C	2 136	54	37	355	626	378	309	121	255
Malaria	31 706	2	—	1 195	58	2 529	27 089	457	378
Tropical cluster diseases	10 600	2	—	3 145	243	596	5 556	780	279
Leprosy	384	1	—	186	7	82	46	52	11
Dengue	750	—	—	444	29	255	21	1	—
Japanese encephalitis	744	—	—	85	479	180	—	—	—
Trachoma	1 024	—	—	26	347	47	355	—	249
Intestinal nematode infections	5 024	—	2	788	1 383	1 527	495	644	185
Respiratory infections and respiratory disease	177 066	6 119	4 214	41 866	34 643	20 354	38 559	8 811	16 799
Lower-respiratory infections	112 898	1 208	1 184	32 940	11 924	15 041	30 221	4 668	15 711
Upper-respiratory infections	1 311	55	24	358	145	176	322	60	171
Otitis media	2 163	84	48	629	308	298	398	128	270
Chronic obstructive pulmonary disease	29 136	2 284	1 081	2 494	17 810	1 237	1 826	1 031	1 373
Asthma	10 775	1 236	497	1 508	2 755	1 473	1 426	967	913

Source: C. J. L. Murray and A. D. Lopez, eds. *The Global Burden of Disease: A Comprehensive Assessment of Mortality and Disability from Diseases, Injuries, and Risk Factors in 1990 and Projected to 2020* (Cambridge, Massachusetts, Harvard School of Public Health on behalf of World Health Organization and World Bank, 1996), annex tables 9a-9i.

NOTE: Regions: *EME* = established market economies; *FSE* = former socialist economies of Europe; *IND* = India; *CHN* = China; *OAI* = other Asia and Pacific; *SSA* = sub-Saharan Africa; *LAC* = Latin America and the Caribbean; *NASWA* = Northern Africa and South-central and Western Asia.

tions of less developed regions of the world lack access to basic education, which has been repeatedly shown to be associated with lower morbidity and mortality, especially among children. That education is strongly associated with knowledge about critical interventions to reduce mortality from traditional environmental health threats is demonstrated by data in table VI.4. Uneducated mothers are much less likely to know about oral rehydration salts (ORS), which offer highly effective protection against the dehydration caused by diarrhoea. Uneducated mothers are also less likely to have had their children vaccinated against the immunizable diseases of childhood. Studies have also demonstrated that interventions such as the improvement of water quality and sanitation have a more significant influence on health when they are combined with appropriate education to improve hygienic practices (Esrey and others, 1985; Esrey and Habicht, 1986).

Climatic factors in tropical regions of the world also provide ideal conditions for the survival and proliferation of disease pathogens. Increases in the prevalence of various diseases, including dengue, malaria and other mosquito-borne arboviruses, have been associated with climate and rainfall (Loevinsohn, 1994; Watts and others, 1989). Although diet undoubtedly plays an overarching role, there are suggestions that recent increases in the global incidence of insulin-dependent diabetes may be related to environmental factors, possibly climate (Leslie and Elliott, 1994). The disease shows a strong south-north gradient in the incidence, with rates increasing with latitude (Rewers and others, 1988). Poverty is also an important mediator of the environment-health link. It is estimated that trachoma, in its active inflammatory form, affects about 46 million people worldwide, but mainly those who live in poverty and under conditions of crowding and insufficient personal and environmental hygiene (Thylefors, 1999). Trachoma, an infection of the eye caused by *Chlamydia trachomatis*, is associated not with mortality but rather with high levels of disability, in particular blindness, especially in China and sub-Saharan Africa (see table VI.2). Urinary schistosomiasis, which is associated with lower abdominal pain and blood in the urine, is similarly related to poverty. One hundred million people, 70 per cent of whom live in sub-Saharan Africa, are estimated to be infected with schistosomiasis, with schoolchildren harbouring the heaviest infections (Ansell and others, 1999; Farid, 1993).

Rapid urban growth, due to high fertility and rural-urban migration, causes pressure on the environment in many na-

TABLE VI.3. INCIDENCE OF FEVER, DIARRHOEA AND RESPIRATORY DISEASE IN CHILDREN UNDER AGE 5 (SELECTED SURVEYS)

Country	Year of survey	Percentage of children with specified conditions in the two weeks before the survey: Fever	Diarrhoea	Cough and rapid breathing
Benin	1996	54.0	26.1	15.7
Bolivia	1994	..	29.9	18.0
Botswana	1988	3.9	9.9	28.7
Cameroon	1998	30.1	18.9	19.7
Ghana	1988	35.3	26.3	20.0
Indonesia	1997	25.8	10.4	9.0
Jordan	1997	20.2	18.0	10.2
Madagascar	1997	32.2	27.1	23.9
Mali	1995/1996	38.7	25.3	15.3
Morocco	1995	..	10.4	..
Nepal	1996	39.4	27.5	34.1
Nicaragua	1998	23.2	14.0	26.4
Niger	1998	48.3	37.8	14.2
Pakistan	1990/1991	30.1	14.5	16.0
Paraguay	1990	31.5	8.1	17.3
Philippines	1998	7.4	25.9	13.3
Uganda[a]	1995	46.3	23.5	27.1
Yemen	1997	39.7	27.5	23.4

Source: Demographic and health surveys, various country reports (Calverton, Maryland, Macro International, Inc.).

[a]Data refer to children under age 4.

tional settings. In many countries, urban growth has outpaced the provision of safe water and sanitation. Crowded living conditions also facilitate the spread of diseases such as tuberculosis and measles (World Health Organization, 1997).

C. NEW AND RE-EMERGING DISEASES

The latter half of the twentieth century has witnessed the emergence of new diseases such as human immunodeficiency virus (HIV) infection and acquired immunodeficiency syndrome (AIDS), Ebola and other zoonotic diseases, and the emergence of drug-resistant strains of previously known pathogens. Emerging zoonoses are diseases caused by new agents attributable to animal vectors or reservoirs. Rapid population growth, expansion of agriculture and greater incursions into the natural land and water habitats have fostered the growth of this class of diseases. The Ebola virus, which caused major epidemics of haemorrhagic fever in parts of Africa in the 1970s and again in the 1990s, is believed to have resulted from animal sources (Meslin, 1992; Kochtcheeva and Singh, 2000). Increasing international trade in live animals and foodstuffs also readily transfers disease pathogens from one context to another. Similarly, commercial food processing and vending, and modern processes in slaughterhouses favour the spread of salmonella and Escherichia coli infections in developed countries. In 1986, for example, the contamination of commercially available brands of apple cider resulted in outbreaks of Escherichia coli O157:H7 and cryptosporidiosis in several states in the United States. The contamination was attributed to the use of apples contaminated with manure in the production process (Centers for Disease Control, 1996, 1997).

Insect-borne diseases that were previously limited to certain domains are also spreading globally. Dengue, which used to be confined to tropical Africa, has now become endemic in tropical regions in the Americas and Asia, where a new acute form of the disease, dengue haemorrhagic fever (DHF), affects mostly children, and results in a high case-fatality rate. Although previously absent, dengue viruses are now endemic in parts of Argentina, Bolivia, Brazil, many of the Caribbean islands, most of Central America, China, Colombia, Cuba, Ecuador, Peru, Paraguay and the United States. This spread of dengue in tropical regions of Asia and the Americas has been attributed to rapid population growth, which has worsened sanitation conditions in urban environments (Halstead, 1992).

By far the most important new disease of the twentieth century is AIDS, which is estimated to have killed more than 18 million people since the epidemic began, with 2.8 million deaths having occurred in 1999 alone (UNAIDS, 2000). HIV, which causes AIDS, is transmitted mainly through sexual contact and injecting drug use; but once an individual is infected, the progression from HIV infection to full-blown AIDS is faster when opportunistic infections are present (Muller and others, 1999; Cohen and Miller, 1998).

Environmental factors influence the transmission of a number of the most common opportunistic infections (OIs) that complicate HIV/AIDS. These OIs include: (*a*) toxoplasmic encephalitis, which may be contracted through poor sanitation and exposure to animals, raw meat, soil and contaminated fruits and vegetables; (*b*) histoplasmosis, which may be contracted from working closely with chickens and around chicken coops; (*c*) cryptosporidiosis, which is transmitted through faecal contamination of food and water, and exposure to animals; and (*d*) cytomegalovirus and adenovirus infections (Centers for Disease Control, 1997, 1999; Hierholzer, 1992). Cytomegaloviruses (CMV) are found in virtually all populations and are transmitted through contact with infected saliva, semen, vaginal secretions, blood and urine. HIV-infected persons who are child-care providers or parents of children in child-care facilities are at increased risk of CMV infection. However, the risk of infection is diminished by proper hygiene after contact with faeces, urine or saliva (Centers for Disease Control, 1999). Adenoviruses commonly infect the respiratory and gastrointestinal tracts and their spread is facilitated by crowded living conditions (Centers for Disease Control, 1998). HIV/AIDS is also frequently complicated by *Mycobacterium avium complex* (MAC) infection, which is caused by ingesting contaminated food and water and is associated with more severe HIV/AIDS (Inderlied and others, 1993). Tuberculosis remains the primary opportunistic infection in HIV/AIDS patients in developing countries, especially in sub-Saharan Africa, where the epidemic is most severe. The transmission of tuberculosis is facilitated by conditions of crowding and poor sanitation, where droplets of saliva from an infected person are more likely to be inhaled by others. One half of HIV cases in developing countries are complicated by tuber-

TABLE VI.4. PERCENTAGE DISTRIBUTION OF MOTHERS WITH CHILDREN UNDER AGE 5 WHO KNOW ABOUT ORAL REHYDRATION SALTS, BY EDUCATION LEVEL AND RURAL OR URBAN RESIDENCE

Country	Date of survey	Mother's education[a]				Mother's residence	
		No education	Level I	Level II	Level III	Urban	Rural
Benin	1996	55.2	79.8	96.3	..	74.0	55.2
Bolivia	1998	66.8	76.8	86.8	97.1	90.1	75.6
Bolivia	1994	68.8	80.9	85.7	96.0	90.9	75.1
Botswana	1988	79.5	85.9	88.0	90.4	88.5	84.5
Cameroon	1998	37.5	65.2	60.1	72.5	66.3	51.9
Ghana	1988	43.6	60.7	65.8	86.2	68.2	51.6
Indonesia	1997	83.3	95.6	98.4†	..	97.8	93.1
Jordan	1997	95.0	98.6	99.3	98.9	99.0	98.3
Madagascar	1997	22.6	40.9	80.2	..	67.9	39.2
Mali	1995-1996	46.3	69.4	93.9	..	82.3	39.8
Nepal	1996	93.6	98.5	99.7	100	96.9	94.6
Nicaragua	1998	95.6	96.3	96.6	99.1	97.4	96.9
Niger	1998	69.7	87.8	96.9	..	94.1	67.9
Pakistan	1990-1991	87.3	98.3	98.9	99.1	96.7	86.7
Philippines	1993	45.2	85.1	85.9	85.8	84.3	84.7
Philippines	1998	57.9	91.5	94.2	93.9	93.4	91.7
Uganda	1995	61.5	74.5	89.3	..	89.2	70.4
Yemen	1997	72.1	92.2	97.2	97.6	94.6	69.1

Sources: Demographic and health surveys, various country reports (Calverton, Maryland, Macro International, Inc.).

[a]Number of years of schooling for each education level varies by country. For each country, higher levels indicate successively higher number of years of schooling.

culosis (UNAIDS, 2000), and this may reflect the prevalence of crowding in households and communities and the overall higher prevalence of tuberculosis in these contexts.

D. CONCLUDING REMARKS

Modern environmental pollutants clearly pose important threats to health in both developed and developing countries. Traditional health threats are likely to decline in importance in developing countries as development proceeds. However, new and emerging diseases threaten to erode health gains achieved by reducing traditional health threats. Both affluence and poverty have played, and will continue to play, important roles in the persistence of environmental health threats. On the one hand, affluence, leading to increasing demand for more and better consumer goods and services, results in intensification of production in ways that have led to pollution from various chemicals that are inputs or outputs in the production process. In developing countries, poverty, in conjunction with high population growth, has led to sustained pressures on natural resources, to the growth of urban slums and to increased opportunities for disease transmission. The high rate of many emerging diseases in developing countries has been propelled by population growth and density and by migrant labour in its quest for new and better opportunities (Bassett and Mhloyi, 1991). Poverty also underlies the inability of developing-country Governments to provide the equipment and drugs required for diagnosing and treating the opportunistic infections that complicate HIV/AIDS. Poverty eradication and improvement in levels of education can enable individuals to implement better hygiene and sanitation measures and to reduce exposure to harmful environmental pollutants where they exist.

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VII. POPULATION, ENVIRONMENT AND DEVELOPMENT IN URBAN SETTINGS

Urbanization will be one of the most important demographic trends of the twenty-first century. Indeed, virtually all the population growth expected during 2000-2030 will be concentrated in the urban areas of the world (United Nations, 2000). Growth will be particularly rapid in the urban areas of the less developed regions, averaging 2.3 per cent per annum during 2000-2030, consistent with a doubling time of 30 years. Although urban areas will encompass an increasing share of the world population, the proportion of people living in very large urban agglomerations is still small (in 2000, only 4.3 per cent of the world population lived in cities of 10 million inhabitants or more). In contrast, the proportion of the world population living in small cities is considerably larger (in 2000, 28.5 per cent of the world population is estimated to have been living in cities of less than 1 million inhabitants) (United Nations, 2000).

Population growth influences the spatial concentration of people, industry, commerce, vehicles, energy consumption, water use, waste generation, and other environmental stresses (Bartone, Bernstein and Leitmann, 1992). It is often assumed that cities' environmental problems are made worse by the number of people and their high concentration; but in fact this same concentration provides many potential opportunities. The concentration of population and enterprises in urban areas greatly reduces the unit costs of providing each building with piped water, sewers, drains, roads and electricity. Moreover, cities concentrate populations in ways that usually reduce the demand for land relative to population. Although valuable land is being lost to urban expansion, in most nations the area taken up by cities and towns is less than 1 per cent of their total surface area. Indeed, the world's current urban population of about 3 billion inhabitants would fit into an area of 200,000 square kilometres—roughly the size of Oman or Senegal—at densities similar to those of inner-city residential areas in a number of European cities (Hardoy, Mitlin and Satterthwaite, 2000).

A. The relationship between city population size, rate of growth and urban environmental problems

The relationships between city population size or city size distributions, on the one hand, and environmental damages, on the other hand, are numerous, complex and very poorly understood (Prud'homme, 1994). The environmental impact of city size is generally considered negative. The larger the city, it is assumed, the greater the per capita environmental costs or damages. However, a number of caveats are in order. Since what ultimately counts is not so much pollution discharged, but rather pollution discharged minus pollution eliminated, it is important to note that, for a number of pollutants (for example, solid waste, water pollution), there are economies of scale in pollution abatement. Also, large cities are generally resource-saving relative to smaller cities, they are usually denser, and they lend themselves better to public transportation usage and include a larger share of apartment buildings; hence, they consume less land and less energy per capita. Finally, because transportation flows increase with population dispersion, environmental impacts associated with transportation (for example, fossil fuel consumption, greenhouse gas emissions, air pollution) presumably could be reduced by increased concentration in a few large cities.

Given that, in most countries, a significant proportion of urban-dwellers live in relatively small urban centres, there is a remarkable lack of documentation on environmental problems other than those in the largest cities. The limited information available about provision of water, sanitation and garbage collection in smaller cities suggests that most have serious environmental problems (Hardoy, Mitlin and Satterthwaite, 2000). This is perhaps not surprising, given that larger cities are typically more prosperous and obtain more government resources and attention. In most smaller African urban centres, for example, local authorities lack the capacity to ensure adequate provision of water, sanitation and garbage collection. In Asia, there is far more documentation of the environmental problems in large cities—partly because census data about the quality of housing and of provision of water, sanitation and drainage are rarely made available for individual urban centres. However, a number of independent research studies provide examples of serious deficits in urban infrastructure and services in smaller cities in India (see, for example, Ghosh, Ahmad and Maitra, 1994). Likewise, there are also case studies of a number of smaller cities in Latin America, showing the inadequacies in provision of water, sanitation and drainage (see Foronda, 1998; Browder and Godfrey, 1997). One such case study—of "boom cities" on the Brazilian agricultural/forest frontier—illustrates the fact that environmental problems are likely to be particularly serious in cities that grow very rapidly in newly settled areas, since it is rare for there to be any government institution able to manage the rapid growth and ensure adequate provision for environmental health (Browder and Godfrey, 1997).

In general, however, there is no direct linkage between the rate of urban growth and environmental problems. Over the past several decades, the growth rates of many of the world's largest cities have slowed considerably (United Nations, 2000). Yet a variety of urban environmental problems have worsened in many of these cities. Conversely, rapid urban change need not produce serious environmental problems. Cities such as Curitiba and Pôrto Alegre in Brazil have been

piped water supply is in generally good condition when it leaves the treatment plants, there are breaks in both the water and sewerage mains; the intermittent supply of water results in negative pressure, which sometimes causes sewage to be sucked into the water pipes, causing serious contamination (United Nations, 1990b). Likewise, water that is collected from public supply points, such as standposts or wells, is frequently contaminated during collection and storage in the household because of lack of understanding of basic hygiene.

In most of the countries in the more developed regions, the introduction of more stringent provisions relating to effluents has led to a considerable reduction in the amount of heavy metals and oxygen-depleting substances discharged into surface water. Nevertheless, a number of developed countries face serious problems with regard to water quality. In Kazakhstan, for example, the unsatisfactory sanitary and technical conditions of water supply equipment and networks, combined with a shortage of chlorine, are having an adverse effect on the quality of piped water and are one cause of the high level of morbidity from acute intestinal infections and viral hepatitis. Drinking-water supply has been a problem in the Russian Federation for a number of years and is still an acute issue. Approximately one third of the samples taken from piped water supplies do not meet hygiene standards in terms of chemical indicators (World Health Organization, 2000).

D. Sanitation

Sanitation is a major problem affecting water quality. As cities become more densely populated, the per-household volumes of waste water exceed the infiltration capacity of local soils and require greater drainage capacity and the introduction of sewer systems. Most municipally provided sanitation systems are based on conventional sewer systems. Coverage is generally poor, with the proportion of the metropolitan population served by piped sewerage being less than 20 per cent in Dhaka, Karachi and Manila, less than 30 per cent in Delhi, less than 40 per cent in Jakarta, and less than 45 per cent in Calcutta (Brennan, 1992). Sewers are generally in poor condition, and sewage treatment plants discharge effluents that are little better than raw sewage. Because sanitation is a service that depends for its effectiveness on a high level of consistent and reliable coverage, providing service only to part of a city's population, or service that is intermittent, does not produce the anticipated public-health and environmental benefits (Kalbermatten and Middleton, 1991).

As in the case of water supply distribution networks, sewer systems in most developing-country cities were constructed to meet the needs of the population of the original core city. Manila's primary sewer network was built during 1904-1911, for example, to serve a target population of 500,000. Currently, only 11 per cent of the population of metropolitan Manila has sewer connections. In the large number of unsewered areas, sewage effluent is conveyed via road gutters, open ditches and canals to watercourses that overflow during the rainy season, and then either is pumped, untreated, into Manila Bay or is allowed to flow into the bay via the tides. Mexico City's population growth long ago passed the city's ability to process sewage. Although about 80 per cent of the population has piped indoor plumbing, an estimated 3 million residents in peripheral areas are not hooked up to the sewer network. In these areas, raw sewage is discharged into riverbeds or seeps into the ground, polluting the underground aquifers (United Nations, 1991).

E. Solid waste

Many cities in the less developed regions are characterized by inadequate waste management policies and practices. A major problem regarding solid waste in cities in the developing world is one not of disposal or recycling but of failure to collect garbage in the first place. Unaccounted-for garbage—the difference between the amount of waste generated and the amount collected—is usually over 30 per cent and may constitute more than 50 per cent of the total (Brennan, 1992). Typically, it not only blocks the streets and creates a public-health hazard but also, more seriously, contributes to the atmosphere of squalor (Kalbermatten and Middleton, 1991).

The problem varies considerably from city to city, with the amount of waste generated tending to increase with the level of development. The technological solution most commonly adopted in the industrialized countries—having heavy compactor vehicles take all types of waste and crush it into a mixture that is then dumped into a landfill—does not serve as an appropriate model for the large cities in the less developed regions. For one thing, the waste generated in developing countries is typically much denser, with a high proportion of organic materials and a high moisture content, and the wet, dense material overloads both compactor trucks and the road structure (Kalbermatten and Middleton, 1991). For another, so-called sanitary landfills in many developing countries are little more than open dumping sites and major sources of groundwater pollution from infiltration of leachates.

Increasing quantities of waste are being generated in almost all countries in the more developed regions, with serious implications for health from the resulting pollution of the air, water and soil. The amount of municipal waste generated in the countries of the European Union has increased by an average of roughly 20 per cent per annum (World Health Organization, 2000). The situation is particularly serious in a number of countries that were part of the former Soviet Union. In Kazakhstan, for example, only one third of urban settlements are equipped with systems for planned, regular garbage disposal; only 12 per cent of solid waste is transported to specially equipped sites, with the remainder stored in improvised dumps, which leads to pollution of the soil and underground water in the areas around cities (World Health Organization, 2000). In the Russian Federation, in 1997, 130 million cubic metres of solid household waste were produced as a result of municipal cleansing operations; however, solid waste processing plants and incinerators processed only 3 per cent of this total volume (World Health Organization, 2000).

F. Air pollution

The problem of air pollution arises from the fact that emissions from vehicles, industrial boilers and domestic heating sources exceed the capacity of cities' natural ventilation sys-

tems to disperse and dilute these emissions to non-harmful exposure levels. Of the major sources of air pollution in urban areas, sulphur dioxide comes chiefly from emissions from oil burned in power generation and industrial plants; suspended particulate matter comes mainly from domestic fires and power generation and industrial plants; carbon monoxide and nitrogen dioxide come mainly from the gasoline fumes of motor vehicles; and ozone is formed by the action of sunlight on the smog from vehicle emissions (World Health Organization and United Nations Environment Programme, 1992). Ambient lead is almost exclusively generated by motor vehicles burning leaded gasoline, except in China, where it also originates from the very large amounts of coal that are burned.

Automotive air pollution in the developing countries is largely an urban phenomenon confined to the very large cities. In many mega-cities, atmospheric pollutants commonly associated with motor vehicles often exceed WHO guidelines (World Health Organization and United Nations Environment Programme, 1992). WHO recommends, for example, that human beings should not be exposed to ozone concentrations of greater than 0.1 part per million (ppm) for more than one hour per year and that ozone levels not be exceeded for more than 30 days per year. The population of Mexico City (which has half of Mexico's total vehicle fleet) was exposed to more than 1,400 hours of high ozone concentrations during 145 days in 1991 (Pendakur, 1992). The situation was equally bad in two other Latin American mega-cities, São Paulo (which has a quarter of Brazil's vehicle fleet) and Santiago. Although the Asian cities do reasonably well in terms of ozone levels, many of them greatly exceed WHO standards for suspended particulate matter and sulphur dioxide; five cities exceeded these thresholds in 1991: Bombay, 100 days; Beijing, 272 days: Jakarta, 173 days; Calcutta, 268 days; and Delhi, 294 days (Pendakur, 1992). The situation is also quite serious in Lagos, Cairo and Teheran (Faiz, 1992).

Cities in the developed world, however, are not exempt from air pollution. Indeed, WHO has found that fine particulate pollution is responsible for 7 to 10 per cent of respiratory infections in European children (more than 20 per cent in the most polluted cities) (Davis, 1999). In the United Kingdom of Great Britain and Northern Ireland, the change from coal to oil and gas in domestic heating and energy production has led to a steady reduction of soot and sulphur dioxide emissions. Nevertheless, in the early 1990s, the United Kingdom had the second highest emission of sulphur dioxide per capita. As the consumption of fossil fuels is still increasing slightly, the emission of pollutants such as nitrous oxides is tending to increase. As a result, no reduction has been achieved in secondary pollutants such as ozone or nitric acids, and episodes of winter-type smog (high concentrations of particulate matter and sulphur dioxide) and summer-type smog (ozone) are an increasing problem in urban areas (World Health Organization, 2000). The situation is particularly serious in countries that were part of the former Soviet Union. In Kazakhstan, the products of combustion from oil wells are a major source of air pollution. Moreover, whereas the majority of industrial plants that used to be the main source of air pollution are now standing idle or working below full capacity, there has been a steady and rapid increase in automobile transport, which is becoming the major source of environmental pollution, not only in cities, but also in practically all populated areas (World Health Organization, 2000). In the Russian Federation, the rise in the number of motor vehicles is leading to an increase in pollutants such as carbon dioxide, nitrogen dioxide and particulates. In towns with heavy traffic, concentrations of lead in the air are 10-15 times as high as the health and safety standards, owing to the continued use of tetraethyl lead additives in petrol (World Health Organization, 2000).

Although automotive lead emissions have declined sharply in most countries in the more developed regions, they are generally rising in large cities in the less developed countries. Moreover, shares of automotive sulphur dioxide and particulate and lead emissions are likely to be significantly higher in the future because of the high rate of motorization in many of the world's large cities, the more extensive use of diesel-powered vehicles and the poorer quality of automotive fuel (Faiz, 1992). Indeed, in many large cities, vehicle engines waste 70 to 80 per cent of the energy content of fuel through exhaust losses—losses that are greatest at the suboptimal speeds (for example, slow moving or idling) typical of rush-hour traffic congestion.

Action to control air pollution in the world's cities is a high priority, particularly in the light of what is known about its long-term health impacts. In many cities, the chief stationary sources of air pollution are a relatively few (often old) factories, refineries or power plants. In a number of cities, substantial reductions in pollution have taken place as a result of such measures as installing improved equipment, adding on pollution control equipment, or moving or closing the worst offenders (Hardoy and Satterthwaite, 1989). In São Paulo, for example, as a result of the enforcement of emission standards, provision of loans for industrial pollution control equipment, and mandating the use of best available practice for the largest sources of industrial air pollution, there have been large reductions in overall levels of industrial air pollution (United Nations, 1993). Relocating large manufacturing plants away from cities may offer some relief to the build-up of atmospheric pollutants in highly polluted areas. However, whereas larger enterprises are fairly easily regulated, it is very difficult to directly regulate the mass of petty manufacturing units (often with old, outdated and poorly maintained machinery and furnaces) that are so typical of most large developing-country cities (United Nations Development Programme (UNDP), 1992). Relocating or shutting down polluting industries also frequently results in a difficult trade-off between jobs and the environment.

A number of cities in developing countries have experimented with various measures to reduce ambient air pollution, with somewhat mixed results. In Bangkok, where it has been estimated that an eight-hour exposure at street level to Bangkok's air is equivalent to smoking nine cigarettes a day, air quality improved slightly, following the conversion of the city's fleet of *tuk-tuks* (motorized rickshaws) to liquid propane gas (LPG). However, the improvement was soon cancelled out by the increase in the number of motorized vehicles and by the steady worsening of the city's traffic congestion (to the point that it could take up to three hours for a cross-city trip).

In summary, rising incomes in many of the world's cities, combined with an increasing propensity for personal mobility and travel, are likely to result in a pronounced increase in automobile ownership and bus transportation, leading to higher levels of air pollution. As noted, a number of cities have adopted control measures, which include changes in fuel types and composition, changes in basic engine design and adjustments, and direct exhaust and emission control systems. In order to succeed, these measures have to be reinforced by emissions surveillance and recall programmes and should cover both new and in-use vehicles. However, even if technological breakthroughs in vehicle and fuel technology were to reduce pollutant emissions from motor vehicles to near zero, the long fleet turnover in developing countries (15 to 20 years) would still be a major obstacle. An additional problem is the fact that, whereas emissions standards can be an effective instrument to achieve reductions in pollutant emissions, because regulations on new cars raise the relative price of new vehicles, they induce substitutions of older vehicles.

G. Environmental impacts on urban health

Having briefly examined a number of macro-environmental problems (for example, water and air pollution citywide), it is important to address the issue of environmental impacts on the health of urban residents. Compared with the complex linkages among the environment and city size and rates of urban growth, the linkages between environmental degradation and health are more straightforward. Again, as in the case of aggregate levels of air and water pollution, there is much impressionistic evidence, but few comprehensive studies, using comparable data. Water is an important vehicle for the transmission of many pathogenic micro-organisms as well as organic and inorganic toxic substances. Many of the more important transmissible diseases in the developing countries can be classified according to the role played by water in the chain of transmission: water-borne diseases (for example, enteric and diarrhoeal disease, typhoid fever, hepatitis); water hygiene diseases (for example, trachoma, shigellosis); water contact diseases (for example, schistosomiasis); and water vector diseases (for example, malaria, onchocerciasis) (Bartone, 1990). Many debilitating and easily preventable diseases are endemic in the world's large cities, including diarrhoea, dysentery, typhoid, intestinal parasites and food poisoning. Whereas water-related diseases are a primary cause of infant and child mortality, mortality from air pollution typically occurs later in life. Relatively few deaths can be attributed directly to air pollution. However, millions suffer from respiratory infections (although the extent to which chemical air pollutants can reduce people's resistance to acute respiratory infections is not well understood) and many will die from some form of cancer caused or exacerbated by air pollution. Lead, for example, causes damage to bone marrow, liver and kidneys, and permanent neurological damage, especially in young children. Carbon monoxide can cause both neurological and cardiovascular damage. Indoor air pollution is particularly serious among low-income urban-dwellers, who commonly use fuelwood for cooking and heating in poorly ventilated housing. The impact of air pollution in workplaces is also very serious. Workers in quarries, cement plants, and rubber product factories, for example, are susceptible to silicosis, talcosis and stenosis, incurable lung diseases that may be fatal (Hardoy and Satterthwaite, 1989).

In most cases, the poorer residents of the world's large cities bear the human costs of the most debilitating impacts of environmental degradation. In many large cities, environmental pollution affects the poor more severely in part because many of them live at the periphery where manufacturing, processing and distilling plants are often built. The periphery is also where environmental protection is frequently the weakest.

In recent years, there has been a growing body of literature on the linkages among the urban environment, poverty and health (see Harpham and Molyneux, 2000). A notable aspect of many of these studies is the focus on differentials in health status or mortality rates between various population groups within cities. Not surprisingly, many of the studies found conditions in poorer areas of cities to be much worse than in the more affluent areas or even than the city average. Infant mortality rates in poorer areas, for example, were often four or more times as high as in more affluent areas, with much larger differentials apparent in the poorest district as compared with the most affluent district. Large differentials between rich and poor districts were also common in the incidence of many environmentally related diseases, for example, tuberculosis and typhoid (Satterthwaite, 1993).

H. Cities and sustainable development

In examining the linkages between urbanization and environmental issues, one central problem is that economic development exacerbates many environmental problems (for example, solid waste, automotive pollution) because the quantity of urban wastes generated per capita also tends to increase steadily with increased per capita income. Moreover, in recent decades, as incomes have risen in many countries and transport costs have declined, cities' "ecological footprints" have broadened. City-based consumers and industries often draw on the carrying capacity of rural regions, separating the environmental impact of the needs for natural resources from the city itself—to the point where city inhabitants and businesses are unaware of the environmental impact for which they are responsible (United Nations Centre for Human Settlements (Habitat), 1996).

In general, the countries with the largest draw per person on the world's natural capital (for example, with the highest levels of resource use, waste generation and greenhouse gas emissions) are also the countries with the highest proportion of their populations living in urban areas. Moreover, it is within urban areas that most of the world's resource use and waste generation is concentrated. Urban policies have very large implications in regard to future levels of greenhouse gas emissions and the use of most resources in each nation which are related both to the design and construction of urban buildings and to the spatial form that cities and urban systems take. Urban policies that encourage energy-efficient buildings and energy-efficient production units and that also ensure urban forms that are not increasingly dependent on high levels of private automobile use have a major role in de-linking high living standards from high greenhouse gas

emissions (Hardoy, Mitlin and Satterthwaite, 2000). Thus, urban policies, plans and regulations should have a central role in any national strategy that promotes sustainable development, and city and municipal governments will be important actors in any successful strategy.

Cities can provide healthy, safe and stimulating environments for their inhabitants without imposing unsustainable demands on natural resources and ecosystems. A successful city, in this sense, is one that meets multiple goals, including healthy living and working environments for its inhabitants; water supply, provision of sanitation and solid waste collection, drains, paved roads and footpaths, and other forms of infrastructure essential for health; and an ecologically sustainable relationship between the demands of consumers and businesses and the resources, waste sinks and ecosystems on which they draw.

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VIII. CONCLUSIONS

The twentieth century has been a century of change. It has been a century of unprecedented world population growth, unprecedented world economic development and unprecedented change in Earth's physical environment.

From 1900 to 2000, world population grew from 1.6 billion to 6.1 billion persons, about 85 per cent of the growth having taken place in Asia, Africa and Latin America (United Nations, 2001). And although population growth rates are slowing, United Nations population projections (United Nations, 2000, 2001) show that the world population is likely to exceed 8 billion people by 2030. As was the case with world population growth in the past, future growth is expected to be uneven: from 2000 to 2030, the more developed regions are expected to grow by about 2 per cent, while the less developed regions would grow by about 45 per cent.

In 1900, about 86 per cent of the world population were rural-dwellers and just 14 per cent were urban-dwellers (Matras, 1973); but by 2000, the share of the world population living in rural areas had declined to 53 per cent, while the number of urban-dwellers had risen to 47 per cent (United Nations, 2000). By 2030, over three fifths of the world will be living in cities. Virtually all the population growth expected during 2000-2030 will be concentrated in the urban areas of the world.

The enormous expansion in the global production of goods and services driven by technological, social and economic change has allowed the world to sustain much larger total and urban populations, and vastly higher standards of living, than ever before. For example, from 1900 to 2000, world real gross domestic product (GDP) increased 20 to 40 times (DeLong, 1998), while world population increased close to 4 times and the urban population increased 13 times. The benefits accruing from the unprecedented growth of the world economy have occurred among both more developed and less developed countries, but growth has been unevenly distributed. The twentieth century's economic progress was disproportionately greater in the regions that had already been more advanced at the start of that century.

Partially as a result of this economic expansion, substantial improvements have occurred in developed and developing countries alike in the quality and length of life. These achievements reflect progress in providing basic social services such as education and access to safe water and sanitation and have contributed to lowering levels of infant and child mortality and illiteracy, and raising life expectancy and school enrolment ratios. Although living standards have improved during the twentieth century throughout the world, the pace of improvement has varied among countries. In particular, acquired immunodeficiency syndrome (AIDS) and other emerging or re-emerging diseases in some countries and economic and political dislocations in others have reversed past progress in improving health and mortality.

Relatively rapid and uneven population growth and economic development are occurring simultaneously with degradation of aspects of Earth's physical environment. For example, according to J. R. McNeill (2000), the twentieth century experienced topsoil loss equal to that of the previous 1,000 years. Total energy use during the 100 years of the twentieth century was 10 times that of the previous 1,000 years. World food production has increased at a faster rate than population and more food per capita is available now than ever before in world history; but the increasing scarcity and degradation of agricultural and other environmental resources cast serious doubts as to how long food production can surpass population growth. Throughout the world, many fragile, biologically unique ecosystems, and the many species of plants and animals they contain, are threatened. Forest areas are diminishing, especially in tropical areas. Industrial pollution and harmful run-offs from agricultural production threaten the quality of water and air. Fresh water is already in short supply in some regions—approximately one third of the world's population lives in countries classified as experiencing moderate to severe water stress or scarcity—and future population growth will only increase the pressure on this renewable, but limited, resource. Emissions of carbon dioxide and other greenhouse gases continue to mount.

Although scientists debate the exact numbers and rates of change, the general trends in population, environment and development noted in the present report seem clear. As this report shows, what is more uncertain is the extent to which the size, growth and distribution of population have affected economic development and environmental trends. The review of the relationship between population growth and economic development contained in an earlier edition of this report (United Nations, 1999) concluded that the relationship was complex and varied over time and place, while emphasizing the intermediary role of institutions with respect to the form and size of the population impact. The 1999 report reflected the consensus that slower population growth buys time for Governments and relevant institutions to respond to changing conditions.

A study by the Intergovernmental Panel on Climate Change (Watson, 2000) concluded that there was no doubt that human activities were disturbing the global carbon cycle through the combustion of fossil fuels and through land use, land-use change and forestry activities. A recent study at Texas A&M University (Crowley, 2000) concluded that 75 per cent of global warming since 1900 had been due to human influences, "particularly to rising levels of carbon dioxide and other heat-trapping 'greenhouse gases' that come from the burning of fuels and forests". Such human influ-

ences, however, stem mainly from modes of production, not from the size, growth and distribution of population. Moreover, humans may have a positive effect on the environment also; it was the combat of humans against the traditional environmental threats of bubonic plague, smallpox, tuberculosis and the like that led to the twentieth century gains in life expectancy and health.

This report indicates that population and demographic change interact with environmental change and economic development in a variety of ways. To begin with, it is clear that population affects and is affected by the environment and economic development. The challenge is to identify the complex interactions and effects of population, environment and development. To date, while some progress has been made, this challenge remains formidable for researchers and policy makers alike. Sorting out the interactions between population, environment and economic development needs more and better data.

While all the environmental problems discussed in this report are largely or entirely the result of human activities, they vary in the extent to which they can be linked directly to population size, growth or distribution. For example, growth in some types of pollution is primarily the by-product of rising per capita production and consumption in industrialized economies, where population has generally been growing slowly. Even for those environmental problems that are concentrated in countries with relatively rapid population growth, it is not necessarily the case that population increase is the main root cause, nor that halting population growth would resolve the problem: other social and technological "driving forces" are usually also contributing to environmental degradation. Nevertheless, other things being equal, continued increase in population plays an important role by increasing aggregate economic demand and hence the volume of pollution-causing production.

Population growth is generally regarded as the single most important force driving increases in agricultural demand. While most recent expert assessments are cautiously optimistic about the ability of global food production to keep up with demand for the next quarter-century or half-century, food insecurity, associated with poverty, is projected to persist for hundreds of millions of people. Nonetheless, the Food and Agriculture Organization of the United Nations (FAO) concluded (in an assessment prepared for the World Food Summit in 1996) that "with regard to poverty alleviation and food security, the inability to achieve environmentally sound and sustainable food production is primarily the result of human inaction and indifference rather than natural or social factors" (Food and Agriculture Organization of the United Nations, 1996).

The need to feed a growing population is placing mounting stress on water supplies in many parts of the world. On a global basis, irrigation accounts for more than 70 per cent of fresh water taken from lakes, rivers and underground sources. While water is often inefficiently used, institutional mechanisms for implementing effective water management policies are often time-consuming and expensive and, in some cases, they are not viable options.

Population growth, through its effects on the expansion of cropland and the harvesting of wood for fuel, is an important factor contributing to deforestation in some areas, often tropical areas and areas rich in biodiversity. However, in several instances, it was government policies favouring the colonization of forested areas that accelerated the human settlement of the agricultural frontier and, in turn, caused rapid deforestation. Commercial logging is also a major cause of deforestation in some areas.

In rural areas of low-income countries, rapid population growth has often resulted in added pressures on agricultural land, resulting in land fragmentation and the reduction of yields. Such a process is at the root of a further cycle of environmental damage as the people who lack adequate land in one region migrate to ever more environmentally fragile areas in search of better chances of subsistence. Although the rural population of developing countries is expected to increase more slowly in the future than it did over the past 30 or 40 years, several regions already have very high population densities relative to available agricultural land. Consequently, even low levels of rural population growth are likely to result in added pressures on the rural environment. In those regions, the continued destruction of natural resources as a result of attempts to extend the agricultural frontier is very likely to continue or to accelerate in the future.

When considering responses to environmental problems it is necessary to recognize that social-institutional factors can be as important as, if not more important than, technological ones. The general problem of managing locally scarce or fragile resources is not new. Many examples can be found where traditional societies developed communal rules for managing a scarce resource. Population growth has the potential to destabilize such communal arrangements, since rules that functioned adequately at a low population density may lead to overexploitation and/or pollution at a higher density. Successful adaptation may be possible—as, for instance, in the transition described by Boserup (1965) from shifting to settled agriculture—but it is important to note that changes in the social allocation of resources are likely to be required as part of such adaptation. Even though the overall social as well as environmental benefit to such organizational change may be large, the process may prove to be contentious and politically difficult.

The relationships between urbanization and environmental degradation are complicated, involving interactions with the natural and the human-made environment. The regional ecosystem (for example, coastal regions, arid regions, humid-tropical regions, mountainous regions) in which a city is located, for example, is often a critical determinant of environmental conditions. In the case of ambient pollution, for example, the vulnerability of large cities to the adverse impacts of vehicle emissions depends on certain natural features (for example, altitude, direction and speed of prevailing winds; amount of sunlight; precipitation and humidity). Economic development exacerbates many urban environmental problems (for example, solid waste, automotive pollution) because the quantity of urban wastes generated per capita also tends to increase steadily with increased incomes.

With globalization, and new and emerging technologies and modes of production and consumption, the relationships among population, environment and development have become issues of heightened concern for Governments, the

international community and the average citizen. Population growth, structure and distribution are important aspects of environmental stress in so far as everyone requires the basic necessities of water, food, clothing, shelter and energy, which directly or indirectly affect the ecosystems (World Resources Institute, United Nations Environment Programme, United Nations Development Programme and World Bank, 2000). However, environmental stress is not just a matter of population change; it is also a matter of how and what people produce and consume now and in the future (World Resources Institute, United Nations Environment Programme, United Nations Development Programme and World Bank, 2000; United Nations, 1997).

In his message to the Global Ministerial Environment Forum (Malmö, Sweden, 29-31 May 2000), the Secretary-General noted that: "Technological breakthroughs that are unimaginable today may solve some of the environmental challenges we face. But it would be foolish to count on them and to continue with business as usual" (United Nations Environment Programme, 2000). Government domestic programmes and effective international agreements to curtail environmentally harmful activities are essential. However, population pressures are contributing factors to environmental stress. Population and development policies—especially those relating to the size, growth and distribution of population—are necessary and vital components of the constellation of actions needed to ensure sustainable development and to safeguard the environment during the twenty-first century and beyond.

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ANNEX I*

Availability and quality of data

The present annex provides a concise summary of the sources, coverage and quality of data regarding population and the environment. "The environment" has many aspects, and it is beyond the scope of this report to review the status of data collection for the enormous range of indicators that have been proposed or for which measurement has been attempted (United Nations, 1982, 1983, 1998). The emphasis here is on general features and problems of the data rather than on particular indicators.

At the outset, it should be noted that errors and gaps in the availability of data are not the only problem in relating population to environmental variables. One difficulty is that the demographic data are likely to be compiled for geographical units different from those of the environmental indicators. Another is that the time periods for which geographically detailed data are available may differ between population and environmental indicators. Beyond this, in order to obtain an understanding of the ways in which local population trends affect the environment, or vice versa, it may be necessary to have information about people's motivations, their social conditions and institutions, their health, their knowledge and their resource management practices. Such information does not flow from routine data-collection systems. A growing number of studies have tried to investigate such local issues in depth, and some of these have been multidisciplinary studies involving such specialists as demographers, anthropologists, economists, ecologists and experts in remote sensing (Liverman, 1998). Such studies can be very valuable for understanding the process of, for instance, colonization of "frontier" forests. However, such studies are too few, and too diverse in content and methods, to lead to any clear generalizations at present,[a] and their high cost is an impediment to wide application. For the most part, therefore, the data available for studying population and environment issues on a broader scale are limited to information that has been gathered for purposes other than the analysis of population-environment interrelations.

POPULATION DATA

The empirical basis for estimating population size, growth and structure is in general better than the one that exists for monitoring the aspects of the environment that are discussed in the present report. The primary data-collection systems for demographic and social information are population censuses, civil registration systems and sample surveys. These provide the primary bases for measuring demographic parameters, such as the size and growth of population, components of growth, birth and death rates and migration. Other relevant sources of demographic statistics include population registers (in some countries), immigration and emigration statistics and other "administrative" data, such as school enrolment data and lists of eligible voters. Such administrative data are commonly available on an annual or more frequent basis, and their trends can be of use for deriving demographic estimates for the period since the most recent census, particularly for local areas.

Population censuses are customarily taken decennially or quinquenially. The key features of a census include individual enumeration of all units, universality within a well-defined territory, simultaneity and periodicity. Population censuses can provide detailed data for small geographical areas, and results which are not affected by sampling error. Censuses are a major source of many of the broad macrolevel indicators required to measure and monitor progress in the areas of population and development and public policy. Census coverage and content have improved substantially over the past several decades. During the 1990 census decade (1985-1994), 202 of 237 countries or areas conducted a census, and these included 95 per cent of the estimated world population. During the 1980, 1970, 1960 and 1950 census decades, the numbers of countries or areas conducting a census had been, respectively, 194, 162, 85 and 65 (United Nations, 2000).

Sample surveys are an important tool for obtaining demographic data, particularly with respect to fertility and mortality in those countries where the vital registration system misses many births and deaths. Sample surveys apply to selected entities of the population. Many such surveys are designed, through application of statistical sampling methods, to be representative of the national population, while others concentrate in depth on selected local areas. Because of their smaller scale, surveys provide an opportunity to study a topic in greater depth than that of a census, and they tend to employ better-qualified and better-trained enumerators. As a result, the data generated are generally found to be more accurate than census data. The growth in use of sample surveys, which has occurred mainly since the mid-1960s, has been a major factor in improving the quality of information about fertility and mortality (especially child mortality) in developing countries, where vital registration systems have been slow to improve. However, by their very nature, sample surveys that are nationally representative do not provide comprehensive information about small geographical areas, and survey estimates are subject to sampling error.

A variety of demographic techniques have been developed for evaluating data quality and deriving improved estimates (see United Nations, 1983, 1988). In virtually all countries, the available population data are evaluated and, if necessary, adjusted for incompleteness and error. The population data and projections discussed in this report have been evaluated and adjusted by the Population Division of the United Nations Secretariat as part of its preparations of the official United Nations population estimates and projections.

ENVIRONMENTAL DATA

Recognition of the importance of environment statistics received an impetus from the United Nations Conference on the Human Environment (Stockholm, June 1972), which noted that environmental concerns had increasingly become the subject of mainstream socio-economic policies, at both the national and international levels. It recommended that environment be added to the existing social, economic and demographic statistics to form a more complete system of national statistics. Twenty years later, a consensus was achieved at the United Nations Conference on Environment and Development (Rio de Janeiro, June 1992) that strategies of sustainable development should integrate environmental issues into development plans and policies. Such integration needs to be supported by environmental and socio-economic data.

Environment statistics, despite its almost 30-year history, remains a relatively new and developing area of statistics. To a great extent, the field depends on evolving scientific knowledge about the interrelationships between humans and their environment. Environment statistics are interdisciplinary and diverse in terms of their sources. They range from pertinent social and economic statistics to the results of laboratory analyses at monitoring stations and field observations made by national scientists. A great variety of methods are applied in the compilation of these data. Environment statistics try to synthetize data from various subject areas and sources with the official demographic, social and economic data.

Among geographical regions and countries, large differences exist with respect to: (*a*) the availability of relevant primary data in the area of environment; (*b*) the quality, comparability and frequency of data compilation; and (*c*) the quality of information systems. The amount of local, regional and global data in the form of country statistics, monitoring data, field measurements, satellite imagery etc. is enormous, but the empirical base for the transformation and integration of raw data into meaningful information is weak. It remains difficult to derive useful information on the current state and trends in environmental issues while there is still little feedback and validation during this process among collectors, collators, analysts, disseminators and users of the data. There are

*Acknowledgement is due to the United Nations Statistics Division for the preparation of this annex.

few comprehensive international recommendations on the concepts and methods used in environment statistics. Data quality therefore depends on the reliability and comparability of the primary sources.

In the field of environment statistics, there are no regular data-collection activities at the global level. The international organizations that are engaged in environmental assessment have developed large databases that include a wide range of data, such as regular economic, social and demographic statistical series and measurement data from monitoring networks. To a large extent, core data sets are being used by many organizations engaged in the assessment of environmental issues, such as the United Nations Environment Programme (UNEP), the Food and Agriculture Organization of the United Nations, the United Nations Development Programme, the Commission on Sustainable Development and the Organisation for Economic Co-operation and Development. The input data on the driving forces and pressures (economy, population, land use, energy consumption etc.) are common to many assessment activities. Underlying observations (surveys, measurements, remote sensing) form the most basic data layer, with considerable overlap among several global assessments. Still, the lack of relevant data is a common experience in reporting about the environment. There are still serious data gaps, and poor data quality is of equal concern.

During the preparation of UNEP's *Global Environment Outlook 2000* (United Nations Environment Programme, 2000), a detailed analysis of the problems of data quality and availability was carried out by the participating agencies. According to this survey, the major constraints affecting data issues are both institutional and technical. In most developing countries, the monitoring and data-collection infrastructure is handicapped owing to limitations in financial, technical and human resources. Those same constraints are also faced by regional and international organizations. The data management infrastructure in many countries is weak and data reporting is fragmented. In the absence of a central compiling system, environmental data remain scattered across many sectoral organizations and departments. Different agencies and organizations report their data for different geographical areas, thus hampering global and regional use and comparability of these aggregated data sets. Among the technical constraints, the lack of internationally accepted standards and definitions ranks highest. Other most important factors include insufficient coverage, both in time and in space, of monitoring networks; different reporting periods; different and non-documented methods used to fill data gaps; and conceptual and technical difficulties of measurement, and differences in measurement methods. The United Nations Statistics Division initiated a worldwide pilot collection of environmental data in 1999. The results and experience gained through this effort also supported the findings of the Global Environment Outlook group.

The regular production of reliable, comparable global environment statistics is still a task for the future. The gradual development of such a reporting system must rest on the continuous improvement of its building blocks. Despite the numerous inconsistencies and shortcomings, core environmental data sets are improving, expanding and becoming more easily accessible. New global or regional compendiums of environment-related data have considerably improved the global stock of data resources, and a growing number of countries have developed systematic compilations of environmental data, in part following the guidelines of the United Nations Statistics Division.

Major initiatives have been launched to improve environmental observations and data collection, and to estimate the economic impact of environmental issues, ranging from ozone monitoring under the Montreal Protocol on Substances that Deplete the Ozone Layer and the three Global Observing Systems, to monitoring by non-governmental organizations of forests and coral reefs, to the establishment of guidelines for integrated economic and environmental accounting (United Nations, 1993; United Nations and United Nations Environment Programme, 2000). There have also been efforts to improve coordination and cost-effectiveness, such as through the Integrated Global Observing Strategy. Another endeavour to monitor global ecosystems is the "Millennium Assessment of Global Ecosystems" (see report of the Secretary-General entitled "We the peoples: the role of the United Nations in the twenty-first century" (A/54/2000)), a process that was officially launched at the fifty-fifth session of the General Assembly in September 2000. The Millennium Ecosystem Assessment is a collaborative effort organized and sponsored by an array of Governments, United Nations organizations and scientific bodies. It will assess on a global level the condition of five major ecosystems: forests, freshwater systems, grasslands, coastal areas and agro-ecosystems. Findings from a Pilot Analysis of Global Ecosystems (PAGE) are summarized in *World Resources 2000-2001* (World Resources Institute, United Nations Environment Programme, United Nations Development Programme and World Bank, 2000). One of the most important conclusions emanating from this assessment of global environmental trends concerned noting the lack of baseline knowledge upon which to properly determine the condition of ecosystems. Filling this void requires a systematic assessment of ecosystems by using an approach that links the range of ecosystem goods and services with the underlying processes that produce them. This would permit policy makers to identify the best policy options for managing ecosystems now and in the future.

Gaps in data and scientific understanding undeniably make it difficult to achieve a consensus on actions needed to solve environmental problems. For example, "because scientific information concerning fisheries is to some degree uncertain, there is always a temptation to assume the best and treat the fishery as though the uncertainty will work to benefit rather than hurt the fishers" (Committee on Ecosystem Management for Sustainable Marine Fisheries, 1999, p. 67): this observation, though made in respect of only one environmental issue, applies as well to others. This temptation is a potent obstacle to action, wherever this would impose significant short-term costs on powerful constituencies. The precautionary principle, endorsed in 1992 at the United Nations Conference on Environment and Development, recognizes that action should not wait until all the scientific evidence is in place: "In the face of threats of irreversible environmental damage, lack of full scientific understanding should not be an excuse for postponing actions that are justified in their own right. The precautionary approach could provide a basis for policies relating to complex systems that are not yet fully understood and whose consequences of disturbances cannot yet be predicted" (Agenda 21, para. 35.3).

NOTE

[a]For a review of many studies in this area, see United Nations (1994).

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ANNEX II

Theories and frameworks: modelling the impact of population growth on the physical environment

The present annex discusses the concepts underpinning the empirical analysis and modelling of the impact of population growth on the physical environment, including non-renewable and renewable natural resources, and on climate change. The first section of the annex reviews the models that consider the relationships between population and the environment from a technological standpoint.[a] The second section considers the social mechanisms that mediate and shape the impact of population dynamics on the environment, with particular emphasis on patterns of land use.

A. Relationships between population, technology and the environment

Since ancient times, statesmen and philosophers, despite being essentially favourable to population increase, have expressed opinions about such issues as the optimum number of people and disadvantages of excessive population growth. In this context, the recurrent theme was the balance between population and natural resources conceptualized as means of subsistence, or, more concretely, food. Ancient writings anticipate aspects of more formal concepts developed later and contain seeds of certain ideas that figure prominently in modern theoretical works.

The works of ancient Chinese philosophers, including Confucius and his school, contain some concept of optimum population at the local level. It was posited that the Government was responsible for maintaining an ideal balance between land and population by sponsoring migrations from overpopulated to underpopulated areas. Plato and Aristotle were alert to the necessity of population's being self-sufficient in food, and warned that the fact that cultivated land could not be expanded rapidly enough to match rapid population growth would lead to overpopulation and poverty. Although early and medieval Christian doctrines were mainly populationist and considered population issues from a moral and ethical standpoint, some writers regarded the excessive growth of the known world population as the cause of poverty and suffering and attributed to nature the ability to re-establish the balance between population and resources through pestilence, famine and war.

Mercantilist ideas, which dominated economic thinking in Europe during the seventeenth and part of the eighteenth century, also contained the concept of a ceiling on population increase imposed by the amount of subsistence. By supplementing, in their doctrine, domestically produced food with imports from abroad made possible by manufacturing and trade, the mercantilists contributed to the reconciliation of the populationist argument with the notion of limits to growth. The physiocrats, by virtue of their belief in the central role of agriculture in economic growth, were more inclined to consider the amount of domestically produced subsistence as the limiting factor of population increase. In the late eighteenth century, the technocratic optimism of Godwin and Condorcet proclaimed the unlimited ability of science to ascertain a practically unlimited supply of food.

For the last two centuries, the Malthusian perspective has shaped the debate on population-development relationships. Both its proponents and foes shared concerns about the balance between demographic trends (essentially population growth), natural resources and economic growth and poverty. Whereas initially the debate focused on Great Britain in the midst of its industrial revolution, in the second half of the twentieth century that debate widened in scope to include the availability of arable land for food production by and for the poor in the developing countries.

In his two famous pamphlets, Malthus (1798 and 1803; republished 1960) postulated that whereas agricultural production of food grows only arithmetically, human population has a tendency to grow geometrically, therefore outstripping the productive capabilities of land resources. The result is that "positive" checks, such as famines and increased mortality, or "preventive" checks, such as postponement of marriage and limitation of family size, work to reduce population growth. In more general terms, the Malthusian view suggested that limited natural resources place a restriction on population growth. Malthusian theory, formulated before the agricultural revolution, is built upon the assumption that environmental resources such as land are fixed and the returns to capital investments tend to bring diminishing returns. Malthus did not foresee the technological changes that have accompanied modernization, which allowed agricultural output to increase faster than population growth.

In the nineteenth century the classical school of economics and in the twentieth century the neoclassical school generally pursued Malthus's approach and incorporated two concepts—the pressure of population on subsistence and the principle of diminishing returns—into its theory of long-term economic growth. Yet, as the classical economists were concerned mainly by profit and equilibrium, they discussed population-subsistence balance in terms of labour productivity and market efficiency rather than as an issue of land availability. Socialist and Marxist critics of Malthus, concentrating on his concepts of poverty, human misery and demographic patterns, rejected the law of diminishing returns, and maintained that the productive power of people was unlimited, but also paid little attention to the environmental aspects of his writings.

The relationship between population and resources lies at the basis of the concept of optimum population, whose ingredients can already be found in the works of Malthus and economists of the classical school. This theoretical concept received most attention during the 1920s and 1930s. In its static sense, the concept relates the population size (defined as either point estimate or range) to a given size of the area and maximum industrial productivity. The dynamic version of the optimum population theory modified the concept of diminishing returns by stating, inter alia, that the productivity of labour tended to decrease as the ratio of labourers to land increased after a certain optimum density had been reached. Still another variant reformulated the problem into harmonizing population trends with the changes that occur in the other factors involved.

With the acceleration of population growth in the developing countries in the 1950s, the population-environment relationships gradually resurfaced and entered the foreground of population debate. Boserup (1965, 1976 and 1981) explicitly takes into account technological change. Boserup suggested that in some cases population growth and the resulting increase in population density might induce technological changes, such as reductions in fallow time and increasing input of labour per unit of land, that allow food production to keep pace with population growth. Since the long-range perspective is implicit in this concept, it is not necessarily suitable to situations where agricultural practices rapidly become unable to cope with high rates of population growth.

Simon (1981, 1990, 1996) went further to suggest that population growth induces technological change sufficient to expand food output faster than population. He held the view that in the short run more people may increase the scarcity of resources and cause prices to rise. The higher prices, in turn, prompt inventors and entrepreneurs to innovate, and in the long run prices eventually end up being lower than before the scarcity occurred.

Thus, the concept that frames the population-environment relationships in terms of per capita availability of resources has led to opposing perspectives. On the one hand is the "limits to growth" perspective developed by the Club of Rome (Meadows and others, 1972) and on the other is the "cornucopian" perspective (Hogan, 1992). Both perspectives imply direct relationships between population and food production—whether mediated or not by technology.

1. *Carrying capacity*

The Malthusian viewpoint has had a direct influence on the development of the concept of carrying capacity, which implies that the ability of land to produce food is limited, and exceeding those limits will, in the long term, result in degradation and declining land productivity. Population ecology and human ecology, which deal with questions of environmental carrying capacity, equilibrium and optimum population size, also reflect this

perspective (Drummond, 1975; Hawley, 1986). The concept of carrying capacity has also formed the basis for numerous macro-model studies that have aimed to predict limits to population growth.

Defined in biology as the maximum population that can be sustained indefinitely in a given environment, biological carrying capacity is derived from observed relationships between population density and mortality, whereby population density is restored to equilibrium by increases in mortality. In studies of human carrying capacity, the basic assumption is that there are critical levels of population that any given area can support, particularly in terms of locally produced food, but also in terms of other selected commodities, such as wood and fuel. Sometimes attempts are made to widen the concept, whereby carrying capacity becomes defined as the number of people that could be supported for the foreseeable future without degrading the physical, ecological, cultural and social environment (Cohen, 1995). Such an all-encompassing approach, however, resists operational interpretation and empirical measurement.

In the last third of the twentieth century, the viewpoint emphasizing the global limits to growth informed much popular discourse on population-environment relations, most notably the reports to the Club of Rome (Meadows and others, 1972; Meadows, Meadows and Randers, 1992), the work of the Worldwatch Institute (Brown, 1983; Brown, Gardner and Halweil, 1999) and research in population biology at Stanford University (Ehrlich, 1968; Ehrlich and Holdren, 1971 and 1974; Ehrlich and Ehrlich, 1990 and 1992; Ehrlich, Ehrlich and Daily, 1993 and 1995). The common drawback of these models has been that they tend to be based on assumptions and generalizations founded on scattered evidence.

By and large, these global-limits models have attempted to simulate the feedback of food deficit on mortality. The concept of carrying capacity has also been applied from a different perspective. Instead of trying to incorporate strong assumptions about the feedbacks, a less ambitious but perhaps more thorough approach seeks to measure the food production potential of land and then to compare it with population estimates and projections. The landmark attempt to assess maximum population that can be supported in a sustainable way by national agriculture of developing countries (China not included) is the Food and Agriculture Organization of the United Nations (FAO)/United Nations Population Fund (UNFPA)/International Institute for Applied Systems Analysis (IIASA) study (Higgins and others, 1983, 1984; Food and Agriculture Organization of the United Nations (FAO), 1994). In that study, the estimated potential population-supporting capacity of the developing countries ranged from 4 billion people in the case of low levels of agricultural input to 33 billion in the case of high inputs to agriculture such as full mechanization and optimal application of fertilizers and chemical controls for pests, diseases and weeds.

Those estimates suggest the tremendous technological potential of agricultural development to meet global food requirements under any plausible scenario of population growth. Characteristically, even the low FAO/UNFPA/IIASA estimate was comparable to the current population of the less developed regions, implying that there are no land constraints on the achievement of food self-sufficiency of the developing world as a whole. A universally high level of farming technology would be able to produce the amount of food several times in excess of demand as implied by population projections. This estimate combines data on crucial natural constraints on food production with productivity potential of available (albeit not necessarily economically feasible) technological inputs. The FAO/UNFPA/IIASA findings are consistent with the assessment that human consumption takes no more than 1 per cent of what is produced by the terrestrial components of the biosphere (Le Bras, 1994).

The FAO/UNFPA/IIASA study provoked considerable controversy as to whether the concept of carrying capacity should be used to study the interactions between population, resources, environment and development. One drawback of the FAO/UNFPA/IIASA study was that population variables were used only in the calculations of nutritional requirements, which depended on the composition of the population by age and sex, while migration and demographic constraints on the supply of labour were neglected (Cohen, 1995). Also, demographic projections treated population growth as independent of economic development and ignored any effects of population growth on the environment (Srinivasan, 1988).

Other criticisms focused on the study's neglect of the economics of agriculture and, in particular, its unrealistic assumption of no exchange of products and labour; yet, in fact, food needs of the population of a particular agro-ecological zone or country are often effectively satisfied through trade (Srinivasan, 1988; Le Bras, 1994). Therefore, while the concept of carrying capacity would be most relevant at the global level, it would be of lesser value in the local context. However, even at the global level, the carrying-capacity concept is fraught with problems of measurement. The global (as well as national) carrying capacity is assessed by adding the estimates for ecologically homogeneous zones, while it was demonstrated that the carrying capacity of the whole area often exceeds, by a significant margin, the sum of the carrying capacities of its constituent parts (Behnke and Scoones, 1993; King, 1991). On the contrary, it is sometimes argued that within a nation, total carrying capacity is less than the sum of its parts (United Nations, Economic Commission for Latin America and the Caribbean (ECLAC), United Nations Population Fund (UNFPA) and Latin American Demographic Centre (CELADE), 1993).

Critics of the concept of carrying capacity have also pointed out that it does not adequately account for the potential impact of technological change, aspirations for higher standards of living, and institutional, social, economic and political constraints on land use and production (De Sherbinin, 1993; Leff, 1993; Zaba and Scoones, 1994). On the other hand, advocates of carrying-capacity studies claim that the concept of carrying capacity continues to have relevance as a heuristic device and recent attempts to calculate carrying capacities have more effectively taken into account variations in institutional and socio-economic factors (Hogan, 1993; Hogan and Burian, 1993).

The concept of carrying capacity has gained renewed attention within the context of sustainable development, which interprets food security as the result of a significant and sustainable increase in agricultural production and of the achievement of substantial improvements in people's food entitlement (Ruttan, 1996). Even within this context, studies that have assessed population growth as being one of several possible causes of unsustainability do not, for the most part, corroborate alarmist statements with respect to population pressure. For instance, a recent study of land carrying capacity in China concluded that, contrary to popular belief, food sustainability of China is increasing (Heilig, 1999).

2. *Multiplicative perspectives*

Natural and social scientists have introduced a variety of models about the population-environment link, including several multiplicative (or decomposition) models. One of the most frequently used multiplier approaches is the "I = PAT" equation (Commoner, 1991; Bongaarts, 1992; Ehrlich and Holdren, 1971, 1974; Ehrlich and Ehrlich, 1992; Harrison, 1992). In this formulation, total environmental impacts (I) are seen as a product of population size (P), the level of affluence or per capita consumption (A) and the level of environmentally damaging technology (T). Human impact on the environment is seen as the direct function of patterns of use of natural resources and patterns of emission of pollutants into the ecosphere in the process of production and consumption of goods and services. In the dynamic application of the model, the growth rate (or its logarithm) of natural resource use or pollution (that is to say, I) becomes the sum of the growth rates (logarithms) of these three elements (P, A and T).

In this generalized formulation, the first element (P) encompasses the demographic effect; the second (A), the development or "affluence" effect; and the third (T), the technological effect. Since the overall impact on the environment and consequently the ratio of all used natural resources and generated pollution to output cannot be measured by a single indicator, the empirical applications of this model have focused on the increase in use of specific resources or emissions of particular pollutants associated with the increase of supply of particular goods or services. Pollution itself is sometimes measured by proxies, as, for example, the level of nitrate in surface waters resulting from use of fertilizers.

Consequently, the results of decomposition analysis using this model are influenced by the choice of variables and the assumptions made. For instance, population growth in the developing countries appears to be a major factor in the increase of cultivated land and livestock (Harrison, 1992), whereas its contribution to environmental pollution is less than half that of technology (Commoner, 1991). In addition, multiplicative models assume that the three environmental impact factors are mutually independent; but this assumption would be unrealistic if population increase retards the growth of per capita income, which, in turn, may intensify the use of such resources as arable land and wood fuel and increase the emission of such pollutants as untreated waste. Similarly, population growth may induce or obstruct technological change, with important repercussions for the resource use and/or pollution generation per unit of produced good.

The lack of evaluation of these interaction effects warrants caution in interpreting the results of multiplicative models. Nonetheless, these models are valuable in framing the debate on complex population-development-environment interrelations, particularly on long-term global-level interactions and strategic policy perspectives.

(*a*) *Climate change models*

The logic of the multiplicative models is widely applied in the complex modelling of global climate change. Population size and growth invariably figure among the numerous variables involved in the analysis. On the one hand, it is sometimes asserted that population growth is the only certain variable in the modelling of the global climate, which is otherwise an essentially chaotic system. On the other hand, the enormous growth in human population may cause catastrophic consequences of any change in global climate.

The Intergovernmental Panel on Climate Change (IPCC) developed the IS92 emission scenarios based on different combinations of population growth and economic development (measured by gross domestic product (GDP)), in order to assess the impact of greenhouse gas emissions on four different world regions to the year 2100 (Intergovernmental Panel on Climate Change (IPCC), 1990; Leggett and others, 1992). These models triggered new directions for global modelling (Weyant and others, 1996). For example, a reference study is the Special Report on Emission Scenarios (SRES), which includes four sets of qualitative storylines of possible futures structured in numeric scenarios with respect to emissions. An important aspect of the SRES emission paths is that they neither include dedicated climate policies nor suggest a "best guess" scenario. Rather, they describe "non-intervention" or "baseline" conditions of future developments, which provide a guide for additional assumptions to be made in detailed climate impact and mitigation analysis (Alcamo and others, 1995). This type of analysis was done in the study for the Climate Change Group, where eight summary indices were applied to different SRES scenarios, in order to assess the greenhouse effect of changes in income, population dynamics, non-renewable resources, land use and air pollution. Demographic dynamics are captured by two summary indices: the population index, consisting of population size, completed fertility, infant mortality, and life expectancy at age 1; and the population characteristics index, which includes population density, rate of urbanization, literacy rate and literate life expectancy (Pitcher, forthcoming).

(*b*) *Other global and regional models*

While most of the theorizing about population-environment interactions assumes continuous and linear trends, there is also a growing interest in modelling discontinuities. This approach takes into account that utilization of certain renewable resources has passed or is dangerously close to critical thresholds, beyond which the resource is no longer reproduced. In fact, discontinuity was already explicitly incorporated into the Club of Rome models (Meadows and others, 1972; Meadows, Meadows and Randers, 1992). Later, this approach was developed with respect to natural resources that were on the brink of irreparable exhaustion. Fishery exemplifies issues common to forestry, soils, fur-bearing animals and biodiversity. Prior to a critical point, harvesting fish does not affect the resource base. After that critical point, too many fish are taken out for the resource to be maintained, and the cumulative diminution of the resource begins. Hence, the relationship passes from a linear to a non-linear one (Keyfitz, 1991).

In 1998, the Economic Commission for Africa (ECA) designed a PEDA model that linked population change (P), environment (E), socio-economic development (D) and agriculture (A), to demonstrate the impact of different policy options on food security in the ECA region (United Nations, Economic Commission for Africa (ECA), 1999). The model consists of interlinked modules pertaining to land, water, the economy and human development. At the core of the model is the human development module, which combines demographic factors, food security status, education and place of residence in a multi-State population projection. The PEDA model assumes a vicious circle of poverty deriving from a rapid population growth, increasing use of marginal lands, and decreasing agricultural productivity. The versatility of the PEDA model will depend on the availability of the various input data. The different prototypes of the model tested for selected countries (Burkina Faso, Madagascar and Zambia) underscore the complexity of modelling population, environment and development relationships.

Studies in the field of global and regional modelling share the assumption of the pivotal role that population dynamics play with respect to such fundamental components of sustainable development as emission levels of greenhouse gases, water availability and food production. For that reason, it is important for researchers and policy makers to acquire an adequate understanding of population dynamics and assumptions behind population projections, in order to allow them to properly incorporate demographic data into the models. No less important is the necessity to incorporate determinants of demographic change, such as scarcity of land and common property resources.

B. Mediating factors: social institutions and multiphasic response

Institutional analyses emphasize the social, cultural and institutional factors that play a role in determining population-environment relationships. The growth and distribution of population have direct impacts on environmental use, but the nature of those impacts is governed largely by culture and institutional realities—market conditions, property rights, land distribution, taxes and subsidies on various types of production and consumption (Keyfitz, 1996). The influence of those factors on population-environment relationships is viewed as multi-level for the reason that layers of mediating variables at the family, household, community, national and international levels have an effect on the relationship. One aspect of institutional analysis shares with Marxism the emphasis on property rights. In so far as the land tenure system shapes and accommodates technological innovations, its interactions with demographic growth and increasing population density may become an important and sometimes even crucial feature of both societal and environmental change. A large body of research traces changes in the ecosystems to demographic growth through transformations of social, cultural and institutional factors. Those transformations could have a positive or negative effect on the environment depending on the stage of development, market conditions and the degree of responsiveness of those institutions themselves to population factors.

1. *Positive change*

Institutional analysis demonstrates that in many societies in the past, slow population growth and increases in population densities were probably some of the major factors of technological progress in agriculture associated with environmental shifts. Particularly popular is the concept postulating that as population grows in relation to land, there is a tendency to use land more intensively, by reducing fallow time and increasing labour per unit of land (Boserup, 1965, 1981).

Generalizing across societies and historical stages, institutional analyses assert that population growth decreases the relative price of labour to land and therefore induces a redefinition of property rights on land and rearrangement of labour relations. As a result, a whole array of rural institutions evolve to minimize the costs of initiating and enforcing contracts among economic agents (McNicoll and Cain, 1989) even as the quality of the environment is compromised. From a slightly different perspective, population growth—similar to the growth in demand for agricultural production—increases competition for scarce resources (land) and leads to the reduction of transaction costs through a clear specification of property rights (Alchain and Demsetz, 1973). A contending view, however, is that the scarcity of resources is socially generated; resource shortages and environmental degradation derive from institutional frameworks characterized by uneven social measures that determine scarcity (Hildyard, 1996; Ross, 1996).

2. *Incomplete information*

The concept of population-induced innovations was refined by incorporating the role of active agents of change, of incomplete information and of imperfect markets (Ruttan and Hayami, 1991; Ruttan, 1993). The incomplete information model better suits the modus operandi of agricultural producers in developing countries. Appropriate institutions emerge there to substitute for the lack of credit, insurance and futures markets (McNicoll and Cain, 1989). In this framework, increasing population pressure is seen as affecting not only land rights and production relations but also production risks and their costs (for example, seasonality, yield risks, market price risks and timing uncertainty), ultimately leading to the adaptive change in rural institutions (Rosenzweig, Binswanger and McIntire, 1988).

3. *Negative change*

The correlation of rapid population growth with environmental degradation and, in several societies, with destabilization rather than constructive transformation of property rights has called into question the validity of the postulate that technological progress and agricultural innovation are a function of population growth. Even the proponents of the cornucopian perspective concede that, in the absence of an appropriate institutional framework, not only are the short-run costs of population growth greater but the long-run

benefits are also fewer than in societies where modern social, economic and political institutions exist (Myers and Simon, 1994).

Institutional analysis was instrumental in explaining how rapid population growth in the second half of the twentieth century, in several settings, played a negative role by inducing decay of the old institutions while preventing development of modern property rights with an ensuing increase in rural and urban poverty and excessive pressure on the regenerative capacities of renewable natural resources. Rapid population growth under the norms of partible inheritance of land contributes to the fragmentation of agricultural holdings. To the extent that land fragmentation is not matched by the introduction of intensive and environmentally sustainable agricultural techniques (for example, intercropping), farmers with exceedingly small plots are forced to "mine" their land (for example, by shortening fallow time or cutting remaining trees) or to migrate and engage in ecologically destructive practices of land extensification on marginal lands where soil and climatic conditions are poorly suited for annual cropping. This logic was found to be working with respect to societies with relatively well defined land property rights and high population pressure on arable land, in particular in South-central Asia (Harrison, 1992; Ives and Messerli, 1989; Lele and Stone, l990), Central America (Bilsborrow and DeLargy, 1991; Bilsborrow and Okoth Ogendo, 1993; Stonich, 1989) and the Caribbean (Baril, Gregory and Jacques, 1986).

4. *Multiphasic response*

Multiphasic response to increased population density in rural areas, as postulated by Davis (1963), asserts that families respond to increasing pressures upon their levels of living by increasing production or altering their demographic behaviour: postponing marriage; reducing fertility within marriage; and/or migrating. It was observed that through most of human history, the major means of increasing agricultural production had been land "extensification", or the process whereby agricultural production grows through an extension of the land area, usually involving migration and appropriation of new lands. Response to these pressures may also take the form of changing technologies (use more fertilizer and irrigation) or reduction of fallow time in addition to the demographic responses. All of these responses to increasing population pressure on land may occur simultaneously.

One variant of the theory states that under population pressure, changes in land tenure institutions are likely to occur first because out-migration is not a desirable option. There may be three possible stages of this change: (*a*) the accommodation stage, where tenurial regimes try to accommodate claims on the land without major modifications (for example, idle land is distributed for agricultural use); (*b*) the fragmentation stage, where the land rights remain the same but a reduction of the operational space occurs; and (*c*) the reclassification stage, when new types of access rights are created (Bilsborrow and Okoth Ogendo, 1993).

An important advantage of the concept of multiphasic response over other models is its potential to incorporate negative environmental consequences of population growth (such as land deterioration as a result of shortened fallow time) with its positive impacts (technological change leading to more intensive use of land and fertility decline) into a comprehensive framework. However, the major weakness of this approach lies in this same elasticity. Because the responses of land use to growing population pressure are multiphasic and can be simultaneous, the extent to which any one of the responses occurs—fertility decline, land intensification or land extensification—depends upon the others and hence upon all economic and institutional factors influencing those responses (Bilsborrow, 1987; Bilsborrow and Geores, 1993). Therefore, the framework has little power to predict which response is likely to occur under particular circumstances.

The interactive triangle of demographic trends, environmental shifts and changes in the family structure has drawn the increasing attention of researchers. The very structure of the family may change significantly because of the increasing practice to have at least one family member in a non-farm job. Out-migration from densely populated rural areas has been conceptualized as a household strategy to cope with population pressure on land resources, resulting in separation of spouses, creating new social and economic links between family members (for example, through remittances) and altering the power structure within the household (in particular gender relations), as well as in the community structure (including, inter alia, empowerment of women) (Shipton, 1984; Bilsborrow and DeLargy, 1991; Bilsborrow and Okoth Ogendo, 1993). While in theory it is difficult to differentiate between such "push" factors as demographically driven land scarcity and degradation and the "pull" factors of economic modernization, several case studies provide evidence that environmental change resulting from population growth often has an appreciable impact on intra-family relations and marital and reproductive behaviour (Tiffen and Mortimore, 1992; Cleaver and Schreiber, 1994; Picouet, 1994).

C. Conclusion

Although it is widely acknowledged that important relations exist between population, development and the environment, there is little agreement about the nature and magnitude of the links. There is widespread recognition that population growth is one of the many factors that affect the environmental resource base. However, whereas some empirical models assert that population growth is not an obstacle to "sustainable" development, others contend that population growth has a strong negative impact on the environment. In an attempt to resolve this controversy, some models include intermediary functions between population and the environment. In this regard, the link between population growth and the environment is mediated either by the technology of production or by economic and social organization (for example, markets and cultural and social institutions) (United Nations, 1994). Even so, each of these variant approaches has drawbacks stemming either from its assumptions or from the choice of variables included. For instance, while in some models population growth is an exceptionally significant factor in sustainable development, in others it is seen as a peripheral factor. Nevertheless, whether mediated by technology or by markets and social institutions, there is no doubt that population growth is a factor in the triad of population, environment and development and that population growth affects the environment resource base. The absence of a comprehensive model encompassing all facets of the triad is a testimony as much of the complexity and dynamism of the relationships as of the lack of availability of data to design and test such a model. Without a model, and "cases that support and cases that disprove any statable general rule, we are thrown back on common sense" (Keyfitz, 1996).

Note

[a]The pre-Malthusian views on population-environment relationships reviewed in this section draw upon a review undertaken by the United Nations in 1973 (see United Nations, 1973).

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