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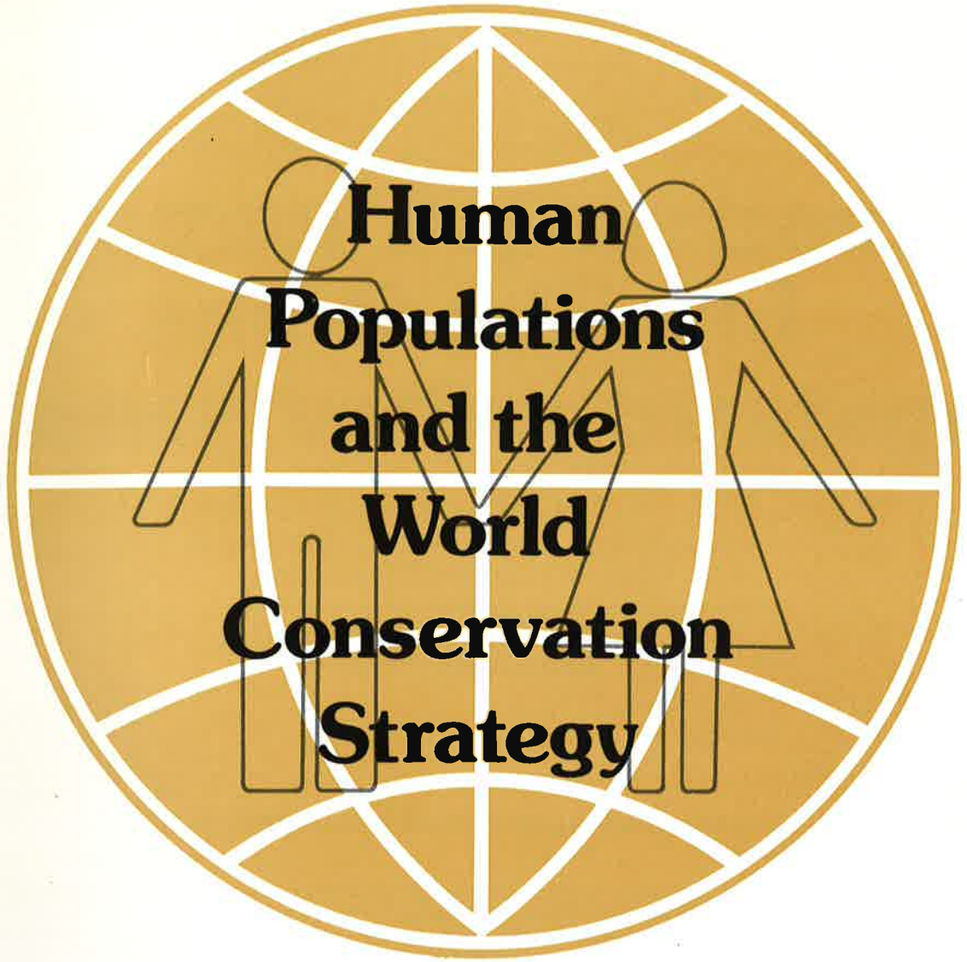

Human Populations and the World Conservation Strategy

Commission on Ecology Papers Number 11

International Union for Conservation of Nature
and Natural Resources
1986

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IUCN Commission on Ecology

The Commission on Ecology of the International Union for Conservation of Nature and Natural Resources (IUCN) is a scientific commission of an independent, international, non-governmental organization. IUCN was founded in 1948 at a conference convened by Unesco and the French Government. The Union comprises today 58 governments as state members, 125 government agencies, and 374 non-governmental national and international organizations. This membership represents 115 countries.
The Commission on Ecology was established in 1954. At present it has 200 members from 50 countries in all the continents, carefully selected for their international scientific status and expertise.
IUCN's Commission on Ecology provides scientific information and advice to ensure that action directed towards the sustainable use and conservation of natural resources makes the best use of current ecological knowledge. The World Conservation Strategy, launched in 1980, provides an overall plan for action in this direction.

Through its Working Groups, the Commission gives particular attention to:
- the ecological problems of arid lands, mountains, marine coastal areas, agro-ecosystems, islands, tropical forests, coral reefs;
- the conservation of marine diversity, river basins and threatened landscapes;
- the relation between cultural values, socio-economic constraints and environmental management practices;
- the dynamics of species extinction, and the identification of meaningful conservation indicators.

The Commission is also active in the field of human ecology, particularly in rural development and traditional life styles.

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Human Populations and the World Conservation Strategy

Report from the Working Group on Population and Natural Resources of the IUCN Commission on Ecology in cooperation with the International Planned Parenthood Federation

Commission on Ecology Paper Number 11

by
J. Hanks

International Union for Conservation of Nature and Natural Resources
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Preface

From 4 to 6 July 1983, the Commonwealth Forestry Institute of Oxford University hosted the first meeting of the Task Force on Population and Natural Resources of the Commission on Ecology of the International Union for Conservation of Nature and Natural Resources (IUCN), which was attended by representatives of the International Planned Parenthood Federation (IPPF). The meeting was chaired by Professor David Pimentel, and the other participants were Mr Vernon Aluvihare, Dr Maarten Bijleveld (*ex officio*), Mrs Frances Dennis, Mr Erik Eckholm, Professor John Hanks, Miss Barbara Hermen, Dr B. H. Kiew, Dr Norman Myers, Dr Jack Parsons, Professor M. E. Duncan Poore, Professor Francois Ramade and Mr John Rowley. In a follow-up to the IUCN Council decision of November 1982, the Working Group discussed the linkage between human populations and the conservation of natural resources, prepared a position statement on population, conservation and development (published in 1984 as a Commission on Ecology Occasional Paper Number 3), and provided the guidelines for a supplement to the *World Conservation Strategy*.

The Working Group appointed John Hanks to expand the position statement as an additional background document for the supplement to the *World Conservation Strategy*. This document, "Human Populations and the World Conservation Strategy", prepared with the Group's assistance, was presented to the November 1984 meeting of the Commission in Madrid. On the basis of comments made at this meeting, the Commission made no further decision except that the paper should be revised. In August 1985, at the Banff meeting of the Commission, it was decided, following discussions, that the revised paper should be published as a technical background paper with further revisions to the recommendations.

This supplement outlines some critical aspects of the interaction between human populations, natural resources and social and economic development. As an introduction to the subject, the need is stressed to encourage the implementation of the *World Conservation Strategy* through programmes which integrate development and conservation planning with a population policy. Compiled by John Hanks, it reflects the views of the Working Group particularly from the perspective of non-migration. It provides a starting point for considerations of human resources development in consonance with the *World Conservation Strategy* – considerations which will have to take into account the role of women, of families, and of communities in determining developmental lifestyles, the importance of human skills, patterns of resource utilization and management, and the place of beliefs and ethical values in the techno-cultural adaptations of human populations to natural resource levels. Such considerations will demand considerable inputs both from specialists in a wide array of disciplines and from institutions, in order to arrive at a balanced, dynamic and 'macro-ecological' view of conservation.

JOSÉ I. FURTADO
Chairman,
IUCN Commission on Ecology

Human Populations and the World Conservation Strategy

1. SUMMARY

Although the World Conservation Strategy *refers to human population growth and the impact of this growth on natural resources, it has given no indication of the importance of integrating development planning and conservation planning with a population policy as a basis for sustainable development. This supplement addresses this need by outlining some critical aspects of the interaction between human populations, natural resources and social and economic conditions, and recommending IUCN action to tackle the problems concerned. Particular emphasis is placed on the importance of planning* with *people, and on packaging conservation programmes so that they are more likely to be accepted by people who are trapped in a vicious circle of poverty. Critical areas of concern include population growth, agriculture and declining food production, soil erosion, loss of biological diversity, reduction of forests and open woodland, declining water resources, and resource destruction and pollution associated with man's demand for energy.*

It is concluded that if the present high rates of population growth are maintained, these detrimental interactions between human populations and natural resources will increase in number and extent, making it extremely difficult, if not impossible, to accomplish the goals of the World Conservation Strategy. *Conservation organizations should actively promote programmes of sustainable rural development, especially where degraded environments in developing countries contain or are close to threatened species or ecosystems. Finally it is recommended that every country should introduce a population policy, which defines an optimum population size that will conserve all natural resources and enhance the quality of existence of all people. Such population policies should be integrated with national conservation and development strategies.*

2. INTRODUCTION

The *World Conservation Strategy* and the linking of conservation and development

In 1980, IUCN published the *World Conservation Strategy*, a new and unambiguous philosophy for conservation which attempted to resolve conflicts between conservation and development. In a significant departure from the comparatively rigid 'preservationist' attitude of the traditionalists, conservation was defined as "the management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations" (IUCN, 1980). The goal of the *Strategy* is the positive linking and integration of conservation and development so that the people of the world may all have a reasonable and sustainable way of life. The essential message is that conservation is concerned with human survival and sustainable development, and in line with this new philosophy, the *Strategy* sets out the following three objectives for living resource conservation:

(1) to maintain essential ecological processes and life-support systems;
(2) to preserve genetic diversity;
(3) to ensure the sustainable utilization of species and ecosystems.

Until the publication of the *Strategy*, those concerned about the conservation of nature and those concerned about development and economic progress were often involved in bitter disputes, but since 1980 all the parties involved have begun to realize that they need the others' insights if any of the goals are to be met (Eckholm, 1982).

The *World Conservation Strategy* has joined the rapidly growing list of international resolutions and declarations of intent. Like all of them it remains a very vulnerable document, virtually worthless unless implemented. Successful implementation in the presence of continued rapid population growth is most unlikely, for although IUCN is committed to the promotion of the *Strategy*'s implementation, the success of such a venture is becoming more remote as each day goes by. Regrettably, the new philosophy has not yet been accepted, nor even recognized, at the grass roots level in most countries, and a more positive reception is unlikely as long as poverty and accelerating environmental degradation persist.

Two other important issues of concern have unfortunately so often been overlooked by conservation, development, and family planning agencies. First, although 'global' statistics, syntheses, and solutions, coupled with the broad-based ecological concepts as set out in the *Strategy* are of use in stimulating international and national organizations to tackle population/resource/environmental problems, *little significant progress will be made without the support of the local communities in which the relevant programmes are to be initiated.* Second, for too many years the socio-economic and environmental issues that are discussed here have been left in separate 'boxes', and all too often defined and tackled in isolation. For

example, conservation was seen as being solely concerned with the preservation of fauna and flora, and quite unrelated to the problems of rural poverty. Similarly, development activities have, in places, been promoted with little or no awareness of the vulnerability or concern for certain ecosystems and species – their conservation seemed irrelevant. *The failure of many of these activities shows that population/resource/environment issues cannot be regarded as separate and unrelated entities, and emphasizes that an integrated approach to conservation, development and fertility management is long overdue.*

Human populations and natural resources

The quality of human life in both developed and developing countries is being increasingly influenced by a complex mixture of environmental and population stresses, often associated with the overexploitation of certain natural resources. Even when human members were much lower than they are now, environmental degradation occurred from time to time, but it was usually possible for people to escape the consequences of their actions by migrating to new areas. With few exceptions, the option of movement within rural areas no longer exists, because populations have grown too rapidly in relation to land availability.

Some communities have adopted life-styles that continue to have high levels of resource consumption by trading manufactured goods and skills in exchange for basic raw materials, and they are thus able to support higher numbers than their primary resources would warrant. At the other extreme are the poorer communities, usually characterized by rapidly increasing numbers, many of whom live *directly* off the forests, grasslands, soil and other resources that are being so seriously threatened and degraded. These are the people who are losing the basic resources that have made their way of life possible. With their present levels of knowledge and infrastructure, in order to stay alive *they have to deplete* many of the resources on which their future survival depends. In too many of the countries where these communities live, population pressures and environmental and social stresses have become so severe that they are denying millions of people their basic human needs, and leaving them with little hope of betterment in the future.

In much of the Third World, poverty and its associated problems originated within rural societies, and the growth of urban poverty can, in a sense, be viewed as a derivative of rural poverty (McNicoll and Nag, 1982). Very often, the neglect of rural development and the associated environmental degradation have stimulated and accelerated rural-to-urban migration. In fact, the vicious circle of poverty which is developing in many of these countries and is characterized by stagnating or even declining agricultural production, low productivity, malnutrition, degradation of natural resources, low incomes, and high birth and death rates, is becoming one of the most difficult challenges facing Third World conservation and development agencies (Fig. 1). The extent of this poverty is frightening, and those who suffer are faced by a condition of life so degraded by disease, illiteracy, malnutrition and squalor as to deny them basic human needs. Yet this condition of life is so common as to be the lot of 40 per cent of the peoples of the developing countries (McNamara, 1981). No major area in the Third World is exempt from these problems. For example, between 80 and 90 per cent of the nearly 400 million people in sub-Saharan Africa live in rural areas, and most survive on an annual per capita income of less than US$ 150 (Lele, 1981).

Extremely high rates of population growth (more than 3 per cent per year) are found in several of these African countries, and threaten to cancel out any progress made in agricultural production and nutrition (Bonvin, 1982). Furthermore, rapid population growth postpones the attainment of universal education and health care, and places considerable organizational demands on a society.

Only through concerted efforts to develop rural as well as urban areas can the people of the poorest nations begin to move away from absolute poverty, but this can be done only if the energies of the people themselves are mobilized to enhance the quality of their lives and to rebuild their environment. Within most communities, social and economic conditions will generally have to show some improvement before births decline significantly, and this illustrates the dilemma of the circle of poverty, which can also be perceived as a vicious cycle of causality. To put it simply, large, poor, rapidly growing populations eventually cause environmental deterioration, which in turn creates living conditions that make reduction in fertility more difficult to achieve, while the continuation of population growth brings further depletion of natural resources.

Planning with people

The world is full of examples of development plans that have failed because they were done *for* the people rather than *with* the people (Kennan, 1980). Such plans have involved an approach which overlooked the felt needs and aspirations of the recipients, and placed very little emphasis on the importance of identifying cultural and social norms, sensitivities and perceptions of the communities concerned. Furthermore, the recipients of development were often *told* what to do, without any attempt to assess their comprehension or acceptance of the plans. Thus the community came to depend on the outside source for initiative and help, but once these stopped, the programme came to a halt. There is at least a growing awareness among development agencies that *development cannot succeed without the support of the people it intends to help, because people are both the basis and the object of development planning.*

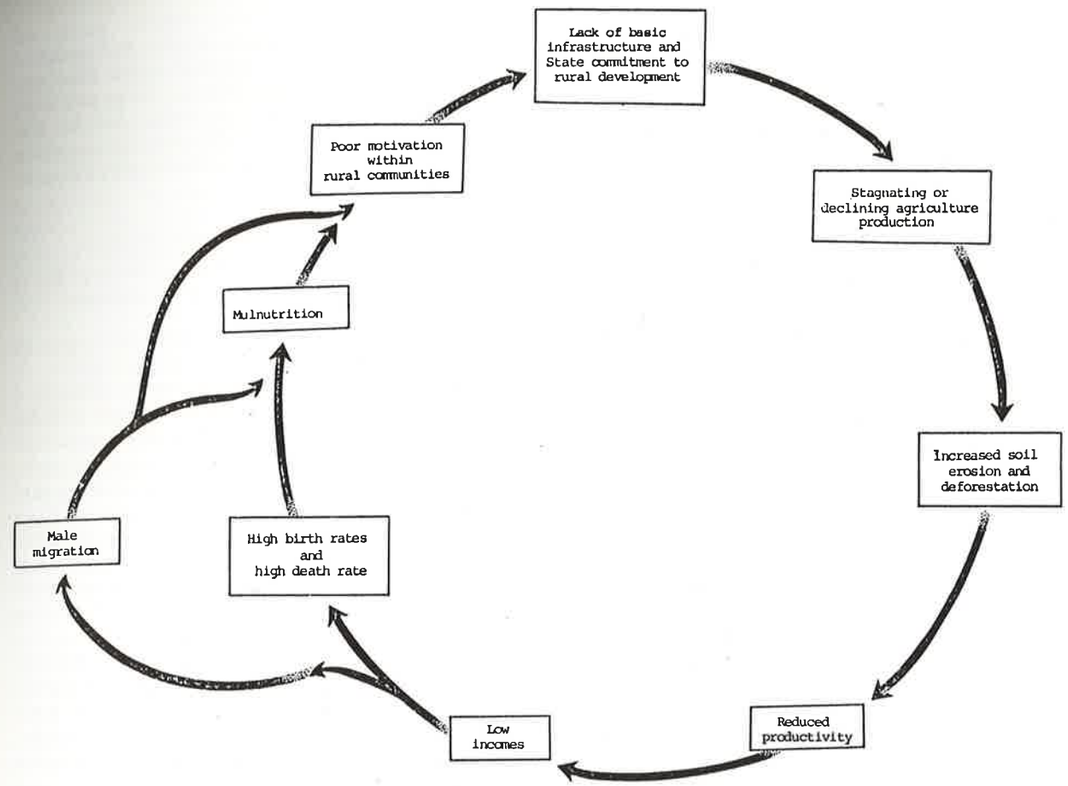

Fig. 1. The vicious circle of poverty in rural areas is one of the most difficult challenges facing Third World conservation and development agencies.

'People involvement' is just as important for the successful implementation of the *World Conservation Strategy* in Third World countries. When these programmes mimic those of the developed world, they are usually ill-suited to local conditions and social needs. For example, many African conservation organizations have placed great emphasis on the aesthetic and ethical aspects of species conservation, concepts that are often irrelevant and incomprehensible to hungry and destitute people living in a degraded environment close to a well protected and inaccessible national park (Hanks, 1983). In such circumstances, it should come as no surprise that these same people, believing that the welfare of wildlife is being put before that of human beings, lack enthusiasm for the nature conservation movement. The parks of Mexico present a similar dilemma, for they are intended primarily to protect unusually beautiful or interesting areas, limiting the activities of man to tourism and recreation. Unfortunately, as in much of Africa, the interests and needs of people living in adjacent areas were not taken into consideration, and the parks do not always have the full support of local communities (Halffter, 1981). As with development agencies, conservation authorities must appreciate the vital importance of packaging conservation by planning with people, and by relating the conservation of species and ecosystems to human survival.

Conservation problems of a different nature, but nevertheless often just as critical for human survival, also exist in many of the developed countries. The collective action of individuals, for example, can rapidly destroy or degrade the natural environment. Such is the case with acid rain. As in the Third World countries, *conservation must involve people*, above all by emphasizing that environmental management is not an abstract concept, but a personal concept where individual actions and attitudes can and do make significant impacts.

Until recently, many of the health care and family planning programmes in developing countries were also initiated and implemented from the 'top down' by outside agencies. As with development and conservation activities, the same shortcomings and prob-

lems of planning for people have occurred, but there is now a growing acceptance of the importance of a grass roots approach, which builds on traditions of community cooperation and self-reliance. Health care and family planning programmes are being accepted in areas where they were previously rejected, because the community approach fosters increasing emphasis on programmes designed to fit local perceptions and needs. This is coupled with the active participation of the community in all stages of planning and implementation which, in turn, gives each individual a sense of belonging and dignity (IPPF, 1982).

Planning with people presents a great challenge both to the recipients and to the development agencies, but it should not be viewed as the panacea for conservation, development, and fertility reduction programmes. Some countries, notably China, have planned their communities, and have made a national commitment to increase environmental resources and control the rate of usage so as to keep population and environment in equilibrium. Undoubtedly stimulated by serious environmental problems, China now recognizes that people, natural resources, and environment are interdependent and interacting, and it is explicitly stipulated in the country's National Constitution that "The State provides family planning so that population growth is in balance with the plan for economic and social development" (IPPF, 1983a). Through the deep involvement of the country's national leadership in designing and supporting family planning programmes, China has fostered public discussion on the population problem and the effect of continuing growth on future living standards (Brown, 1984). The speculatular fall in fertility in China of 60 per cent in the last 25 years shows that 'top-down' planning can work, provided that the whole community is deeply involved.

An integrated approach to conservation, development and fertility reduction

Throughout this supplement, the emphasis is on the importance of integrating human population growth with economic and social development and with conservation planning. The links between human numbers and natural resources form the basis of the discussion that follows. The interconnections and interactions are never simple, and generalizations can be dangerous, as there will always be exceptions when such complex relationships exist. The *World Conservation Strategy* recognizes to a certain extent the importance of these relationships by stating: "Conservation, like development, is for people; while development aims to achieve human goals largely through use of the biosphere, conservation aims to achieve them by ensuring that such use can continue" (IUCN, 1980). The *Strategy* also notes that: "The predicament caused by growing numbers of people demanding scarcer resources is exacerbated by the disproportionately high consumption rates of developed countries" (IUCN, 1980). Put another way, the *Strategy* is stating that sustainable development and the quality of life human beings can look forward to on this planet are influenced by the quantity and quality of available natural resources and by human numbers and demands upon them. In summary:

$$\text{Sustainable development and quality of life} = \frac{\text{Natural resources}}{\text{Human numbers} \times \text{Per capita demand}}$$

Such a simple equation is a useful first step in appreciating some of the linkages involved in resource/population relationships, but it neglects a vital component, that of societal constraints and the ability of societies to improvise. The 'firewood crisis' is a case in point. Many subsistence-level communities depend on wood for heating, cooking and building purposes, and they have collected wood from natural forests faster than the forests have been able to regenerate, forcing people to turn to dried dung and crop residues as a fuel alternative. The resource/population equation might identify the problem as no more than population-induced deforestation, but this totally overlooks the reasons behind the deforestation. All too often it has been accelerated by inequalities of income distribution (whereby poor people are unable to purchase alternative fuels), population translocation programmes, lack of infrastructural development and other inputs in rural areas, inadequate attempts to increase crop yields on existing agricultural land, and, above all, a complete absence of re-afforestation where forests are under pressure.

Isolating high rates of human population growth as the main cause of our environmental problems overlooks the importance of the vicious circle of poverty described earlier and the *over-consumption of some of the developed nations*. The world appears to be faced with a dilemma, because recent studies of human population growth have shown that with most populations, sustained, rapid, economic growth creates conditions that make for fertility decline, largely irrespective of governments advocating a population policy (McNicoll and Nag, 1982). The demographic transition of Europe and North America is frequently quoted as the best example for developing nations of the way in which prosperity can bring birth rates down (Jacobsen, 1983).

The possibility of rapid economic growth, however, is becoming increasingly remote and unrealistic. The world economy is going through a significant and irreversible structural change, the most important aspect of which is that the industrial economies are not likely, perhaps not ever, to return to the boom days of the 25 years following the Second World War (The World Bank, 1980). Contracting global economies will affect all countries, and when coupled with rapid population growth the economic recession will slow down or even prevent a break in the circle of poverty and the consequent increase in wealth that is supposed to reduce population growth. Against such a discouraging background, the conservation of natural resources to ensure sustainable development as outlined in the *World Conservation Strategy* assumes even greater importance in the resource/population equation. In some communities, it might even be the *sine qua non* for successful development and fertility reduction.

In a number of countries, including China, fertility has declined rapidly in the presence of family planning programmes and in the absence of significant development (IPPF, 1983b; Ramade, 1983). Furthermore, a high or improving standard of living *per se* does not necessarily result in a lowering of the population growth rate (IPPF, 1983b). Nevertheless, a consensus is emerging that both family planning *and* development contribute to fertility decline, and that the two tend to have a synergistic effect (Mauldin and Berelson, 1978). However, calls for unlimited economic development are becoming increasingly unrealistic, as they ignore the finite nature of resources and the need for a *sustainable society*. There is insufficient land, energy, and other resources for the poor of the world to achieve anything close to the sort of economic development seen in Europe, North America or Japan. In most developing countries, economic growth is likely to remain slow, barely keeping pace with population growth where fertility rates are high, and these countries should not rely on significant economic improvements to reduce births as happened over a long period in the industrial countries. Rather, they should turn to inexpensive and well-designed family planning programmes to reduce fertility without the widespread economic gains and depletion of resources that characterized the demographic transition in the industrial societies (Brown, 1984).

Human carrying capacity and a sustainable society

If governments are to take an informed view of population pressures, they need to know not only how many people there are likely to be, but also how many the carrying capacity of different parts of the world can support (Thomas, 1983). The concept of carrying capacity is a useful means of quantifying and understanding the relationship between populations and natural resources, and in a way it is a quantification of the resource/population equation described earlier. *The carrying capacity indicates the level of population which may be supported by a country at a given level of welfare*. More precisely, it may be defined as the number of persons sharing a given territory who can, for the foreseeable future, sustain a given physical standard of living, utilizing energy and other resources (including land, air, water and minerals) as well as enterprise, skills and organizations (Unesco, 1983). This interpretation is far more flexible than the population/food relationship used to describe carrying capacity in animal studies, because it has now become a dynamic concept which may be extended or restricted by changes in cultural values, including the desired quality of life, export of goods and services which may enable a country to import additional resources, technological discoveries, improvements in agricultural husbandry or land tenure systems, changes in education systems, modifications of fiscal and legal arrangements, discoveries of new mineral sources, or the emergence of a new political will (Unesco, 1983).

The very flexibility of this concept makes it vulnerable to criticism and in some eyes, of questionable value. Nevertheless, for those national leaders or development agencies who struggle to introduce an understanding of the finite nature of resources and the vulnerability of overexploited natural systems, human carrying capacity estimations have considerable value, particularly as a basis for deriving demographic strategies with a population policy. The concept is also a very useful tool for emphasizing resource/population relationships, linking population growth to the carrying capacity of local biological systems. For example, if the populations of India, Pakistan and Bangladesh grow as predicted, the Indian subcontinent could be home to 2.7 billion people when their populations stabilize – more than the entire world population in 1950. National and global resources would be stretched to the breaking point well before increases of this size materialize (Brown, 1984).

3. HUMAN POPULATIONS: NUMBERS AND GROWTH

A discussion on the past, present, and future trends in the relationships between human population growth and resource depletion, must be dominated by the extraordinary population changes that have taken place in the past 150 years, a period in which human numbers increased from 1 billion to more than 4.7 billion in 1984 (United Nations, 1982a). According to the latest medium variant United Nations projections, the population is expected to increase to over 6.1 billion by the year 2000 before becoming stationary at 10.2 billion people in 2095 (United Nations Secretariat, 1983).

Since the early 1960s, population trends throughout the world have been characterized by a general decline in both fertility and mortality. In fact, fertility has declined rapidly in certain regions, and by 1983, there were 12 countries, all in Europe, where births and deaths were more or less in equilibrium, resulting in zero population growth. In all of these 12 countries, population stabilization was not an explicit national goal, the declines in fertility flowing from social

improvements and economic gains, undoubtedly assisted by improved availability of family planning services and the liberalization of abortion laws (Brown, 1984). Some parts of the developing world also recorded a decline in fertility, being faster than anticipated in much of Latin America and in East Asia, and very spectacular in China. These statistics give no cause for optimism or relaxation of concern, for elsewhere in the developing world, either no significant drop in fertility has occurred or there has even been an increase. The combined current population size of those countries which have experienced no reduction in fertility, including those states of India in which fertility remained essentially unchanged, exceeds 1.1 billion (Demeny, 1984).

Although the world *rate of growth* is on the decline, it is essential to appreciate that the *annual increment* to the world population has not declined, but is still increasing. In 1950, 46 million people were added to the world, increasing to 75 million per year by 1980. The peak will be an estimated 89 million near the end of the century. After the year 2000, the average annual increase is expected to decline and by the year 2025 the annual increment is projected to be approximately 74 million people (United Nations, 1982b).

A growing number of leaders in the developing world now express open concern about the negative economic and environmental pressures that are being applied as a consequence of high population growth rates. Leaders of Bangladesh, Costa Rica, the Dominican Republic, Egypt, Ghana, India, Indonesia, Jamaica, Kenya, Mexico, Nepal, the Philippines, and Thailand, for example, have identified population pressures as an important, and sometimes the single most important, development problem they face, and which threatens the future viability of their countries (Population Crisis Committee, 1983).

Global trends and statistics have a serious limitation in that they mask the areas of concern, or potential concern, for conservation and development issues. Clearly, there are large differences in growth rates between the more developed and less developed regions of the world (Table 1) with 34 of the developing countries having population growth rates of more than 3 per cent.

The current annual rate of population increase in the developing countries which contain approximately three-quarters of the world's total population, is about 2.1 per cent, compared with 0.6 per cent in the developed countries (United Nations, 1982b). Equally important differences exist within some of these regions. For example, Africa is the fastest growing continent, and is likely to remain so well past the end of this century. Its growth for the period 1975 to 1980 was 3.0 per cent, compared with 0.4 per cent for Europe for the same period. Africa has the highest birth rate of all the major regions, and the lowest prevalence of contraception. The 1980 population of

TABLE 1
World population in 1980 by major regions, the population growth rate, and the estimated population in 2025, based on the results of the United Nations estimates and medium variant projections as assessed in 1982.

Region	Population in 1980* (millions)	Population in 2025 (millions)	Population growth rate* (%)
Africa	476	1,643	3.0
Latin America	362	787	2.37
South Asia	1,408	2,771	2.30
Oceana	23	40	1.66
East Asia	1,183	1,696	1.42
North America	252	347	1.07
USSR	265	367	0.93
Europe	484	527	0.40
Total	4,453	8,177	1.77

*Average annual growth rate in 5-year period from 1975 to 1980

476 million is estimated by the United Nations to grow to over 877 million by the year 2000, and 1,643 million by 2025. Some of the countries, such as Kenya and Zimbabwe, with annual growth rates of close to 4 per cent, could double their populations in only 18 years. If these growth rates were maintained (unlikely in the face of already serious resource/population conflicts) the populations would increase 51 times in one century (Harrison and Rowley, 1984). In 1982, the population of Nigeria was 80 million. The present population growth rate is 3.3 per cent, and Nigeria is expected to have at least 150 million by the year 2000, by which time nearly one in every four Africans will live in that country (Ogunmodede, 1983). Latin America is the second fastest growing region in the world, and its 1980 population of 262 million is expected to more than double to 787 million by 2025 (United Nations, 1982b).

Ninety-five per cent of the world's growth will probably occur in the currently less developed regions between 1980 and 2050, during which period their share of the total population is expected to increase from 75 to 85 per cent. In that same period, Africa's share of the world total is expected to increase from 10.6 to 22.8 per cent, Europe's share falling from 10.9 to 5.4 per cent (Table 2).

In most of these less-developed regions, the age-structure of the population is pyramid-shaped, characteristic of a young and rapidly-growing population which has a powerful built-in momentum for further growth. For example, if all Indian families were to adopt a 'zero population growth policy' and limit their family size to an average of 2.3 children, the population would still continue to increase for the next 70 years from 600 million in 1977 to more than 900 million in 2047 (Gulhati, 1977). China faces the same problem associated with this momentum. Even if the number of children per family fell to two, the population would increase from 1.02 billion in 1983

TABLE 2
Proportion of world's population resident in seven major regions in 1980 and 2050.

Region	Population in 1980	Population in 2050	Change in 70-year period
Africa	10.6	22.8	+12,2
Latin America	8.2	11.5	+ 3.3
South Asia	31.7	33.6	+ 1.9
North America	5.6	3.8	− 1.8
USSR	6.0	3.9	− 2.1
Europe	10.9	5.4	− 5.5
East Asia	26.5	18.6	− 7.9

(United Nations Secretariat, 1983).

to 1.54 billion by 2050 (Chi-hsien Tuan, 1983), giving China an increment larger than the 1980 population of the whole of Europe.

The number of people in a country can be a statistic of limited value unless related to that country's carrying capacity. Improvements in human living conditions are unlikely to be achieved in the absence of sustainable development, particularly in vulnerable problem areas such as the Sahel, Caribbean, Andes and Himalayas. An integrated approach to conservation, development and fertility reduction must emphasize the importance of *planning the rate of population growth* in relation to the human carrying capacity, thus reducing to a minimum the critical interactions between human populations and natural resources.

Population projections in this supplement are based on medium variant United Nations' estimates as assessed in 1982. As future trends in fertility, mortality and migration are uncertain, the United Nations has also prepared high and low variant estimates. For example, the medium, high and low variants for the world population in the year 2025 are 8.177, 9.185 and 7.278 billion respectively. The distinctions among these three variants are largely due to the differences in assumed birth rates, but in general, the medium variant represents future demographic trends that seem the *most likely* to occur taking into account past demographic trends, expected social and economic progress, ongoing government policies and prevailing public attitudes toward population issues. However, lower populations *can* be reached if birth rates continue to decline, but to do this, further stronger policies on population growth and substantial inputs into family planning programmes will be required.

4. CRITICAL ASPECTS OF THE INTERACTION BETWEEN HUMAN POPULATIONS AND NATURAL RESOURCES

This supplement is not intended to be a comprehensive review of critical aspects of the interaction between human populations and natural resources, nor does it describe the complex interactions between all the areas of concern. The examples that follow call attention to the importance of stabilizing human population growth at levels which individual countries, and the world as a whole, can sustain, with a reasonable quality of life and realistic prospects of implementing the objectives of the *World Conservation Strategy*. Any system of selection must inevitably group issues into distinct entities, and there is a danger that this grouping of concerns will tend to hide vitally important inter-relationships, and also overlook the chain-reactions that are such an integral part of resource/population relationships. Environmental and conservation problems rarely exist in isolation, and without a broad overview of the inter-relationships involved, it may sometimes be difficult to distinguish between the symptoms of a problem and its cause. The growth of urban slums is a worldwide phenomenon, becoming particularly prominent in developing countries, and the socio-economic and environmental consequences of their expansion deserve priority attention. But it is all too easy to concentrate on tackling all the problems in the urban situation *per se* without examining the reasons for the growth of the slums in the first place. So often their growth has resulted from a massive urban influx, caused in turn by a failure to implement sustainable programmes of rural development. The urban slums should be seen in this case as the *symptoms* of a much bigger problem, the *cause* of which is usually overlooked or ignored.

Agriculture and declining food production

Food production

The first years of the 1980s have seen more food produced than ever before, yet more people are suffering from malnutrition than at any other time in history. According to the US Council on Environmental Quality and the Department of State (1980) world food production is expected to increase still further at an average rate of about 2.2 per cent up to the end of this century, and assuming no deterioration in world climates, food production is projected to be 90 per cent higher in the year 2000 than in 1970. In fact, world food production is expected to increase more rapidly than world population over the same 30-year period, but despite this there is little hope for those suffering from food shortages. The World Bank has estimated that the number of malnourished people could rise from 400 to 600 million in the mid-1970s to 1.3 billion in the year 2000, and most of these people will be in Third World countries, where population growth will outstrip rising food production. In *per capita* terms, the output of world grain increased from 248 kg in 1950 to 326 kg in 1973, an increase of 31 per cent, but it has remained at about that level for the past 10 years (Brown, 1984).

Those countries practising subsistence agriculture will be particularly hard-hit by food shortages. According to a recent FAO study, by the year 2000, 65 countries will not be able to meet their own food needs with present systems of agriculture (Harrison, 1983). Fifteen of these are in Asia, but 30 are in Africa, which heads the list of problem areas, where the per hectare yields of many subsistence food crops appear to have stagnated or even declined (Lele, 1981). In the 1960s, agricultural production in the region increased largely in tandum with population growth, and both grew at about 2.3 per cent per year. In the 1970s, however, the annual increase in agricultural production *fell* to 1.3 per cent per year, while population growth *increased* to 2.7 per cent per year (Meerman and Cochrane, 1982). If present trends continue, Africa will have to increase its dependence on food imports both over time and relative to other developing continents. For 22 African countries designated by a special FAO/WFP task force as being in need of exceptional international support, their total food aid requirements for 1983–84 are estimated at 3.2 million tonnes, more than double the food aid they received in the previous 12-month period (FAO, 1983a). Undernourishment will become far more widespread. Indices of ill health and infant mortality are already among the highest in the developing world, and are not expected to decline significantly in the next decade (Lele, 1981).

The 30 problem countries of Africa are expected to have a population of 477 million by the year 2000, of which more than half will be in excess of the land's carrying capacity. Raising inputs to the intermediate level (through the basic initial introduction of higher yielding varieties of crops, pest management, irrigation, fertilizer and improved storage) could reduce the number of critical countries from 30 to 12, while with high inputs only four small countries are likely to remain critical (Harrison, 1983).

Cropland

As the *World Conservation Strategy* emphasizes, one of the most serious environmental developments is the loss of resources essential for agriculture. The quantity and quality of arable land is being reduced by soil erosion, soil compaction, desertification, soil salinization, and the loss of arable land to urbanization and associated developments. Where crops are being grown, significant losses are caused by increasing air and water pollution, and more recently, by more frequent and more severe water shortages, especially where energy and industrial development compete for water.

The loss of forests and woodlands is an example of how the destruction of essential ecological processes can influence the productivity of crop lands, one of the life-support systems. Forests help to absorb, store, and regulate the discharge of water, and their destruction not only results in a general lowering of the water table but also an increase in siltation of rivers and flash floods across agricultural land downstream (Fig. 2). The same areas have a vital role to play in reducing crop losses to air and water pollution by cleansing both the atmosphere and water sources. Most importantly, these natural areas provide an ongoing source of species of fauna and flora that have an indispensible role to play in soil formation and turnover, and in the pollination of crops. For example, in New York State alone, more than 8 million million blossoms may be pollinated in a single day by the wild and tame bees combined, an individual honey bee visiting as many as 1,000 blossoms on a sunny day. Fruit and vegetable production would be drastically reduced without pollination by these and other animals (Pimentel and Pimental, 1979).

The total world arable land presently available is estimated to be about 1.5 billion hectares. Based on a present world population of 4.7 billion people, this amounts to only 0.33 hectares per person, but at least 0.5 hectares per person is needed to produce a USA level diet. Clearly, there is insufficient land to feed the world such a diet, even assuming that there were ample energy resources and other technologies (Pimentel *et al.*, 1983).

Economic and ecological constraints mean that only moderate additions to global arable land will be feasible. Agricultural productivity will have to increase to meet the demands of a growing world population, underscoring the emphasis the *World Conservation Strategy* places on protecting agricultural systems, which in turn emphasizes the importance of conserving a full spectrum of indigenous plants and animals to maintain the essential ecological processes.

Raising yields on arable land of high potential in a manner that is sustainable should receive priority in terms of overall land use planning, as this would help to reduce the pressure for encroachment of farming onto lands that are better suited for grazing, forestry or nature reserves. With populations increasing so rapidly in developing countries, traditional systems of agriculture are becoming less and less viable. This is well-illustrated by the problem facing shifting agriculture. Ideally, under this system the land should lie fallow for 10–20 years before it can be recleared and planted again. During this long fallow period the soil gradually accumulates the nutrients needed for successful crop production (Pimentel and Pimentel, 1979). Unfortunately, few of the regions that still practise shifting agriculture have any new land left to move to, and thus people are forced to continue farming on the same plots long after the nutrients have been depleted. As population pressures continue, more and more people are being forced onto land that is becoming less and less productive, including major and important watersheds (Spears, 1982), which as a consequence become degraded and in turn reduce the productivity of agricultural land in their

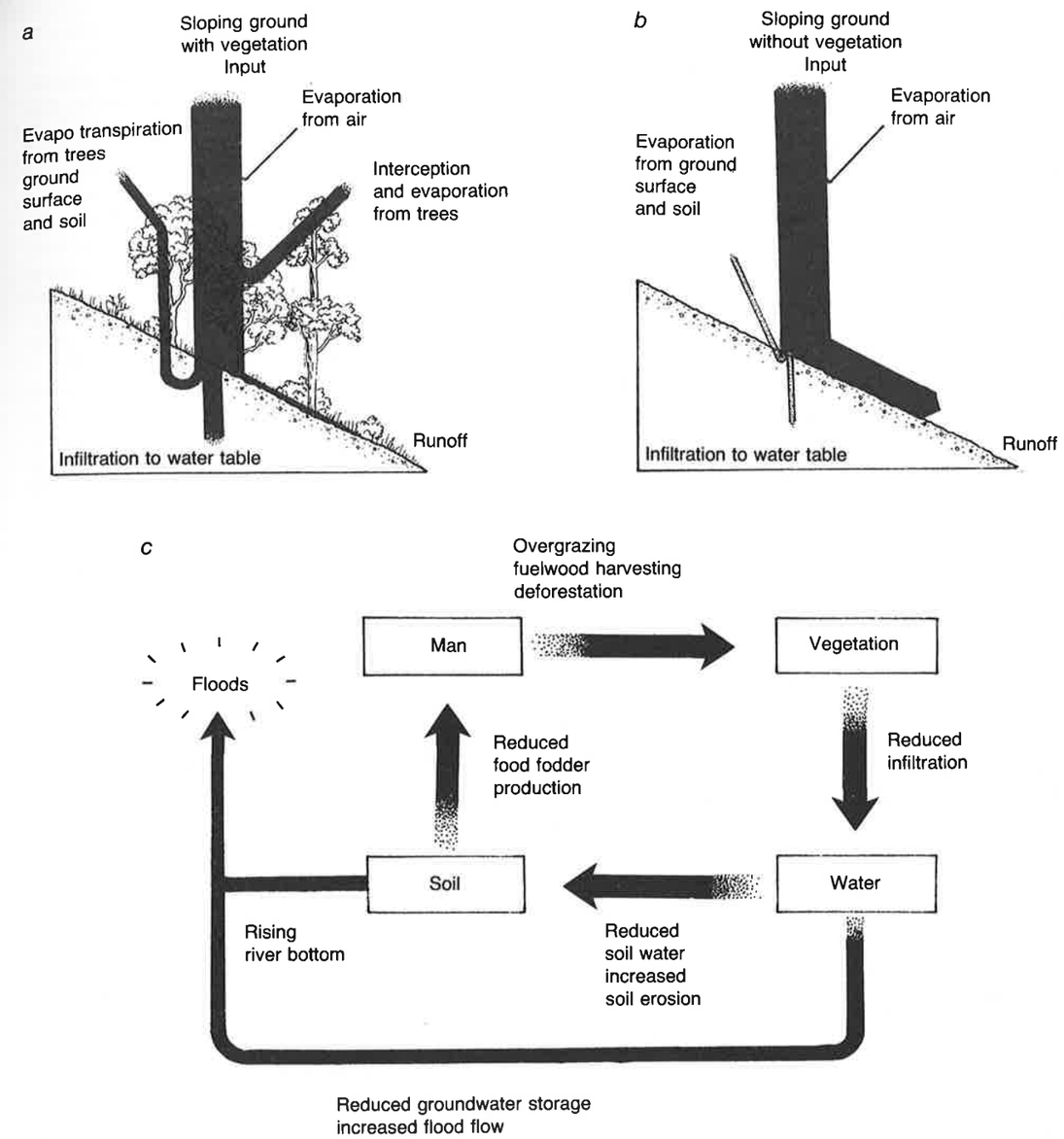

Fig. 2. Vegetation plays a key role in the water cycle (*a*). On sloping ground with a good tree and grass cover, run off is minimal, and the water table is replenished. In contrast, (*b*) when the tree and grass cover is removed, very little infiltration takes place, the water table is not replenished, and the run off is excessive, carrying away topsoil and causing floods downstream (*c*) (After Falkenmark, 1984.)

catchment areas. As people continue their encroachment into marginal lands, the global losses to desertification (at present estimated to be approximately 6 million hectares per year) will accelerate. The United Nations has identified about 2 billion hectares of land where the risk of desertification is 'high' or 'very high' (Council of Environmental Quality and the Department of State, 1980).

In spite of these and similar statistics, which have received wide publicity and circulation, a sense of urgency in environmental issues is still missing, particularly in Africa, where vast empty spaces create a mistaken impression of a surplus of land for food production. In most of these areas, however, a combination of climate, soils, and other ecological factors make farming or even sustained grazing impossible

(Eckholm, 1982). A simple comparison of density figures *per se* can be virtually meaningless *unless qualified ecologically and economically*. For example, in 1981, Africa as a whole had a density of 16 people per square kilometre of surface area, compared with 98 for Europe, 316 for Japan, 1,151 for Bermuda, and 4,932 for Hong Kong (United Nations, 1982a). From such statistics the erroneous conclusion could easily be reached that Africa has space for at least 100 times as many people as live there at present.

Soil formation and its loss

The bulk of our food production depends on soil, a crucial life-support system that is so often taken for granted. Soil erosion and formation are both natural and continuous processes in undisturbed ecosystems (O'Keefe, 1983). With a protective covering of plants the soil is usually regenerated at the same rate that it is removed. Soil formation and turnover are totally dependent upon key organisms such as earthworms which can bring to the surface up to 50 tonnes of soil castings per hectare (Burges and Raw, 1967), and ants which carry up an additional 10 tonnes per hectare (Kevan, 1962). Each year various soil organisms break down and degrade about 20 tonnes of organism matter per hectare. This is essential for the release of bound nutrients and subsequent recycling for reuse by the entire living system (Pimentel, 1983). When the rate of soil loss exceeds the rate of soil genesis, the topsoil thins and eventually disappears, leaving only subsoil or bare rock (Brown, 1982). Once such an advanced stage of soil loss has been reached, soil formation is slowed to insignificant levels because the key soil forming organisms have also been lost.

Soil erosion has now reached epidemic proportions. The world is at present losing an estimated 23 billion tonnes of soil per year from croplands in excess of new soil formation (Brown, 1984).

In the USA, the past 200 years have seen the loss of at least one third of the topsoil from arable land (Pimentel *et al.*, 1976). Average soil loss from US croplands is estimated to be about 18 tonnes per hectare per year, while it is being formed under agricultural conditions at a rate of only 0.5 tonnes per hectare per year (Pimental *et al.*, 1983). The gross soil erosion in the USA is about 5 billion tonnes annually, adversely affecting agricultural productivity by the selective removal of plant nutrients and organic matter by wind and rain. The removal of finer soil particles leads to soil compaction and increased water runoff, which reduces the water availability to crops and causes flood damage to other crops. Such losses have very significant economic implications. The cost of replacing the nitrogen, phosphorus and potassium lost annually through soil erosion has been estimated at US$ 6.8 billion (Pimentel *et al.*, 1976). A loss of 20 cm of topsoil from a topsoil base of 30 cm would *double* the energy inputs needed to offset deterioration caused by erosion (Pimentel, 1983).

Few developing countries have similar statistics on the rate of soil loss and its economic implications, but virtually none of them is exempt from this problem. For example:

- In Ethiopia a US Aid Mission reports that an environmental nightmare is unfolding, the result of millions of Ethiopians struggling for survival, scratching the surface of eroded land and eroding it further, cutting down the trees for heating and cooking and leaving the country denuded. More than 1 billion tonnes of topsoil flow from Ethiopia's highlands each year (Brown, 1981).
- Approximately half of India is already experiencing some form of soil degradation, 1.4 million km² are subject to increased soil erosion, while an additional 270,000 km² out of a total of 3.3 million km² are being degraded by floods, salinity and alkalinity (Bali and Kanwar, 1977). The pressures of population growth are so severe in parts of India that it is difficult to maintain a balance between food production and land degradation (Oza and Gaekwad, 1979).
- In Madagascar, officials have declared soil erosion to be the key problem facing the nation. Soil loss averages 25–40 tonnes per hectare per year throughout the country, and reaches as much as 300 tonnes per hectare per year in the highlands. Approximately 65 per cent of the country's entire land area is believed to be dangerously denuded of vegetation, primarily as a result of destructive agricultural practices, exacerbated by deforestation and overgrazing (Finn, 1983).
- Soil erosion is creating an ecological emergency in Java, a result of overpopulation which has led to deforestation and misuse of hillside areas by land-hungry farmers. Erosion is laying waste to land at an alarming rate, much faster than present reclamation programmes can restore it (US Embassy Jakarta, 1976).

In 1981, the United Nations Environment Programme (UNEP) completed the first draft of a World Soils Policy, in which it warned that within the next 20 years more than one-third of the world's arable land would be lost or destroyed. The response of the member governments to this important initiative was extremely disappointing, and indicated that even in the 1980s there is still a totally unacceptable lack of awareness of the urgency of halting the loss of arable land (Bassett, 1983).

Urbanization and the loss of agricultural land

Although urbanization could relieve some of the pressure on natural resources in rural areas, urban growth itself is becoming a major problem in developing countries, with literally millions of people throughout the world being 'pulled' into the towns and cities by the attraction of the urban economy and 'pushed' out of the rural areas by the downward spiral of degradation and poverty adding to the already rapid growth of the existing urban dwellers. For example, of a total growth of 12.5 million in the urban population of Africa south of the Sahara between 1970 and 1975, 6.4 million was by increase of the existing population and 6.1 million by rural-to-urban migration (Abumere, 1981). United Nations demographers have characterized this movement as "the greatest mass migration in human history", and if their projections materialize, more than half of the world's population will be living in cities in 20 years time (Table 3).

The cities and adjacent settlements will become almost inconceivably large and crowded, a prime example being Mexico City which is projected to have more than 30 million people by the year 2000, more than three times the present population of the New York metropolitan area. As most of these people are likely to end up living in slums and shanty towns, and will be putting extreme pressure on sanitation, water supplies, health care, shelter, food, and jobs, a great deal of national and international attention has been focused on their plight.

Of equal concern should be the loss of prime agricultural land which has been swallowed up in the process of urbanization, but unfortunately this has received far less attention. Towns and cities have tended to grow in precisely those areas where some of the best farmlands occur, namely in river basins where rich deep soils and ample water were available. For example, only 4 per cent of Egypt is arable, nearly all of this land being on and around the fertile Nile delta, yet some 285,000 hectares of this land have been lost to housing projects and factories over the past 10 years, representing 8.5 per cent of Egypt's total agricultural land. With 1 million Egyptians being born every 10 months, this loss of agricultural land has reached crisis proportions. The control of the Nile flood by the Aswan Dam has made the problem worse, because this has led to the loss of a major process whereby the fertility of the soil was maintained (Bradley, 1982).

Developed countries are not exempt from these pressures. England, the most densely populated major industrialized country in the world, is losing 30,000 hectares of land per year (World Environment Report, 1981). From 1945 to 1975 the USA lost 30 million hectares of land to highways and urbanization (Pimentel, 1983). Japan is one country that has become aware of the transfer of ownership of agricultural land without the special permission of the government. This move has resulted in a 50 per cent reduction in the loss of agricultural land to urbanization (World Environment Report, 1981).

In the long term, however, no amount of legislation is likely to halt completely the processes of urbanization, because once again this is treating the symptom and not the cause. One corrective measure for urban drift lies in investing in rural development, because a productive and sustainable programme of rural development could support a network of decentralized, labour-intensive industries and reduce the drift to town. If urban areas are consistently favoured in national economic policies, people will flock to them, and the rural areas will continue to be deprived of men and women with drive and initiative. Should rural incomes achieve parity with urban ones, the element of national coercion in rural-to-urban migration will be largely removed (Newland, 1980). The importance of avoiding planning for people in rural development programmes has already been discussed, *of equal importance is the selection of agricultural activities based on a systematic land capability analysis*. Failures are not only expensive ecologically and economically, but also bring an almost irreparable loss of credibility for the development agency concerned. One of the most spectacular failures occurred with the groundnut plantations in Tanganyika (now Tanzania), where 1,326,000 hectares of land were cleared and deep-rooted trees removed. Although vast amounts of fertilizer were added, severe soil erosion followed, and germination was very difficult in the hard-packed soil. After 6 years of desperate efforts and capital investment of some US$ 100 million, the project to grow groundnuts was finally abandoned (Biswas, 1979).

TABLE 3
Percentage of some Third World populations living in urban areas.

Region	1950	1980	2000
Africa	14.8	28.8	42.3
Latin America	41.2	64.7	75.1
East Asia	16.7	32.7	45.1
South Asia	15.9	24.8	37.1

(Earthscan, 1983)

Biological diversity

The Earth probably has at least 6 million species of plants and animals, but less than 2 million of them have been identified by science. At least two-thirds of the 6 million species occur in the tropics, many of them restricted in their distribution to small areas of tropical forests (Myers, 1983a). Of the species recognized as threatened, it is generally believed that at least 2 or 3 vertebrates and 2 or 3 plants are becoming extinct each year (Nelson, 1982). With approximately 40 hectares of tropical forest being disrupted every minute (Myers, 1983a), it is not unrealistic to suppose that the world is losing at least one species per day, and the rate is increasing rapidly. It is possible that by the end of this century as many as 1 million species could be lost. In the next century, the

extinction rate is likely to increase still further as human populations approach the 10,000 million mark, with a concomitant upsurge in consumption of natural resources and the inevitable destruction of natural habitats.

In the past two decades, conservationists have emphasized and publicized widely the need to slow down or even halt this irreversible loss of unique genetic material, but some credibility problems have arisen when they try to justify spending millions of dollars on species conservation when there is so much wrong with human society. The awakening of public concern for the loss of hundreds of species of virtually unknown plants and animals from an obscure and apparently irrelevant remnant of a tropical forest on the other side of the world remains a major challenge. To date, much of the effort of international agencies in creating this public awareness has concentrated on prominent endangered species such as the panda, the emblem of the World Wildlife Fund, and it is easy to understand why enthusiasm is generated for such an appealing creature. The public's response in showing concern for the demise of the panda and other similar species is to be welcomed, and funds generated from these appeals can, of course, be used for other conservation activities. The time has come, however, to focus the world's attention on the less spectacular species, the 1 million likely to disappear by the end of this century. For these species, the emphasis must shift from the aesthetic and ethical arguments in favour of 'preserving' species to a strong support of the basic philosophy behind the *World Conservation Strategy* which emphasizes that *conservation is concerned with human survival and sustainable development*, an approach which is more likely to gain the support of the leaders of developing countries and, in particular, the support of poor people living in a degraded environment.

The three objectives for living resource conservation as set out in the *World Conservation Strategy* provide the basis for the way in which this new approach to species conservation should be promoted, and each of them is intimately linked to the resource/population equation which forms the core of this supplement. The involvement of often obscure species of plants and animals in the *Strategy*'s first objective, the maintenance of essential ecological processes and life-support systems, is one of the easier concepts to get over to relatively unsophisticated people, particularly to those who live in such close contact with the resources that are being depleted. For example, a poor and hungry family living next to a well-protected and inaccessible national park that emphasized the aesthetics of species conservation would be much more receptive to supporting the park if it were packaged more in terms of ecosystem services (Ehrlich, 1982). They could then relate to such concepts as deforestation followed by land abuse changing well-established water cycles, leading to siltation of streams and rivers, depletion of ground water, and an aggravation of water shortages during dry periods, because suddenly conservation has become relevant and directly related to their own survival. The environmental consequences of deforestation have recently been illustrated by measurements made by the Northwestern Water and Soil Conservancy Bureau of the Loess Plateau in Shaanxi, China. In forested areas, the annual rainfall carried away 60 kg of topsoil per hectare. Under well-covered grassland, topsoil loss rose slightly to 93 kg per hectare, and in exposed land following deforestation, topsoil loss increased over 100 fold to 6,750 kg per hectare. Furthermore, each hectare of forest retained 300 m^3 of water, confirming the extreme importance of forests in the storage of water (Smil, 1983).

The loss of ecosystem services to humanity following the extinction of species can range from trivial to catastrophic, depending on the number of species and individuals involved, and the degree of control each exerted in the ecosystem service concerned. Extinctions have, of course, occurred continuously in the past as part of evolutionary and ecological development, *but there must also be some rate of extinction that a given ecosystem cannot absorb without undergoing reorganization leading to serious impairment of its functioning from the point of view of man*. Attempts to substitute other organisms for those lost have generally been unsuccessful, and attempts to supply the lost services by other means tend to be expensive failures. In the process of evolution, many species of plants and animals have become fine-tuned to their physical and biotic environments, and these are much more vulnerable to change and more difficult to replace than the generalist species with their wider tolerance. Clearly, if present rates of extinction are not reversed, ecosystem services will increasingly depend on substitutions, but these species are unlikely to be found at the rate at which plant and animal communities are being destroyed. The conservation of ecosystems and thus of the species and populations that function within them, is a priority concern if the *Strategy*'s first objective is to be met (Erhlich and Mooney, 1983).

The second objective of the *Strategy* is to preserve genetic diversity, a much more difficult concept to present, mainly because there are so few immediately short-term benefits. The preservation of genetic diversity for future genetic engineering and agricultural use could be the most hopeful starting point, based on well-known species of livestock and crops, all of which at some time have come from wild species. Our breeding programmes and domestication have resulted in a narrowing of the genetic base, resulting in a loss of genetic determinants controlling such things as adapation to marginal environments and disease resistance (Prescott-Allen and Prescott-Allen, 1982a). Plant diseases now cause

annual losses to world crops worth approximately US$ 25 billion (Myers, 1983b). Thus a most important justification for conservation is that the genetic material contained in wild relatives of existing domesticates can be of inestimable value for future biotechnology and breeding programmes through the transfer of more desirable genetic qualities. The reason for this is that pests and diseases are continually overcoming resistance and evolving new strains. They should never be looked upon as genetically static, and as man extends his farming activities into new environments, new varieties of plants are required to give optimum yields with the new combinations of climate and soil. Thus wild species will have an increasingly important role to play in the enhancement of the narrowing genetic base of our existing crop plants. Already many cultivated plants are being strengthened for continued human use by cross-breeding with wild relatives in order to introduce pest and disease resistance, to improve durability, yield, nutritional quality and flavour, and to introduce responsiveness to different climates and soils (Prescott-Allen and Prescott-Allen, 1982b). For example:

- Five important potato varieties have had blight resistance bred into them through *Solanum demissum*, and three other South American *Solanum* species are being used to breed virus resistance into potatoes for British consumers (Oryx, 1982a).
- A rust-resistant strain of coffee has become available from germ plasm collected in the forests of Ethiopia, and this could save hundreds of coffee farmers up to US$ 200 per hectare that would have been spent on fungicides to control the rust disease (Myers, 1983b).
- The top varieties of butterhead lettuce grown in Britain and the USA get their resistance to the most serious disease of lettuce (downy mildew) from wild *Lactuca serriola* from the USSR (Prescott-Allen and Prescott-Allen, 1982b).
- The use of wild species in sugar cane breeding (mainly *Saccarum spontaneum*) has almost doubled the cane yield and the yield of sugar (Simmonds, 1979).
- The wild *Nicotiana glutinosa* from Ecuador and Peru has been used to produce new cultivars which are resistant to tobacco mosaic (Prescott-Allen and Prescott-Allen, 1982b).
- Greater vigour of pineapples (particularly a stronger root system and a longer plant life) has been achieved by using two species from the north of South America (*Ananas bracteatus* and *Pseudananas sagenarius*) to produce new varieties (Collins, 1960).

Wild species of animals will also have an increasingly important role to play in the enhancement of the narrowing genetic base of our existing domesticated animals, most of which were probably first domesticated about 10,000 years ago by the early agriculturalists in the Mediterranean basin and western Asia. The indigenous wild animals of those regions were man's first choice: the sheep and goat were soon followed by the pig, donkey, horse, and cow as agriculture spread to other areas. However, within recent years we have selected so intensively and efficiently for characters of economic importance that much of the natural variability has been eliminated. An infusion of new genes from the wild might open up many new possibilities for selection. For example, the domestic goose (*Anser anser*) could probably be improved by an infusion of genes from the greater snow goose (*Anser caerulescens*) which has an incubation period of only 23–24 days (compared with 33–35 days of the domestic goose), a very rapid growth rate, and an excellent efficiency of food conversion. Similarly, possibilities exist for improving the growth rate and efficiency of food conversion in sheep by hybridizing wild species of sheep with our domestic breeds (Short, 1976).

These and other equally important cross-breeding programmes have already done much to enhance human survival and sustainable development, but these activities would have been impossible if the unspectacular species concerned (which have very little public appeal in terms of our present approach to creating an awareness of loss of biological diversity) had followed the path to extinction.

An increasing number of species of plants and animals are being used as both traditional and commercial sources of herbs and medicines, which also indicates the importance of conserving genetic diversity. Up to 80 per cent of the population in many developing countries still depend on traditional remedies, due to a combination of poverty and a greater cultural acceptability of traditional systems. The export of medicinal plants provides some of the developing countries with useful revenue, as shown by Thailand, which earns US$ 1.3 million per year from the export of drug plants (Prescott-Allen and Prescott-Allen, 1982a). Less than 1 per cent of the species that exist in the tropical forests have been scientifically examined for their value as medicines, health foods, and pharmaceutical products, and yet these and other species are yielding promising results. For example:

- The rhizomes of the Mexican Yam (*Dioscorea mexicana*), contributed to the development of the birth-control pill. Scores of other forest plants are being screened for contraceptive purposes (Nelson, 1982).
- In India, at least 2,500 plants out of the 18,000 so far recorded in the country are used for medicinal purposes. India now exports phytochemical materials (plant derived), primarily medicinal and pharmaceuticals, worth more than US$ 55 million (Myers, 1983b).
- Digitoxin, atropine and morphine are collected

from wild plants and are still used directly as therapeutic agents (Hansell, 1972).

- The leaves of *Stevia* have been used for generations by the rural Paraguayans as a sweetener, and recent research has shown that the leaves contain a substance that is calorie-free, harmless to humans, and 300 times sweeter than sugar (Nelson, 1982).
- A tropical species of periwinkle provides a chemical used to fight leukaemia (Eckholm, 1982). The National Cancer Institute of the USA has stated that the elimination of plants from tropical forests is a major setback in the fight against cancer (Nelson, 1982). Amazonia alone could well contain at least three species of plants with potential to generate drugs as valuable as the two derived from the periwinkle.
- The widely used muscle relaxant curare is still distilled from vines by the Indians in the Upper Amazonian. A concentrated extract of curare is still used by the Indians to poison their arrow tips and blowgun darts (Eckholm, 1982).

As with the plant breeding programmes, *we have no idea to what extent apparently insignificant and vanishing species can become of use to man*, and thus it should be self-evident that the reduction in the present rate in the loss of species will increase our options for future biotechnology use. Furthermore, wild species will provide the genetic resources for the fast-growing technology of genetic engineering, which has the potential to cross the barriers between different families of plants (Tudge, 1983).

The conservation of genetic resources is a sadly neglected aspect of conservation biology. Crop genetic resources alone require priority attention, and an essential prerequisite for this is to ensure that designated wildlife areas are designed, distributed and managed so that they maintain as much genetic diversity as possible (Prescott-Allen and Prescott-Allen, 1982c). Very few of the protected areas in developing countries have a comprehensive list of the plant species that occur there. This omission not only reduces the value of the area concerned but also makes its conservation and management more difficult.

The cultural and aesthetic values of wild species of animals and plants are also important arguments in favour of preserving genetic diversity. Particular species and undisturbed natural habitats have provided inspiration for sculptures, literature and music. Consequently, the greater the species and habitat diversity of an area, the more likely it is to be attractive and aesthetically pleasing to people. To many in the developed world, an aesthetic justification provides their sole motivation for supporting conservation organizations. For example, Myers (1983a) has noted that whales have enormous public appeal because of their size and intelligence. To the conservation community they are of exceptional importance, and he asks if we cannot win the battle for whales, does that not say something about the entire campaign to save species? In addition, certain species of plants and animals have a symbolic significance for many nations and, in particular, for people following a traditional way of life (for example, the bald eagle in the USA and the fish eagle in Zambia). The loss of such species would have great significance.

The spiritual and moral arguments related to the preservation of genetic diversity must not be overlooked. Some believe that as human population pressures increase these considerations become more important. Wilderness areas can act to counter the stress of living in a modern industrial or urban environment, as they allow people to stand back and to put society in perspective. These areas also give man a unique opportunity to consider the moral principle related to a further loss of species. The argument that *all* wildlife species have a right to exist and that we should act accordingly in our conservation activities is philosophically unassailable.

The third objective for living resource conservation according to the *World Conservation Strategy* is to ensure that any utilization of species and ecosystems (notably fish and other wildlife, forests and grazing lands), which support millions of people living in rural communities as well as major industries is sustainable. This objective still meets with considerable opposition from the rigid 'preservationists', because it *actively encourages using wildlife for the benefit of man*. However, this active use gives the species concerned a value as a resource, and could well ensure that the community using that species (or indeed an entire ecosystem as with a flood plain fishery) does not allow it to be exterminated. A land capability analysis might even show that using indigenous fauna and flora in a region on a sustained yield basis is the optimum form of land use, in some cases to be preferred to the introduction of livestock and crops. For example:

- Terrestrial wild animals provide a significant portion of animal protein in certain countries, such as Botswana, where 3.4 million kg of springhare meat are taken off each year by the people living at the subsistence level, a yield equivalent to that obtainable from 20,000 cows (Butynski, 1973).
- Freshwater fish are equally important as a source of protein in poor rural areas. In Maputaland, a traditional *fonya* drive by 500 people lasting no more than 3 hours may yield up to 3 tonnes of fish (Institute of Natural Resources, 1982).
- Swarming termites are an important part of the traditional diet of many communities in Africa, and they are eaten raw. They are high in energy (560 calories per 100 grams), and they also contain 46 per cent protein and 44 per cent fat (in contrast to a sirloin steak that offers only 23 per cent protein and 32 per cent fat). Termite protein also contains more of the essential amino acids than does protein from cattle (Myers, 1983b).
- Crocodiles are an integral part of the tropical fauna, they are ecologically important, biologically interesting, and, potentially, a renewable natural resource of considerable economic value. Crocodile farming is singularly appropriate for rural, isolated, lowland communities in the tropics, where the land is often unsuitable for conventional agriculture (National Academy of Sciences, 1983).
- Millions of people throughout the world depend on wild plants for fuelwood, building materials, grazing for domestic ruminants and for food. Regrettably, in many places the human and animal carrying capacities are being exceeded, and such dependence on wild plants has little hope of remaining sustainable.
- Although bamboos are widely cultivated, they are also collected extensively from the wild. Bamboos have an astonishing variety of uses, from building houses and furniture to musical instruments. Bamboos can be mixed with cement to form 'bamboo-crete', allowing a durable house to be built for US$ 600. The most important industrial use of bamboo is in paper. In India, 2 million tonnes of bamboo provides 600,000 tonnes of paper pulp (Lessard and Chouinard, 1980, Myers, 1983b, Prescott-Allen and Prescott-Allen, 1982a).
- The apple-ring thorn-tree (*Acacia albida*) has been successfully planted as part of an agroforestry programme in Malawi. The leaves are shed at the onset of the rainy season, and they decompose rapidly, releasing nutrients into the soil. The tree's deep roots do not compete with shallow-rooted annual crops for moisture or nutrients, and thus field crops can be grown right up to the bole of the tree. Vital elements are thus drawn up from beyond the reach of many plants, and are released through leaf fall and subsequent decomposition (Casey, 1983).
- Apparently obscure and useless plants can be of great economic importance. A desert shrub the jojoba (*Simmodsia chinesis*) has a seed with 50 per cent of its weight composed of liquid wax which is a higher percentage than sperm whale oil. Commercial plantations of the species have now been established in 13 countries (Myers, 1983b).
- Certain aquatic weeds constitute a free crop of great potential value, a highly productive crop that requires no tillage, fertilizer, seed, or cultivation. Aquatic plants have potential as animal feed, human food, soil additives, fuel production, and wastewater treatment (National Academy of Sciences, 1976).

IUCN will continue to encourage the wide use of such species of animals and plants, but if a species is on the verge of extinction, every effort must be made to give it complete protection until numbers build up again. The IUCN Species Survival Commission has published a series of Red Data Books for major groups of fauna and flora in which those species in the endangered category are defined as: "taxa in danger of extinction and whose survival is unlikely if the causal factors continue operating". These species must, of course, be given total protection, in marked contrast to those whose status is secure.

It would be irresponsible to claim that *all* species of animals and plants are in some way or other essential for human survival and sustainable development. With few exceptions, our knowledge of the interrelationships that exist in most ecosystems, especially between those key organisms which participate in the essential ecological processes, is woefully inadequate, and virtually nothing is known about critical levels of species loss that may occur before these processes are affected. The conservation movement will have to accept that the process of habitat destruction is already too far advanced to halt the loss of thousands of species in the years ahead. Myers (1983a) believes that the key challenge facing conservationists lies in the most efficient way to allocate funds and expertise to save species and to determine priorities for action. A useful starting point, and one that should be relatively easy to promote, would be to give a priority rating to those threatened species of animals and plants that have a key role to play in the three objectives for conservation as proposed by the *World Conservation Strategy*.

Forests and open woodland

In terms of the interaction between human populations and natural resources, man's impact upon the forests and open woodlands of the world deserves special mention. The ecological role of forests in the essential ecological processes (the ecosystem services) and their importance as a source of biological diversity have already been described, but of equal importance the world over is their economic role as a source of wood and wood products for building houses and furniture, for manufacturing fibreboard, plywood and paper, and of great economic significance to most Third World countries, is the role of forests and open woodlands as a source of fuel for heating and cooking. It is this last role which is providing one of the most critical interactions between man and his environment.

According to an FAO survey of 95 developing countries, of the 2,000 million rural people who depend on wood as their principal fuel, close on three-fifths of them did not have access to adequate supplies in 1980. High population growth rates and declining supplies will raise the number affected by the shortage from 1,148 million in 1980 to 2,400 million in the year 2000 if present trends continue. An acute scarcity of wood already exists in 27 coun-

tries, where resources have been depleted so far that people cannot obtain enough wood to meet basic needs even by overcutting. In another 42 countries, part or all of them have a fuelwood deficit, and a situation exists where present needs can be met only by depleting the stock of trees. In sub-Saharan Africa, 18 countries face acute scarcities, but the largest number of people affected by the deficit (886 million in 1980) is dependent on fuelwood (FAO, 1983b). In Indian towns, rising prices are fast making fuelwood purchases impossible for many residents. Between 1971 and 1980, the price of fuelwood in Bombay nearly tripled (Postel, 1984a). Once a deficit situation has been reached, the ecological consequences are severe in the extreme, the total loss of ecosystem services often affecting the lives of people who live hundreds of kilometres away from the point of deforestation. As an added complication, people in such a situation turn to dried dung for fuel, and essential nutrients and organic material that should be returned to the soil go up in smoke. Eckholm (1982) has estimated that approximately 400 million tonnes of cow dung are annually burned in Asia, Africa and the Near East, each tonne being equivalent to a loss of about 50 kg of potential grain output.

As with so many other issues discussed here, the rural poor are immediately influenced by the destruction of the resource base from which they must eke a living, but it would be a big mistake to blame just the Third World nations for the loss of forests. Although developing countries contain three-quarters of the world's population and more than half its forests, they account for a mere 14 per cent of commercial wood consumption in the form of paper and other wood products.

The disparities in consumption are graphically illustrated by the example of the average US citizen consuming about as much wood each year in the form of paper alone as the average Third World resident burns as cooking fuel (Eckholm, 1982).

As a result of the activities of both the subsistence and commercial sectors of the global economy, forests and open woodlands are disappearing rapidly and the possibility exists that if present trends continue, most of the physically accessible forests in the developing countries will have been cut down by the year 2020. The rate of global loss is difficult to quantify, mainly because of the inadequacies of such data when collated from so many different sources, but it could be as high as 11.3 million hectares per year (Poore, 1983). Such statistics are of rather limited value, because they tend to mask pronounced regional differences. For example:

- Haiti was completely forested when Columbus visited it in 1492. Now, as a result of tree-cutting by farmers desperate for new land, coupled with a massive removal of trees to provide wood and charcoal for 98 per cent of the population, Haiti is suffering from a degree of environmental degradation almost without equal in the entire world, making it the poorest nation in the Western Hemisphere (World Environment Report, 1981).
- More than two-thirds of Central America's 400,000 km² of lowland and lower montane tropical rain forests have been eradicated, and the remaining forested areas are disappearing at an alarming rate of 4,000 km² per year (Nations and Komer, 1983).
- In five of China's major forests provinces, at least 16 million hectares have been deforested in the past decade. Since the revolution, China is estimated to have lost about 24 per cent of its total forested areas. Illegal cutting for household use, black marketing on a large scale, uncontrolled fires, and conversion to croplands are the primary causes (Smil, 1983).
- Of the 250 forests in KwaZulu, Natal, proclaimed under the Trust Land Act of 1936, 75 per cent had all but disappeared under the axe by 1983 (Murless, 1983).
- Although Africa as a whole is losing about 1.3 million hectares per year of its tropical forests, the rain forests in Central Africa were still relatively intact in 1982 (Eckholm, 1982).

The process of re-afforestation is one of the few cases where one relatively straightforward plan of action, if successfully implemented, can bring far-reaching ecological and economic relief. For example:

- In 1970, South Korea was a barren, denuded country, plagued by soil erosion. Its hillsides were eroded, and the land has lost most of its water-retention capacity. By 1977, 643,000 hectares had been planted to fast-growing pine trees, and the face of the Korean countryside had been transformed (Brown and Shaw, 1982).
- In Rwanda, the World Bank's International Development Association (IDA) recently approved a US$ 21 million credit for a long-term plan which will establish 8,000 hectares of fuelwood plantations to supply charcoal and firewood to urban populations, and the IDA will finance studies of more efficient charcoal production and more economic stoves (World Environment Report, 1981).
- A Forestry Fund was established in China in 1981 to give economic assistance to afforestation, and the 3 March each year is set aside as 'Afforestation Day' when people throughout the country from Party leaders to peasants are mobilized to plant trees (Bassett, 1981). This programme has now been stepped up, and every fit person over 11 years of age must plant 3 to 5 trees per year to reach a target of 2,500 to 3,000 million new trees annually. The aim is to have 20 per cent of the country forested by the year 2000 (Oryx, 1982b).
- Progress is being made with a plan to plant a barrier of trees 20 km wide and 3,600 km long between the Atlantic and the Red Sea. The objective is to arrest the encroachment of the Sahara Desert, which has been advancing on a broad front at the rate of more than 1 km per year for more than a century (Hughes, 1983).

Such positive steps are most welcome, but a much bigger commitment is required if the awesome projected fuel needs are to be met. According to World Bank calculations, the rate of firewood planting must increase five-fold if enormous ecological and economic costs are to be avoided. At present, projected rates of tree-planting programmes, the ratio of tropical areas being deforested to areas being planted with trees will be 10 to 1, planting falling far short of compensating for deforestation. The current rate of planting will have to be increased more than 13 times to reach the level needed to meet the estimated needs in the year 2000 (Postel, 1984a).

A major area of ecological concern appears to have been overlooked when single-species tree plantations are substituted for an original mixed forest. These trees cannot satisfactorily be substituted for native species as they lead to reduced energy flow through the ecosystem, less cycling of minerals, and a loss of soil nutrients, at least under prevailing management practices (Ehrlich and Mooney, 1983).

Most of the tropical forests are disappearing because of their conversion into croplands and pastures for beef cattle. Furthermore, huge areas of tropical forest have been removed to provide land for growing agricultural cash crops for export, such as rubber, oil palm, sugar, tea and coffee. A promising approach to reverse this trend is to encourage the growth of agroforestry whereby trees are planted together with crops rather than trees or crops being planted on their own. In order to avoid planning for people, efforts are being made to promote suitable traditional agroforestry techniques particularly those used by a region's indigenous people. For example, a rain forest Indian group in Chiapas, Mexico, called the Lacandon Maya practise a multi-layered cropping system that combines up to 75 crop species in single hectare plots. The same rain forest clearings are harvested for up to seven consecutive years, after which the farmers plant the plots with tree crops such as rubber, cacao, citrus, and avocado. Far from being abandoned fields, these 'planted tree gardens' continue to provide food and raw materials as the clearings regenerate with natural forest species. When forest regrowth finally overcomes the fruit tree crops, the farmers clear the plots for a second cycle of food and forest. The advantage of this traditional life-style is that a Lacandon farmer clears less than 10 hectares of rain forest during his entire agricultural career (Nations and Komer, 1983). Traditional life-styles may well have a much more significant role to play in sustainable conservation and development activities than has been acknowledged in the past. Far from being destructive, primitive and irrelevant, they have much to offer, and are urgently in need of further investigation (Hanks, 1984).

Water resources

Water is a natural resource that is taken so much for granted, because supplies appear to be unlimited. In addition to soil and sunlight, water is one of the most vital resources required for food production. Over the 25-year period from 1975 to the end of the century, increases of at least 200 to 300 per cent in world water withdrawals are expected, by far the largest part of the increase being for irrigation. Surprisingly large quantities of water are required for irrigated crop production. For example, 1 kg of corn requires 1,400 litres, 1 kg of rice 4,700 litres, and 1 kg of cotton 17,000 litres (Ritschard and Tsao, 1978). In the USA, agriculture accounts for 83 per cent of the water consumed, compared with a mere 17 per cent for industry and urban areas (Pimentel *et al.*, 1976). With populations demanding increased food production, more land is being brought under irrigation, but in several major areas of the world, irrigated lands are reverting to dryland farming. For example, in the southern plains of the USA, much of the irrigation water comes from the Ogallala aquifer, an essentially non-rechargeable water resource. The move to irrigated farming in the area will only last for a few decades, and then reconversion to dryland farming has already begun in parts of Colorado, Kansas and Texas (Brown, 1984).

Thus, the demand for water is growing several times faster than the population, and by the year 2000 half of all the Earth's annually renewed water, precipitated on land, will be used by man. Much of this increased demand will be in the developing countries, where water for human consumption and irrigation is often already in short supply, with local shortages made worse by the deforestation of watersheds. Further increases in agricultural production will consume an estimated 64 per cent of the total water withdrawn. An additional complication is caused by the fact that about one-third of the world's major river basins are shared by three or more countries. Thus, it seems likely that there will not only be internal competition for water use, but this competition will also extend to nations that share common water supplies (Pimentel, 1983).

The productivity of poor people, already low in most developing countries, is made worse by debilitating malnutrition, and dirty and inadequate water supplies. Through no fault of their own, tens of millions of rural women and children spend long hours each day fetching and carrying heavy loads of water, and for more than half the people in the Third World (excluding China) this water is not safe for human consumption. At least 10 million people die each year from diseases caused or aggravated by these

unclean supplies, and totally inadequate sanitation facilities aggravate the problem. According to estimates from the World Health Organization, up to 80 per cent of all illnesses may be due to these causes. The following examples give an indication of the scale of the problem (Earthwatch, 1981). At any one time there may be:

- 500 million people with trachoma, which can cause blindness;
- 250 million with legs swollen by elephantiasis;
- 200 million people urinating blood as a result of bilharzia (schistosomiasis);
- 160 million incapacitated by malaria fever;
- 100 million people aching with constant diarrhoea and unable to work;
- 30 million people already blind or succumbing to river blindness.

Several million people have a combination of these sicknesses, to which may be added typhoid, cholera, dysentry, gastro-enteritis and hepatitis (water-borne diseases spread by contaminated water or dirty hands), and scabies, yaws, leprosy and conjunctivitis (diseases aggravated by lack of sufficient water for washing).

Stimulated by such statistics, the United Nations has declared the 1980s the International Drinking Water Supply and Sanitation Decade, the hope being that Third World governments and international aid donors would drastically step up their investments in water and sanitation, providing these facilities to all by 1990 (Eckholm, 1982). Regrettably, a combination of further rapid population growth, the destruction of well-established water cycles, and inadequate financial support will make it virtually impossible for any of the developing countries to meet this target.

The introduction to this supplement emphasized that if conservation and development programmes are to succeed in developing countries, the vicious circle of poverty must be broken. Dirty and inadequate water supplies lead to debilitating diseases, and when coupled with malnutrition, reduce further the motivation and productivity of people who are poor. Cutting down forests in major catchments and watersheds results in the lowering and siltation of rivers and streams, and consequently the water they carry becomes deoxygenated, stagnant, and an ideal breeding ground for disease organisms. Water is another vitally important area of interaction between human populations and natural resources; its conservation and management are intimately connected with the maintenance of the ecosystem services described in the *World Conservation Strategy*.

In the developed countries, there is the additional problem of chemical contamination of water supplies. The chemical industry manufactures more than 100,000 chemicals, all of which in some way, in some form, enter the environment, where they are constantly being changed. An Environmental Protection Agency study in the USA revealed that the waste water of one industrial plant was supposed to contain 17 chemicals deliberately discharged by the plant into a stream. By the time the stream reached the mainriver, 37 chemicals were detectable (Hall, 1981). Chemicals are not inert. They constantly react with each other and with natural substances in unpredictable ways, forming unpredictable products with unpredictable effects on life, as has been most strikingly demonstrated by acid precipitation, one of the most talked-about environmental phenomena in the world.

The combustion of sulphur impurities in fossil fuels and smelter ores emits sulphur oxides into the atmosphere. Nitrogen and oxygen which combine chemically under very high temperatures are also emitted into the atmosphere, this time as nitrogen oxides. These precursors undergo a complex series of chemical reactions in the atmosphere to produce sulphuric and nitric acids, which may dissolve in raindrops as they form and be washed out of the atmosphere as acid rain (Clapham, 1981; Ramade, 1982). Exceptionally acidic rain with a *p*H of 1.5 has been recorded in Pennsylvania, USA (Chadwick, 1983). The acid particles can be carried hundreds of kilometres, the resulting acid rain falling far away from the original source of emission, and in the process causing serious environmental degradation. For example, acid rain is affecting some of the forests in West Germany, where silver firs are particularly affected, and whole forests may die in the next 5 years (Oryx, 1982c). West Germany's Ministry of Agriculture has already indicated that one-third of the nation's 17 million hectares of woodland have already been damaged by acid rain. By 1990, more than 3 million hectares of forest may be lost in Poland alone if the country proceeds with its present industrialization plans, which call for increased burning of the nation's high-sulphur brown coals (Postel, 1984b). Substantial tree damage has also been reported in Austria and Switzerland (World Environment Report, 1984), although there have been no reports from any countries of tree damage or loss occurring on lime-rich (calcareous) soils. Hundreds of soft-water lakes in central and eastern Canada, in north-central USA and in Scandinavia have become so acidic that aluminium has been released from the soil, and fish have been killed as a consequence. An estimated 50,000 more lakes in the USA and Canada will have no fish within 15 years if present trends are allowed to continue (Clapham, 1981). Acid rain might also threaten human health by dissolving heavy metals found in the soil around water bodies, and making them more likely to get into drinking water or food crops (Eckholm, 1982).

The European Commission has called for radical reductions by 1995 of air pollutants emitted by coal and oil-fired plants. Coal-fired plants account for 80 per cent of all sulphur dioxide emissions and 40 per cent of nitrogen oxide emissions in the Community area. The cost of emission reduction at source is approximately equal to the cost of environmental damage in the area, between US$ 1.4 and 4.2 billion per year (Lubinska, 1984). Regrettably, the development, acceptance, and implementation of appropriate agreements to control the release into the atmosphere of the sulphur and nitrogen oxides still seem a long way off, and another critical area of conflict between man and his resources remains unresolved.

Coal will be the primary polluting fossil fuel in the years ahead. Approximately 660 billion tonnes are now technically and economically recoverable, which at today's rates of production would last well over two centuries. What is happening in the forests today shows that the biosphere is *not* infinitely resilient (Postel, 1984b).

Energy resources

Probably one of the most important factors responsible for resource destruction and rapid human population growth in the past 200 years was the increased use of fossil fuel to manipulate and manage ecosystems. Energy has been used to improve the quality of human life in a variety of ways, two of the most important of which are disease control and increased agricultural production to feed the growing populations.

In the USA, an estimated 16.5 per cent of fossil energy is spent on food production. This total includes land preparation, crop planting and harvesting, and food processing, distribution and preparation. This amounts to approximately 1,400 litres of oil per capita. Pimentel and Pimental (1979) have estimated that if attempts were made to feed the world population a similar high protein diet using US agricultural technology and assuming that petroleum were the only source of energy for food production, oil reserves would last a mere 11 years. There is no doubt that the ready availability of relatively cheap energy has made an enormous difference to the quantity of food that can be produced. One farmer producing corn by hand in the USA can manage only about 1.5 hectares, but by using fossil fuels to run his mechanized equipment, he can manage up to 100 hectares. China is another striking example of the increased reliance on fossil energy for food production. While crop yields have tripled in the last three decades, fossil fuel inputs have risen 100 fold. A doubling of the food supply during the last 25 years would help offset serious conditions of malnourishment that 500 million humans presently endure, but to do this a 3–4-fold increase in the total quantity of energy expended for food production would be required, mainly because an increasing amount of fertilizer would have to be used for each unit of food produced (Pimentel, 1983).

The finite supply of fossil fuels and the inability of most rural people in the poorer Third World countries to purchase them, means that increased food production based on US-type technologies is unlikely to be a feasible way of boosting food production in those countries. In fact, the gap in energy consumption as a whole seems to be getting wider between the developed and developing countries. For example, Ethiopia shows a per capita energy consumption of 20 kg coal equivalent, Sweden having a corresponding figure of 6,000 kg (Hosiser *et al.*, 1982). However, with minimal fossil energy inputs, food supplies can be increased if world populations consumed more than plant foods. At present, more than 3 billion livestock are maintained to supply the animal protein consumed annually in the USA alone, and more than 420 million hectares of land are used to feed these animals, which consume about 10 times as much grain as is consumed by the total US human population (Pimentel *et al.*, 1980). Under such a system, 10–20 calories of energy are needed to obtain 1 calorie of animal protein. Thus a change in diet would not only reduce energy expenditure, but also increase food supplies, because less grain suitable for human food would be fed to livestock (Pimentel, 1983).

The global output of the most convenient fossil fuel, petroleum, has reached a peak, and most estimates indicate that most of the world's readily accessible remaining reserves of petroleum will be consumed within a few decades (Brown and Shaw, 1982). Although coal is more plentiful, a large increase in its use will aggravate atmospheric pollution problems, not only by increasing the release of sulphur and nitrogen oxides, which in turn lead to acid rain, but also by increasing the build-up of atmospheric carbon dioxide. The latter will probably result in an increase in the average global temperature because of the 'greenhouse effect', whereby atmospheric carbon dioxide allows solar heat to reach the Earth's surface, but acts like a greenhouse to stop the heat returning to space. Although there is still not universal agreement on the extent to which carbon dioxide levels will rise, most scientists accept that a further doubling of levels will bring about an average 3 + 1.5°C temperature rise, sufficient to alter global patterns of rainfall, wind and ocean currents (Council on Environmental Quality, 1981). Even the most conservative estimates suggest that such a temperature rise would have strong impacts on coastal areas, with sea levels rising up to 5 metres as a result of ice melting in Antarctica and Greenland, with a further rise by thermal expansion of the existing oceans of the world (Rind, 1984). This would inevitably have a detrimental and socially disruptive effect on regional patterns of food production, but precise changes are extremely difficult to predict. A further unknown but, nevertheless, probably still significant contributing factor to atmospheric carbon dioxide levels is associated with massive deforestation. Not only will many of the trees that are removed release their massive carbon stores into

the atmosphere when burned, but also a carbon dioxide 'sink' will be removed, further increasing atmospheric levels. The latter is a matter of some dispute, although trees remove vast quantities of carbon dioxide from the atmosphere in the process of photosynthesis, the extent to which the oceans will be able to absorb the additional quantities of carbon dioxide released from burning wood and by the removal of the forest 'sink' requires further investigation.

Although the end of the petroleum era is in sight, there is great potential for the development of alternative sources of energy. In 1984, renewable energy sources provided approximately 18 per cent of the world's energy mainly in the form of hydropower and wood fuel, and substantial progress has been made with new developments with wind power, wood fuel, geothermal energy, and photovoltaic solar cells. 'Wind farms', a clustering of turbines connected to the electric grid, are now generating power commercially in California and a few other areas. The goal of the California Energy Commission is for the State to have 4,000 megawatts installed by the end of the century, enough to supply 8 per cent of the State's electricity (Brown, 1984). These renewable sources of energy have two great advantages over fossil fuels. First, they are largely indigenous, and thus outlays of foreign exchange are minimal. Second, many renewable energy sources are virtually inflation-proof.

Brazil is emerging as a leader in its attempt to eliminate most oil imports by 1990, based on the development of its vast hydroelectricity potential, and the use of wood as a residential and industrial fuel. In the USA in 1984, biomass consumed as fuel accounted for about 3 per cent of the country's total gross energy consumption, but this could increase to as much as 11 per cent by the year 2000. However, the use of additional biomass for energy production would almost certainly intensify soil erosion, water runoff and nutrient loss problems. Furthermore, natural ecosystems would have to be converted into energy-crop plantations, reducing natural habitats and food sources for wildlife and replacing these species with disease-susceptible monocultures. Although biomass energy does have the potential to make a significant contribution to the USA's energy needs, the potential environmental problems associated with it require further careful evaluation (Pimentel *et al.*, 1984).

As some of the developed countries turn to nuclear energy, the risk of radioactive contamination of the environment due to nuclear power reactor accidents will be increased. An additional complication lies in the safe disposal of radioactive wastes, for which no nation has yet demonstrated a safe programme.

The use of energy resources is yet another example of interaction between human populations and natural resources where the repercussions of resource use extend far beyond a simple resource/population equation.

5. CONCLUSION

Population and conservation

If the present high rates of population growth are maintained, critical interactions between human populations and natural resources will increase in number and extent, making it extremely difficult or even impossible to accomplish the goals of the *World Conservation Strategy*. Although human survival might not be *immediately* affected, the world will become not only more crowded but gradually less stable both ecologically and politically and, consequently, far more vulnerable to the disruption of the essential ecological processes on which human survival depends. For example, there is now evidence that population growth may be influencing climate change in Africa. The people seeking to survive on arid and marginal lands may be driving a self-reinforcing process of dessication, literally drying out the continent. Brown (1985) believes that a breakdown has occurred in the relationship between people and environmental support systems which could lead Africa into a crisis of historic dimensions – one that goes far beyond short-term emergency food relief.

Development and economic progress must go hand-in-hand with the conservation of the world's fauna and flora, because few development activities can be maintained in the long term without the services of one or more of the essential ecological processes. The loss of species caused by the high rate of human population growth is much more than an aesthetic irritant – it is an extremely useful early warning system that economic and ecological problems lie ahead. Thus conservation and development agencies should not be seen as opposing forces, but as complementary agencies both of which place emphasis on human survival and sustainable development. When genetic material is irreversibly lost, the resource/population equation will usually be adversely affected, sometimes seriously so, and the quality of life will deteriorate. Continual loss of species would inevitably lead to the loss of genetic material that could have been used by man in cross-breeding programmes with livestock and crop plants to increase productivity and disease resistance. Furthermore, our options for using new species of plants and animals on a sustained yield basis are being reduced as each day goes by, and this continual loss of diversity in the face of increasing human numbers must ultimately reduce the Earth's human carrying capacity.

The interactions between human populations and natural resources are often complex, with interrelationships and chain reactions influencing species, ecosystems and even man himself far removed from the initial point of conflict or interface. For instance, sulphur and nitrogen oxides which start by polluting the air over Western Europe can end by falling as acid rain and killing fish in Scandinavia. Poor people resettled in or near a tropical forest can participate in the removal of that forest, lowering the local water table, causing flash floods and siltation downstream, and an increase in water-borne diseases where clear-flowing rivers have been transformed into stagnant pools. Thus an increase in gastro-enteritis, typhoid and cholera downstream may have been caused indirectly by the removal of a forest many hundreds of kilometres away. High rates of population growth under existing systems of land use will increase the intensity and variety of such human environmental problems. Many natural disasters such as floods, droughts, fires, and landslides are often related to conditions where sound ecological management did not exist (Pryor, 1982). Whether water, once in the ground, becomes a productive resource or a destructive hazard, depends very largely on man's management of vegetation and soils (Unesco, 1974). These and other resource/population problems serve to re-emphasize the importance of both stabilizing population numbers and vigorously supporting the three objectives for living resource conservation as defined by the *World Conservation Strategy*.

Importance of rural development

It would be a mistake to attempt to tackle fertility reduction in isolation without at the same time trying to reduce poverty. The Brandt Commission in its *North–South: a program for survival* realized the integrated nature of the problem. In its recommendations to help the poor out of their present difficulties, the Commission urged immediate action in at least three inter-related areas – poverty, hunger, and rapid population growth (Brandt, 1980). A similar approach was advocated in 1983 by the President of the World Bank, who stated that the key to poverty reduction lies in raising the productivity of the poor themselves. Welfare programmes aimed at the poor which do not increase the productivity of the recipients can only be short-lived and counterproductive. He also noted that governments have to take measures to ensure that the employment opportunities and earning power of the poor are not limited by sickness, insufficient food and lack of education, such non-income aspects of poverty calling for a commitment on the part of governments to human development programmes on a wide scale (Clausen, 1983).

Bearing these considerations in mind, international development agencies are emphasizing, not merely recognizing, the agrarian core of most Third World countries (UNDP, 1979), and for African countries in particular it is now recognized that increasing productivity and incomes in agriculture are the keys to more rapid economic growth, swifter alleviation of poverty, improved balance of payments, and a stronger basis for industrialization (Acharya, 1981). A complete 'package' for rural development must do more than just increase food production, for it must transform agrarian society in order to reach a common set of development goals based on capacities and needs of people. Such goals should give priority to the reduction of poverty, malnutrition, unemployment and inequality, and stress self-reliance and the participation of all the people in the development process, particularly those with the lowest standards of living. Furthermore, a rural development package would integrate the *World Conservation Strategy* philosophy into its programmes where relevant, stressing the importance of stabilizing human population numbers.

Few would dispute that the environmental problems in the rural areas of developing countries should receive priority attention from international agencies, including conservation organizations. A programme of sustainable rural development as outlined should have as its target the breaking of the circle of poverty, for unless this happens, poor and rapidly growing populations will continue to deplete their resource bases, and may encroach into and even absorb the bigger national parks as population pressures increase. It should thus be self-evident that it is in the interest of conservation organizations to promote programmes of sustainable rural development, especially where degraded environments in developing countries contain or are close to threatened species or ecosystems. Such programs are as important to the conservation movement as the stabilization of human population numbers. In fact, in some rural areas, the two activities may be synergistic, to the obvious benefit of the conservation of fauna and flora.

A population policy for world conservation

In a World Bank study of 63 developing countries, it was concluded that birth rates fell most in countries that had adopted and implemented family planning policies and programmes with specific demographic objectives. Birth rates fell less in countries without family planning programmes. The survey also indicated that both socio-economic development and family planning programmes have to be pursued *simultaneously* if fertility is to decrease in the future (Cuca, 1980). The message from the survey to conservationists and policy makers is that fertility reduction is less likely to occur in the absence of modernization and social development, yet without fertility reduction, environmental degradation will almost certainly continue unchecked, with a further loss of fauna and flora.

Legitimate human demands for natural resources will always be present, but in order to reduce the critical areas of interactions between human populations and natural resources such as are described here, every country would benefit enormously by

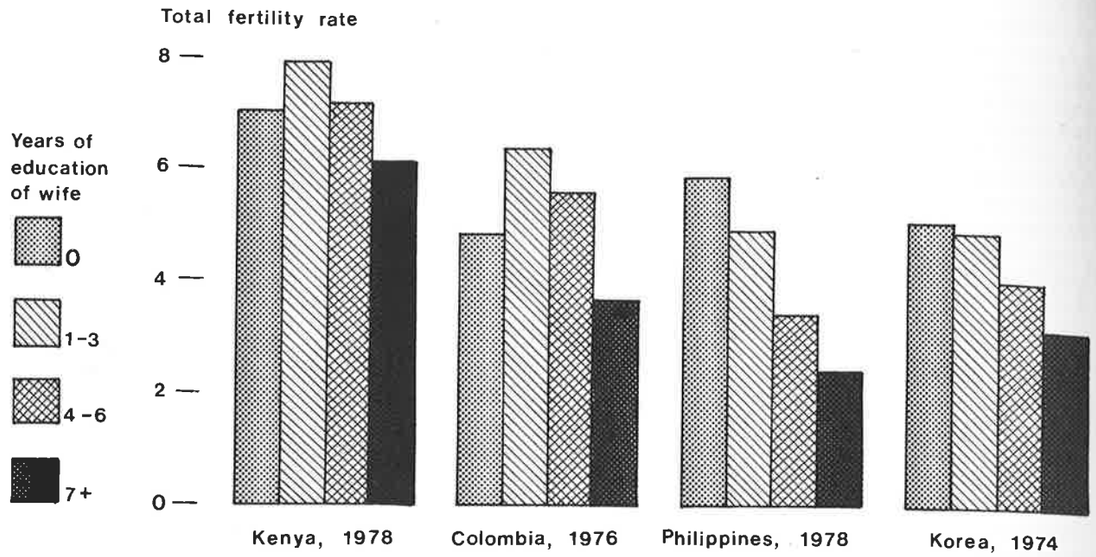

Fig. 3. The relationship between total fertility rate and years of education of wives in Kenya, Colombia, Philippines and Korea. In virtually all developing countries, the number of children declines regularly (and usually substantially) as the education of mothers increases above the primary-school level. (After Birdsall, 1984.)

having a *population policy* which defines an optimum population size that will conserve all natural resources and enhance the quality of existence of all people. Far from being a narrow resources-population concept, a population policy places considerable emphasis on the quality of life (including the provision of health facilities, education, housing, and employment), sustainable development and the conservation of fauna and flora. Furthermore, a population policy should be linked to definite socio-economic development objectives, integrating the population component in all aspects of economic planning (Bordes, 1981, Population and Development Review, 1981). It is important to stress that a positive population policy does not depend on hoped-for declines in birth rates that might be an incidental benefit of economic growth. Rather, such a policy must combine positive incentives for low fertility with negative incentives for high fertility (Hardin, 1985).

An essential concomitant activity in implementing a population policy is formal population education, which is designed to teach children in schools about basic population issues and to encourage them eventually to have smaller families (Population Report, 1982; Daly, 1983). The real challenge in such an education programme is to bind the family's fate to that of the nation, so that family considerations can be extrapolated to problems and solutions with national dimensions. Education of women is particularly important. In virtually all developing countries, women who have completed primary school have fewer children than those with no schooling (Fig. 3), and this pattern persists regardless of family income, occupation, religion and other factors (Ainsworth, 1984).

In all countries, especially those developing countries where high population growth rates occur, the establishment of a high-level government institution to define adequately a population policy in the context of national development planning, should be given higher priority. Technical help is needed by all developing countries in implementing programmes which integrate development planning, conservation planning (based on the *World Conservation Strategy*) and population planning. The World Population Plan of Action explicitly affirmed the important role of population in development, and recommended that population measures and programmes should be integrated into comprehensive social and economic plans and programmes, this integration being reflected in the planning needs for each country.

There are no quick or easy solutions to the problems of poverty and environmental degradation. However, insofar as sustainable development should be an integral part of any population policy, it follows that population policies and programmes must be integrated with national conservation strategies. Such a linkage could, in the long run, break the circle of poverty for millions of people, slow down the rate of environmental degradation, and conserve biota, land, and water resources for development.

6. IUCN ACTION

The achievement of equitable and sustainable development for human survival requires not only the acceptance and implementation of the three objectives for living resource conservation as set out in the *World Conservation Strategy* but also the adoption of a population policy. However, the *World Conservation Strategy* is unlikely to be accepted in most Third World countries at the community level for as long as the circle of poverty persists. Nor will any conservation, development or fertility reduction programme be accepted without the support of the people the programme intends to help. Accordingly, it is recommended that IUCN, in cooperation with IPPF and other agencies, should:

(1) Emphasize the importance of an *integrated* approach to conservation, development and fertility reduction in its policies, programmes, resolutions and public statements, where appropriate.
(2) Actively promote sustainable rural development programmes designed to break the circle of poverty.
(3) Encourage governments to recognize the limits of natural resources and the need for a population policy that will ensure sustainable economic, social and environmental development.
(4) Encourage non-government organizations, including local conservation groups and family planning associations, to work together to define a human carrying capacity at regional and national levels as a basis for deriving demographic strategies for a population policy and a tool for describing and emphasizing resource-population relationships.
(5) Keep resource-population trends under review, identify and publicize areas of priority concern, and report back on these issues to each IUCN General Assembly.
(6) Encourage conservation and development agencies to consider the possibility of improving the status of women, including the right of choice about frequency of childbirth, as an integral part of their field activities.

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Glossary

Age structure, the age composition of a population i.e. the relative numbers of people in different age classes.
Agrarian society, communities of people whose livelihood depends on agriculture.
Agroforestry, a combination of forestry programmes, cropping, livestock breeding and pasture management on the same land.
Alkalinity, having the properties of an alkali, the opposite of acidic.
Annual increment, amount of increase in 1 year.
Arable, ploughed land, or land suitable for ploughing on which crops can be grown.
Bilharzia, a common trematode parasite of tropical countries (*Schistosoma*), which is spread by dirty water in which the intermediate snail host lives. Together with malaria, one of the two most serious prevalent diseases on earth.
Biogeochemical cycle, the chemical interactions that exist between air, water, soil and living organisms.
Biological diversity, the number of species and the number of individuals of these species of both plants and animals.
Biotic environment, portion of the environment that includes all living organisms.
Birth rate, the number of births per 1,000 people per year.
Blight, an insect or fungus producing a plant disease, the disease itself.
Catchment area, the area from which rainfall flows into a river.
Cholera, a disease (spread by dirty water) which is characterized by diarrhoea and vomiting.
Conjunctivitis, inflammation of the membrane lining the eyelids.
Contraception, the planned prevention of pregnancy.
Death rate, the number of deaths per 1,000 per year.
Decomposition, the breakdown of nonliving organic matter and its conversion to simpler substances.
Deforestation, the removal of trees or the clearing of forests.
Demographer, a person who studies human populations, particularly birth and death rates, age structures and life expectancy.
Demographic transition, a falling of birth rates that follows declining death rates until birth and death rates are more or less equal.
Deoxygenate, removal of free oxygen from a substance or compound.
Desertification, the destruction of the biological potential of the land leading ultimately to desert-like conditions.
Development, a process of socio-economic change involving the transformation of society in order to reach an agreed set of goals based on capacities and needs of people.
Domesticates, animals brought under human control, and over a period of time, changed by selective breeding.
Dysentery, inflammation of the intestines, often accompanied by abdominal pain, and passing faeces containing blood and mucus.
Ecology, the science which deals with the relationship between all living things (including human populations) and their environment.
Ecosystem, a functional system which includes the organisms of a natural community together with their environment.
Elephantiasis, a chronic disease characterized by inflammation and obstruction of the lymphatic system.
Environment, the sum of all external conditions and influences (both biotic and abiotic) which affect the development and life of organisms.
Evolution, the process by which the genetic composition of plant and animal species changes with time.
Fallow, previously ploughed ground left uncropped, usually for a year.
Fauna, animals: the animal life characteristic of a particular region or environment.
Fertility, usually expressed as fertility rate – the number of births per 1,000 women (15 to 44 years old).
Flora, plants: the plant life characteristic of a particular region or environment.
Food conversion, usually applied to the change of grain or other vegetable food to meat, eggs or milk.
Fossil fuel, fuel formed in geological past e.g. oil and coal.
Fungicide, a fungus-destroying substance.
Gastro-enteritis, inflammation of the stomach and intestines.
Gene, unit of hereditary material represented as a small section of a chromosome.
Genetic, of or relating to biological inheritance.
Genetic diversity, the variation of genetic material within and between species and subspecies of animals and plants.
Geothermal energy, energy for man's use generated by the Earth's internal heat.
Germ plasm, the generative or germinal part of a cell.
Habitat, the locality or living place of a plant or animal.
Heavy metal, a metal of high density.
Hepatitis, inflammation of the liver.
Hybridize, to produce by cross-breeding animals and plants from different species.

Hydropower, energy for human use generated by falling water.
Incubation period, time taken for eggs to hatch.
Indigenous, existing and having originated naturally in a particular region or environment.
Inert, without active chemical or other active properties.
Infrastructure, permament installations such as roads, buildings, etc.
Labour intensive, work designed to use people more than machines.
Land capability analysis, an analysis of the options open for land use, based on a study of soils, climate, aspect, slope, etc.
Land tenure, condition or right under which land is held.
Leprosy, a chronic communicable disease which produces lesions in the skin and nervous system.
Leukaemia, a fatal disease of the blood-forming organs.
Life-style, an individual or group's way of life, particularly in relation to the consumption of resources.
Life-support systems, the main ecosystems involved in providing food, health, water and shelter for human survival and sustainable development.
Malaria, an often-fatal disease transmitted by bites of infected mosquitoes and characterized by attacks of fever.
Marginal land, land of low potential for agriculture, which is often susceptible to degradation.
Migration, movement from one place to another.
Mildew, destructive growth of minute fungi, particularly on plants.
Momentum, tendency to keep moving or growing as a result of the existing movement or structure of the body concerned.
Monoculture, the cultivation on a large scale of a single crop to the exclusion of other crops on a piece of land.
Multiple use, the principle of using a given piece of land for a variety of purposes, e.g. recreation, grazing, hunting and gathering.
Natural resource, any raw material, either renewable or non-renewable, obtained from nature.
Nutrient, an element or compound that is an essential raw material for organism growth and development.
Optimum yield, the amount of material that can be removed from a population that will maximize growth on a sustained basis.
Organic matter, carbon-containing, usually derived from living organisms.
Organism, an individual living plant or animal.
Pesticide, any chemical designed to kill animals or plants that humans consider to be undesirable.
Pharmaceutical, related to medicinal drugs.
Pollution, destruction or impairment of the purity of the environment.
Population translocation, the movement of communities of people, usually refers to movements initiated by government.
Poverty, the lack of enough income and resources to maintain an acceptable quality of life by community standards.
Precursor, the forerunner or substance from which another is formed.
Renewable energy, a source of energy that can be produced again e.g. wood, sugar cane, in contrast to finite fossil fuels.
Rural, pertaining to non-urban or agricultural situation.
Rural development, a process of socio-economic change involving the transformation of agrarian society in order to reach a common set of development goals based on capacities and needs of people.
Rust, plant disease with rust-coloured spots caused by fungus.
Salinity, degree of impregnation with salts.
Scabies, a contagious skin disease due to the itch mite.
Shifting agriculture, a system of agriculture which involves moving to a new area, clearing trees and bush for planting, and moving on to another area when the soil fertility is depleted.
Soil genesis, the process of soil formation by the weathering or rocks and the breakdown of organic material.
Species, group of (actually or potentially) interbreeding organisms that is reproductively isolated from other groups.
Subsistence agriculture, a form of agriculture in which communities grow or collect only enough food and raw materials for their own immediate survival and use.
Sustainable environment, a system of development that can persist for many years without depleting resources or degrading the environment.
Sustained yield, the principle of managing a plant or animal population in which there is a balance between those individuals removed and those replaced by natural growth so that the population is not depleted.
Synergistic, a combined effect of two actions or substances that exceeds the sum of their individual effects.
Taxon, a taxonomic group (e.g. species); plural – taxa.
Therapeutic, concerned with the healing and treatment of disease.
Tobacco mosaic, a virus causing mosaic disease in tobacco.
Trachoma, a viral disease of the eye.
Typhoid, a group of related infectious diseases caused by species of *Rickettsia*.
Urban, living or situated in a city or town.
Urbanization, move to city or make rural area more like a town or city.
Yaws, a bacterial infection marked by raspberry-like excrescences on the face, hands, feet and around the external genitals.

The following papers of the IUCN Commission on Ecology have been published:

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by Dr. M. V. Angel, Chairman of the Working Group on Ecology of the Oceans of the IUCN Commission on Ecology.

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