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CONSERVATION AND RATIONAL USE OF THE ENVIRONMENT

Report submitted by UNESCO and FAO

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FOREWORD

This report is concerned with the conservation and the rational use of the natural environments, particularly with those aspects which are not now receiving major support from most national governments or international agencies.

The emphasis in this report is first on the ecological principles which govern the environment and on which any programme for rational use must be based, and secondly on the preservation of environmental quality through appropriate attention to aesthetic, scientific and recreational values of both natural and man-made landscapes, including conservation of wild species and natural communities.

It is recognized that the environments of the earth are of value to man only as they become available for his support, his direct use, or for his contemplation and enjoyment. People must first be kept alive if they are to further appreciate their environment; hence the production of food and other necessities remains a primary concern in conservation.

The need for careful consideration and intensive study of conservation problems and rational use of the environment derives largely from the human population increase and from the impact of technology on nature. Because of the new dimension of these two factors, conservation is now a global problem. World population as well as production of food and other commodities are receiving major attention in national and international meetings and reports, and will not be discussed in detail here although they are necessarily considered as part of the basic framework for world conservation.

This report is further restricted in its area of emphasis to the terrestrial environment and its inland waters. The oceans which comprise the larger part of the world's surface are given appropriate attention in other international reports and studies.

No particular emphasis is placed in this report on pollution, although it is a major environmental problem. A special report on pollution, prepared under the leadership of the World Health Organization is being separately submitted to the Economic and Social Council of the United Nations.

This report was prepared in accordance with a wish expressed by the Economic and Social Council at its 39th session. It is presented jointly by FAO and Unesco. It has been prepared on the basis of a draft submitted, at the request of Unesco, by R.F. Dasmann, Senior Associate, The Conservation Foundation, Washington, D.C. FAO and Unesco wish to record here their sincere thanks to Mr. Dasmann for the work he has accomplished. They also wish to express their thanks to the Conservation Foundation for permitting Mr. Dasmann to undertake this work.

The outline of the report was developed with the advice and assistance of the following individuals: Harold Coolidge and J.P. Harroy (IUCN), Max Nicholson and E.B. Worthington (IBP), Lee Talbot and F. Raymond Fosberg (The Smithsonian Institution), Michel Batisse and S. Evteev (Unesco) and F. Bourlière (IBP).

The text was later completed by contributions from FAO, WHO and Unesco. It was presented for comment to the Unesco Advisory Committee on Natural Resources Research at its second session in June 1967. The summary and the final editing were made by F. Fournier, former director of the Inter-African Bureau for Soils and presently Unesco consultant.

FAO and Unesco wish to express their sincere gratitude to all those who have contributed to this report.

The report has been submitted to the ECOSOC Advisory Committee on Science and Technology at its 8th session held in October 1967 which offered the following comments:

"The Committee was in general agreement with the ideas contained in the report and with the associated recommendations for action. In its view the report constitutes a most commendable effort to analyse and provide a scientific basis for the concept of combining rather than opposing the conservation of natural resources with their rational use. It is the view of the Committee that reconciling the needs of an ever-expanding world population, having ever-expanding requirements in commodities and amenities provided by the environment, with the maintenance of a sustained yield of resources and a proper quality of the environment is going to be a dominating problem in the forthcoming decades. This problem will affect both the developed and "old" countries where the situation is already much deteriorated, and the developing and "new" countries where the chances of avoiding major errors appear greater.

While recognizing that in every country many economic, sociological and financial considerations necessarily affect the approaches to this general problem, the Committee was gratified by the emphasis given in the report to the fact that, thanks to recent developments in the field of ecology and related subjects such as climatology, hydrology and pedology, a scientific approach can now provide a first basis for action. Such an approach should progressively provide a more objective basis for 'physical planning' in each country and in the land areas of the globe as a whole.

The Committee was informed of the preparations for the Intergovernmental Conference on Rational Use and Conservation of the Resources of the Biosphere, which Unesco is convening in September 1968, with the participation of the United Nations, FAO and WHO, and in co-operation with the International Union for the

Conservation of Nature and the International Biological Programme. This Conference should, together with the report under review, constitute a major step forward in informing all countries of present ideas in the scientific field, and in formulating proposals for action at the national and international level for better use and conservation of biological resources, including their land and water support.

The Committee was also gratified to note the excellent co-operation which was taking place between the various organizations concerned, both in the preparation of the report and for the organization of the Conference.

The Committee warmly commends the report to the attention of ECOSOC and of governments of Member States, and expresses the hope that adequate participation of experts will be ensured from all countries invited by Unesco to the Biosphere Conference."

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I. SUMMARY AND SUGGESTED LINES FOR ACTION

Introduction

This report, presented jointly by Unesco and FAO, was prepared in accordance with the wish expressed by the United Nations Economic and Social Council at its 39th session. A first draft was prepared at Unesco's request by R.F. Dasmann, Senior Associate, The Conservation Foundation, Washington, D.C. and was subsequently amplified by contributions from FAO, WHO, Unesco and by remarks from a number of specialists. The report was presented to the Unesco Advisory Committee on Natural Resources Research, at whose suggestion the summary below has been prepared to facilitate its examination by the Economic and Social Council. FAO and Unesco wish to express their gratitude to Mr. Dasmann and to all those who have assisted in the preparation of the report.

The problem

The report deals with one of the most fundamental problems facing man: the preservation of the environment in which he lives and from which he derives his means of subsistence.

This problem is vital today when the size of an increasing world population exerts ever greater pressure on the environment, threatening it with irreparable damage and loss in its utilization potential. The latter must be respected at all costs. Such an attitude in no way implies conflict between the maintenance of the production capital represented by the natural environment and its intensive exploitation by man. If such were the case, production would have

to be curtailed, whereas, on the contrary, an increase is absolutely essential. Conservation of the natural environment must therefore be dynamic and not static. It implies that the potential of the environment must be respected in any exploitation, which must therefore be "rational".

This principle should be an integral part of man's cultural heritage and he must realize that only through its application can he hope to attain the highest standards of living.

In applying this principle, man should take into account not only the elements of the environment on which he depends today for subsistence, but also those of scientific, aesthetic, educational, recreational or other value. In fact no aspect of his environment should be neglected.

The problems confronting man differ with the degree of development, the length or intensity of human occupation and the climate of different countries and regions. In highly developed countries, as a result of technological progress, the environment has been disturbed and often damaged. In countries continuously exploited over a very long period, or in densely populated regions, the original natural environment may even have disappeared almost completely. In the new, developing countries, or in regions where dense population is recent, there is disparity between rapid increase of population and limited exploitation of the natural environment. The inevitable intensification of such exploitation must not lead to a loss in potential. In all cases, lack of both organized planning and control of exploitation is the greatest danger. For example, when activities aiming at short-term results are undertaken, harmful long-term effects are often overlooked. Industrial and urban development can, for instance, lead to excessive encroachment on the natural environment resulting in its destruction or pollution.

Yet only the intensive development of resources is compatible with the needs of modern life. It is therefore imperative to plan and control the use of the resources of the biosphere and any programme of rational exploitation must be founded on principles arising from modern scientific knowledge.

MODERN SCIENTIFIC CONCEPTS AS A BASIS FOR THE RATIONAL USE OF THE RESOURCES OF THE BIOSPHERE

These scientific concepts are drawn mainly from ecology, an integrated science concerned with the study of living creatures in their mutual relationships with their environment, the biosphere, i.e. that part of the world capable of supporting life and including certain parts of the lithosphere, hydrosphere and atmosphere.

The unit of study of the natural environment is the ecosystem, a zone of extremely variable size (being perhaps a forest in the midst of cultivated land or again an area of tropical savanna or tundra) but possessing a definite unity through the complex interrelationships of its living communities between each other and with their physical environment.

It is in the framework of the ecosystem that man can best comprehend the effect of his actions, each ecosystem being characterized by a well-defined soil/climate/flora/fauna complex having its own potential for adaptation and tolerance of change. By maintaining a network of ecosystems for reference, man can measure the gain or loss resulting from his actions. The functioning of an ecosystem involves a series of cycles, the first being an energy cycle linked with the use of solar radiation. Man is a consumer of energy. He is thus integrated into this cycle and becomes a consumption factor. Foremost among all natural biological phenomena, human population increase is a fundamental element of the dynamics of an ecosystem.

The ecosystem furthermore possesses a water cycle. Allowing for evaporation, the soil is a major element regulating the amounts of run-off and percolation. By transforming the soil, man can change this and lose or gain the water so essential for himself, agriculture and industry. He can also change its quality.

Finally, the ecosystem possesses a cycle of nutrients, linked to the energy and water cycles. If life is to continue on earth, there must be constant exchange and continuous return of nutrients, with losses kept to a minimum. The sources of nutrients are soil, atmosphere and water. The return of nutrients to the soil is dependent on agricultural methods. Knowledge of the soil, of its management and of its behaviour is thus of foremost importance. If this cycle is to remain stable, rational exploitation must ensure a balance between extraction and return of nutrients. Essentially this is the problem of scientifically based fertilization.

PRACTICAL CONSEQUENCES OF RATIONAL USE OF THE RESOURCES OF THE BIOSPHERE BASED ON MODERN SCIENTIFIC PRINCIPLES

Through the ecosystem, the unit of study of the natural environment, flows energy entirely dependent on solar radiation. This energy is captured by green plants and becomes available to the higher elements of the ecosystem to which it is transmitted. Thus is established a "nutritional chain" consisting of a series of organisms where one serves as food for the next and from which every man daily draws the 2,000 calories necessary for his life. Man must therefore realize, before modifying nutritional chains in the exploitation of his environment, that the flow of energy through them remains the most fundamental process for the continuity of life on earth. These resources of the biosphere must not be over-exploited.

At each moment the ecosystem contains a total quantity of living elements expressed in weight: the biomass. This varies in time and space over the world's surface since it is linked to temperature and humidity. In the matter of its use, no parallel can be drawn between the development of the biomass and the increase of the productivity potential, i.e. the effective use of solar radiation. A heavy biomass may have little value and a light one quite the contrary. To man, what matters above all is net productivity. He would therefore do well to consider and study its limiting factors.

An ecosystem constitutes a complex of elements which, in natural conditions, possess a certain balance. But as man becomes integrated into an environment, he transforms and simplifies it by exploiting it. He is thus responsible for a modification in the original balance. Monoculture, for example, causes a recrudescence of crop pests. Man must therefore make an overall assessment and establish a new balance if he wishes to make rational use of the resources of the biosphere.

These needs are equally important when considering the adaptability of ecosystems. The latter, when utilized, may be capable of recovery after abusive exploitation, but to a varied extent according to climatic and biological factors. The most favourable situation occurs when these factors are balanced. If one or the other dominates, the durability of the exploited ecosystem diminishes.

When the ecosystem is utilized the main change is usually introduced by man. This is at any rate almost always the case in agriculture, being less true for animal husbandry and less still for forestry. A specific policy must be adopted in each case, and this is the task which man must undertake.

THE SITUATION WITH REGARD TO INTERNATIONAL ACTION

The attention of international organizations was early directed to the problem of the rational use and conservation of the resources of the biosphere, in view of its acuteness everywhere in the world.

All the activities of FAO are aimed at an increase of agricultural production having a rational basis to ensure continuity of yield. With the Indicative World Plan for the Development of Agriculture, this organization is trying to assess and clarify the agricultural, forestry and fishing aspects of the urgent need to increase production to palliate the growing demands of an ever larger world population.

FAO, WMO and Unesco have undertaken joint regional agroclimatological studies (West Africa, Near East).

FAO and Unesco are jointly drawing up an inventory of the world's soils with the World Soil Map at a scale of 1:5,000,000.

Unesco has launched the International Hydrological Decade as a major contribution to the study of water resources.

All Unesco's activities in the field of research on natural resources are aimed to provide the scientific bases necessary for the rational use of resources.

In addition, Unesco provides constant support for the activities of the International Union for the Conservation of Nature and Natural Resources, as well as for the International Biological Programme, which is making important progress in evaluating the world's biological resources and the research necessary for their conservation.

Finally, WHO is making a special study of pollution problems, on which it has drawn up a report in collaboration with the other Specialized Agencies for submission to this session of ECOSOC. Many organizations are working parallel with the United Nations Specialized Agencies on the problem of the rational use and conservation of the resources of the biosphere, in view of its importance to humanity.

FUTURE ACTIVITIES OF INTERNATIONAL ORGANIZATIONS

The report shows that a great deal still remains to be done, at both national and international levels. It is clear that the specialized institutions concerned must draw up a bold programme of action for the planning and control of the use of the resources of the biosphere, with the basic studies and preparation for the required action, working on four levels:

scientific; institutional; educational; legislative.

Scientific action

This should aim:

To recognize which branches of science and technology have a bearing on the elements of the environment, their interaction and their use, in order to provide a scientific basis for the planning and control of the use of the resources of the biosphere. This planning must lead to the integrated use of natural resources to ensure a continuous yield from the biosphere.

To establish which factors should be analysed and chosen in the integrated utilization of natural resources. These will be found through:

survey and inventory of factors constituting the environment;

knowledge of the factors of the environment, the phenomena and processes typifying them, the interrelationships between them, and their potentialities.

In this context, these factors become essential for planning.

To establish, during the study of each environmental factor the best criteria regarding possible choices wherever they apply to:

water;

land;

vegetation;

animals.

To introduce into studies the idea of assessment, because in dealing with water, soil, vegetation or animals, man must make every effort to maintain a proper balance in nature.

To establish rules for land management which lead to the definition of zones useful to man:

natural or scientific reserves, parks, relaxation and recreation zones;

zones of aesthetic and intellectual value;

agricultural zones, for agriculture, forestry or animal husbandry;

industrial and urban zones.

Management must have a scientific basis, especially where water and nutrients are concerned. This should be achieved through the study of losses and calculation of the return or the additions necessary to maintain productivity. The necessity of maintaining the quality of the environment and of avoiding its pollution should also be taken into account.

To show how the study of soils, climate and requirements of vegetation and animals, enables the whole range of potential uses of ecosystems to be determined, among which economists and sociologists with the help of scientists, will have to make a choice when drawing up management plans.

To promote new research, to fill in major gaps still existing in the scientific knowledge needed for the rational use of natural resources.

Institutional action

No one human brain can envisage the multiple aspects of so huge an enterprise as the planning of the exploitation of natural resources. This must be done, on national and international levels, by appropriate associations and multidisciplinary bodies within which interdisciplinary studies leading to integrated planning of resources and management of territories will evolve.

Educational action

Rational exploitation of the resources of the biosphere cannot be realized without full co-operation from the population. It is therefore necessary to fight the ignorance still existing and awaken attitudes of mind. International bodies and information and popularization centres must make every effort to inform public opinion.

Education, at primary as well as secondary and university levels, is the basic means to influence ways of thinking. Instruction in rational use of natural resources for their preservation should be evolved.

If there exists an infrastructure for the promotion of the rational use of the resources of the biosphere, specialists and technicians must be trained, both within the different disciplines and interdisciplinary fields.

Legislative action

Such activities can only succeed if there are means to carry them out. For this reason, appropriate legislation has to be established and adapted according to the different ecological zones of the world.

Simultaneously with all these activities, international organizations must bring home to governments the fact that within their national frontiers they possess irreplaceable treasures and above all they have the means that would ensure their subsistence. They must protect these from the loss of potential in the biosphere which would result from haphazard exploitation techniques. The Intergovernmental Conference of Experts on the Scientific Basis for Rational Use and Conservation of the Resources of the Biosphere, which will be convened in Paris in September 1968 by Unesco, should keep this as a major objective, as well as aiming at establishing the bases of a programme of longer-term action.

FUTURE ACTION OF GOVERNMENTS

Governments must realize the necessity of planning and controlling the use of the resources of the biosphere, basing their action on the principles revealed by modern science. Their action should be in the framework already outlined.

On the scientific level:

To assess the knowledge they have acquired and share it so that the general principles governing the rational use of environment may be known all over the world.

To increase their knowledge through research, so as to be fully informed on the problems set by the exploitation of their resources, with the aim of maintaining production at the highest level of quantity and quality.

To develop ideas useful for the rational development of their territory, in particular by establishing scientific and socio-economic criteria enabling the potential use of different zones to be defined as well as the obligations involved in their exploitation.

On the institutional level:

To create national bodies with the task of promoting and applying (on both administrative and scientific levels) a policy of rational use of resources in the framework of rational development of the territory. This action should lead to a situation favouring increased economic development.

On the educational level:

To increase the population's awareness of rational exploitation and preservation of their environment.

To introduce suitable curricula at all levels of education.

To train specialists and technicians capable of applying the desired policy, notably through the creation of interdisciplinary research and training establishments.

On the legislative level:

To pass laws enabling the country to promote rational exploitation and conservation of resources of the biosphere, and to collaborate with neighbouring countries in the case of common resources.

II. INTRODUCTION

A. THE RELEVANCE OF CONSERVATION

1. Conservation defined

Conservation can be defined as the rational use of the earth's resources to achieve the highest quality of living for mankind. Since people are diverse in their wants and aspirations, an agreement on what constitutes quality of living cannot be expected. Conservation therefore involves the maintenance of the widest practicable diversity in both natural and man-made environments to provide for a maximum variety in potential ways of living for humanity, recognizing that man and his material needs will be dominant ecological factors. Diversity in itself has biological value. Through retention of diversity, deterioration of the environment can be retarded and stability can be maintained under the stress of human treatment.

Conservation has in the past often been equated with efforts to preserve wild nature. This is indeed essential to the maintenance of diversity in the human environment, but it is only a part of the activities of modern conservation. Conservation includes also the imaginative, creative use of land and other resources to blend natural with man-made elements of the environment in the formation of stable, productive and beautiful landscapes and cityscapes for human use and enjoyment.

2. Historical background for conservation

Conservation is not a new phenomenon, but has its roots in the earliest attitudes of primitive people toward land, nature and their own cultures and in

man's deepest aspirations toward creating for himself a secure and pleasant environment. Although many of man's activities have proved destructive of his own environment, this destruction has been in most past instances an unforeseen and inevitable consequence of ignorance of environmental relationships. Man was not formerly endowed with efficient tools that could make rapid, far reaching and irreversible changes in his environment. Far reaching changes there certainly were, as with the upland open pine forest climax of South East Asia which is thought to have been induced by shifting cultivation on a long rotation; but this was a slow adaptation to man as an ecological agent comparable with the rôle of grazing animals in natural grassland. Today the immediate consequences of man's activities may be more accurately predictable but economics and technology set up a chain reaction with less predictable long-term effects. There is even less excuse for ignorance.

Measures to guarantee the preservation of forests and wildlife may be found among the early historical records of mankind. Efforts to stabilize agriculture through proper care of the land are in evidence from early Neolithic times. In many places on earth a high degree of stability and productivity was achieved on agricultural lands in the distant past. One need only compare the highly stable terrace agriculture of the Inca with the destructive use of similar lands by their Peruvian descendants to realize how much conservation knowledge has been lost from their culture. In Southern China, the Nile Valley of Egypt and other long-settled areas sound agricultural conservation has been practised over thousands of years.

The modern renewal of conservation activities is largely a Twentieth century phenomenon. Whereas more primitive conservation sought to adjust the impact upon land and nature of relatively small numbers of men using fire, the plough, the axe and the spear; modern conservation is concerned with greatly increased human populations using more destructive implements - the bulldozer,

the internal-combustion engine, toxic chemicals and structures of concrete and steel - and seeks to adjust their uses to the ecological realities of the human environment.

We must therefore recognize three distinct but interrelated aspects of the conservation of man's environment:

(i) In the first place there is what may be called logistic conservation, relating principally to such non-renewable resources as ores, coal, oil, etc., which must not be improvidently consumed. It may possibly include also land and water resources that should be reserved for future settlement and use.

(ii) The renewable resources of the human habitat require production conservation to support the material needs of the human population and provide not so much an immediate economic profit, but a healthy diet and an acceptable standard of living. Neither of these are now, or have been in the past, assured to man although his numbers have been restricted by the Malthusian controls of misery and disease. Only with prudent use and careful planning can the world's resources for agriculture, forestry and fisheries support sustained yields at the levels that will be required in the foreseeable future.

(iii) The natural environment, wholly or partially unmodified by human activity, remains an inheritance of incalculable aesthetic and scientific value and a balancing factor in the ecology of man's changing habitat. Its survival, together with its irreplaceable flora and fauna, calls for urgent measures of environmental and amenity conservation to which all measures of rural and urban development must be reconciled.

The present report develops concepts arising primarily from the latter category of conservation, although it seeks to relate productivity to amenity and man's physical survival to the survival of the ecosystem of which he is a part.

3. Conservation an integral part of culture

Conservation is not a luxury, but an integral part of man's cultural relationship with his environment. Without it agricultural soils would wash or blow away, forests would be destroyed without replacement, wildlife would disappear, rangelands would become desert, and man would destroy his own means for existence. Much that is best in conservation is known by other names since it has become an accepted and normal part of cultural practice. Thus, if conservation, in the broadest sense, were to cease to exist today, it would have to be created anew tomorrow. The alternative to conservation is destruction of the human environment.

4. The concept of rational use

Conservation is defined in part as rational use. Rational use takes the future into account through planning and application of the knowledge that is available to man's use of natural resources. In non-rational use there is an absence of long-range planning. Short-term expediency prevails, or available knowledge is ignored. Thus it is non-rational to clear a productive forest from a hillside to make way for only a few sparse crops of maize before soil and fertility are lost. It is non-rational to overstock a pasture and convert productive grassland into desert. It is non-rational to destroy priceless natural communities and wild species to allow marginal extension of farming, or an unplanned spread of urbanization. Unfortunately, what is non-rational for society in the long run may be rational for the individual or for the short-term goals of society. A sheepowner may garner immense profits from changing pasture-land

to desert; a land speculator profits from urban sprawl. Society, however, suffers, and it is upon society that the burden of control must fall.

5. Quality of living

An optimum existence for one people or culture may be intolerable to another. The confirmed urbanite may not want wild country in his environment; the farmer may detest cities. No one Utopia can please all men. The goal of conservation is to provide for a "high quality of living" by maintaining diversity in the environment, leaving room for many ways of life, keeping always open the doorway for future change..

Undue emphasis upon quantity of production, with its usual accompaniments of standardization and uniformity in the means of production, can destroy diversity and quality in the environment. To a degree, emphasis upon quantity is essential, since human needs must be satisfied. Beyond this point, however, further gains in quantity can only come with extreme sacrifice in natural diversity. Carried to a logical end, continued emphasis upon production of necessities could lead to a subsistence existence for a maximum number of people, with all resources harnessed and no opportunity for future change without catastrophe. Such an existence would be precarious and subject to catastrophes. Conservation seeks to channel development in ways that will still preserve a rich and varied habitat for man, one in which there is room for standards of living that are materially, intellectually and spiritually of high quality.

6. Commodity versus non-commodity values

The sustained production of commodities necessary to man must usually have first priority on lands best suited to such uses. In any region, however, consideration must also be given to the non-commodity uses of land. These will include the protection or development of various scientific, aesthetic, educational, recreational and other cultural values. They may add little immediate increment

to the gross national product, but in the long run their values will be higher than those that could be gained by full use of all lands for commodity purposes. Indeed such uses may prove essential if the production of commodities and if human life is to be permanently sustained. On many lands the values of commodity production may be achieved while non-commodity values are also protected. Well-planned cities will include parks which serve for human recreation and as habitats for some wild plants and animals. Productive forests can also serve as homes for wildlife, sites for recreation, and as sources for pure water. Since land capability varies widely it is seldom that one use need prevail over any broad area to the exclusion of all others. Thus even a strict natural reserve, set aside primarily for scientific study, can serve limited educational and recreational purposes. It will also by its nature contribute to land and watershed stability.

7. <u>Biotic and mineral resources</u>

The primary concern of conservation today is with the protection and use of the living resources of the earth and the soils, water and atmosphere that are needed for their support. The use of mineral resources and fossil fuels, except to the degree that these influence conservation of biotic resources, have now become basically technological questions and are not considered to be within the scope of this report.

B. THE PLIGHT OF HUMANITY

1. <u>Population pressure and deterioration of environment</u>

Throughout much of the world today the human environment is suffering from varying degrees of deterioration. This results from increases in the numbers of people, particularly those living at low standards of material prosperity, from the impact of an unplanned, or poorly planned, expansion of industrial technology, and from a failure to understand the realities of the environment. A difference

in both the degree and the nature of deterioration of the environment is found between developing nations of the world and those that have achieved a high level of technological advancement.

a. Developing nations

In most parts of the developing world a rapid increase in population, together with a growing dissatisfaction with the limited material rewards of subsistence agriculture, has led to an increasing pressure on the land both for food and for marketable crops. Almost invariably this increased demand has been accompanied by little or no advance in agricultural technology or a sufficiently rapid growth in non-agricultural employment. Both the rate and extent of environmental deterioration has been great; forests and range land have been impoverished or destroyed, while the extension of cultivation to more marginal areas lowers average yields and promotes erosion. For all this loss there is little improvement in standards of living.

Traditional agricultural methods are often ill-adapted to the more restricted area available to the individual cultivator, or to the effective use of kinds of land other than those formerly cultivated. The prevailing low level of education and the lack of both advisory personnel and the economic opportunity to profit by example frustrate attempts to introduce appropriate changes in land use and agricultural method that might otherwise meet the need for higher levels of production.

These difficulties are equally apparent in long civilized and densely populated countries such as India, which some would call "over developed", and in newer, more sparsely populated countries such as Brazil. Both call for revolutionary advances in agricultural methods as well as the conservation of natural resources. In the latter there is certainly more room for manoeuvre and a prospect of providing high quality living within the relatively near future.

b. Developed nations

In technologically advanced nations, commodity production is usually adequate to meet the needs of the human population. This relatively high economic level is achieved by the processes of industrialization, urbanization and a high level of public education including training of technical and professional manpower. However, in most of these nations the long-term effects of technological change are seldom adequately understood or accommodated. Cities sprawl over countryside and in doing so destroy space that could best be used for other purposes. Pollution of the environment has become a world-wide problem. Old cultural patterns have broken down and people have found inadequate substitutes to take their place. Increasing leisure and material prosperity result in pressures upon the countryside by people seeking recreation and open space, pressures that often destroy the amenities that the people are seeking.

c. Lack of planning and control

In both developing and developed nations a lack of planning for rational use of the environment is usually apparent, or where planning may exist, a lack of its implementation. Effective control over human use of the environment is obviously lacking. Ends are confused with means and the long-term goals toward which a people might rationally strive are overridden by techniques used to achieve short-term relief from immediate dilemmas. In almost all areas there is a continuing need for research to produce the knowledge required for rational use of natural resources and for the understanding of human behaviour.

2. Long-term values and short-term gains

a. The humid tropics

The sacrifice of long-term values for short-term needs is often apparent in the exploitation of tropical forest land. Under proper management these forests could supply a continuing yield of useful products, provide a refuge for

wildlife, retain soil and watershed stability and contribute other values to society. Yet from 100 to 200 million of the world's population depend for their food on the practice of shifting cultivation which may, indeed, be regarded as an element in the forest ecology where the period of rotation is sufficiently long and soils, slopes and climate sufficiently favourable to allow the regeneration of the forest cover.

Too often, however, the increasing density of population shortens the period of rotation beyond the critical point of forest regeneration and obliges the people to extend the practice to unstable slopes and zones of marginal rainfall where regeneration is even more hazardous. Loss of fertility, soil erosion, laterization and other processes ensue which may prevent any recovery of the site after its abandonment. This process may be observed throughout the tropics of the New and Old Worlds and the rate at which forests are disappearing has long been of major concern. Aubreville estimated in 1950 that 40 per cent of the tropical forest zone in Africa had been cleared of primary forest and in Nigeria 74 per cent. Rostlund in 1955 estimated that 40 per cent of the forests in Brazil had been cleared; here the production of export crops such as coffee is as much to blame as subsistence agriculture. Thus, values that could have been maintained throughout the foreseeable future are sacrificed for short-term needs.

Only limited areas in the humid tropics are suited to <u>simple</u> systems of stable sedentary agriculture. These are the soils of alluvial plains and valleys, especially where the alluvium is derived from basic rocks, volcanic soils and soils on slopes where the parent material is basic; nutrients are released by weathering as fast as the leached surface soil is removed by the normal process of erosion. Many tropical soils are, however, highly responsive to appropriate <u>combinations</u> of agricultural practice, including irrigation, crop

rotations and the use of fertilizers, which applied together lead to the development of arable soils of greater potential productivity, than the natural soils of the primary forest. Much research is still needed to perfect such agricultural systems and their introduction and general adoption must be a slow process. It is in the planned development of limited areas for a truly productive agriculture that the prospect lies of meeting human needs while conserving the natural resources as a whole and preserving some part of the original environment with its living heritage.

b. <u>Semi-arid grazing land</u>

In many areas of the world, including both developed and developing nations, semi-arid grazing lands are being effectively destroyed at a rate that appears to be accelerating. The process of conversion of productive land to desert-like wasteland may be observed on most continents. It is most marked around the edges of the Sahara and the deserts of South Western Asia, but can be observed also in Australia and in the Western United States, where in the 1930's the Forest Service estimated that the carrying capacity of range-lands had already been reduced 50 per cent as a consequence of mismanagement. In Libya, F.D. Larson estimated in 1957 that the rate of erosion and destructive use of range-land had accelerated during the preceding quarter-century. Under proper management such lands could yield a necessarily limited, but continuing supply of meat and other products from animal populations, either wild or domestic. In some areas, such as East Africa and Rhodesia, a wild animal resource of more value to man is destroyed to permit its replacement by a less valuable domestic animal resource. Over wide areas mismanagement of either domestic or wild animals results in overstocking, overgrazing, destruction of the vegetation, loss of soil and interference with the hydrologic cycle. The damage done may be virtually permanent in its effects. A few owners of domestic animals may receive

high short-term profits by the mining of a plant-and-soil resource that could otherwise yield long-term benefits to the many. Knowledge of how to manage such lands is often available to government agencies in the countries involved. Effective application of this knowledge and effective control over land use are almost always lacking.

c. Loss of irreplaceables

In both of the above examples a highly valuable resource is destroyed by lack of planning and control and the failure to apply sound principles of land management. Productive soils are virtually irreplaceable resources. When they are lost through accelerated erosion, it is difficult to achieve within economically meaningful time periods a restoration of the productivity of the land. Of equal concern, however, is the loss of scientifically priceless and aesthetically valuable resources in order to gain some additional increment of commodity production. Examples of this may be seen in most nations of the world. There is an obvious scientific need to preserve representative samples of all naturally occurring plant-animal communities with the wild species that occur within them. There is an ever-growing need to preserve areas of outdoor open-space for their recreational and aesthetic appeal even where widespread appreciation of these values has yet to be developed. Logically such areas should be in the sites that have the highest biological or scenic attractiveness and need not subtract substantially from lands needed for crop production. Such areas can be considered irreplaceable assets to a nation. Yet, through lack of adequate land-use planning and control they are often sacrificed to obtain a small economic increment in additional crop yield, yield of forest products, water power, urban water supply, or other commodity that could be produced as well in some other area. The continuing destruction of California's primeval redwood forests to add a small increment to the nation's timber supply is an example of this process.

3. <u>The consequences of urban-industrial growth</u>

a. <u>Inadequate planning</u>

Many nations of the world are seeking the economic benefits to be derived from an industrial economy and the application of modern technology to commodity production. However, those nations with the most advanced industrial technologies find themselves in an ever-growing dilemma resulting from failure to adapt the industrial technology to the ecological realities of the environment. Throughout the world, urbanization is occurring to a degree not equalled in any previous period. Yet the quality of living everywhere suffers from failure to develop new urban patterns to meet the needs of cities which differ both quantitatively and qualitatively from those in the past.

Most nations are in a state of conflict between the demand for land for urban-industrial uses and the more traditional demands for agricultural, forestry, fisheries, recreation space and open-space amenity uses. Most industrially-advanced nations are caught in a mesh of inefficiency and frustration by failure to plan adequately for the transportation of vast numbers of peoples and materials. The mistakes of the advanced nations are being copied and repeated by many of the now developing nations. Unplanned spread of urban areas and their associated highways, airfield and industries, threatens the loss of both necessities for living and amenities which make living worthwhile.

Lack of knowledge of the interests and requirements of culturally different groups within nations often results in the creation of man-made environments that fail to provide a satisfactory life for their inhabitants. People move from rural to urban areas only to find a still less satisfactory way of life in the cities. Populations displaced by technological change are often unable to adjust to new environments. Research needed to supply this knowledge of human needs is generally neglected.

b. Pollution

Most nations suffer to a greater or lesser degree from pollution of the environment, air, water and land, by the products or by-products of an urban-industrial technology. Thus the prospect of increasing agricultural production through application of chemical pesticides has resulted in a widespread misuse of these materials. Misused, these chemicals not only fail to control the pests at which they are directed, but set in motion biological cycles that result in even more severe pest problems. An example is the fire ant control programme in the South Western United States. Two and a half million acres were aerially sprayed in 1957-1958 with dieldrin and heptachlor to control the fire ant. Wildlife populations were destroyed in some areas; outbreaks of other insect pests were initiated; the fire ant was not eradicated. Misused, some pesticides will act as general biocides destroying valuable organisms and threatening the extinction of less common species of wild animal life. Thus in Japan the firefly has been virtually eliminated and populations of the Japanese stork and Japanese ibis have been brought near extinction as a consequence of heavy use of pesticides. Misused, these chemicals spread by water or air to areas far beyond those for which they were intended and their effects become not a local but a world problem. Thus DDT has appeared in the tissues of animals in the Antarctic. Similarly, serious problems threaten from the unplanned spread of the by-products of both peaceful and warlike uses of atomic energy, which can pollute all environments.

The by-products of industry and the effluent from dense human populations have created pollution that at present causes a severe loss of environmental amenities and threatens the health of people. In many instances the correction of these problems will be far more expensive than their prevention would have been, yet the conditions that create pollution are allowed to increase and

spread. Some level of pollution is perhaps unavoidable if we are to have the economic benefits of urban-industrial civilization with our present state of knowledge. Much pollution, however, represents failure to put into practice knowledge that is available, such as the installation of pollution control devices on automobiles and failure to adapt our uses of the environment to its physical and biological nature.

c. <u>The interrelationships of the environment</u>

A world programme for conservation through rational use of the environment would seek to find ways by which humanity could emerge from those predicaments that result from inadequate knowledge, inadequate planning and inadequate control for uses of the world's lands, waters and other resources. Such a programme would necessarily be concerned with the use of all lands and the distribution of people and of their activities. The entire spectrum of land use from urbanized areas to remote wilderness would need to be considered since it can be demonstrated that occurrences in one area will often have effects upon almost all others. Improper planning for life in cities can have its consequences upon wild lands. Improper planning for wild lands will have its consequences upon the quality of living within cities.

(1) <u>Urban systems</u>: A modern industrial metropolis such as San Francisco illustrates the extent to which the human environment has become intricately interwoven. This city draws its water supply from forested mountains hundreds of miles away. The state of land management on these watersheds determines the quantity and quality of water provided to the urban population and the cost of processing the water to make it suitable for its many urban-industrial uses. Flowing through the city this water and the water derived from local precipitation, picks up wastes and pollutants, and upon reaching the bay or ocean will affect both the variety and abundance of aquatic life that can be supported in

these areas. Thus a city that occupies less than 50 square miles depends upon and has effects upon, through its water usages alone, an area that covers many thousands of square miles.

The food supply for this city is drawn not just from its own agricultural hinterland, but from all of the continents of the world. The land-use practices of Asia, Africa, the Americas, Europe and Australia all affect the supply, quality and costs of the food imported. The existence of this and other urban import centres in turn affect the demands placed upon the land and resources of continental areas thousands of miles removed from these centres of consumption. Movement of people and supplies to and from this city requires transportation networks that influence all the lands through which they pass, over thousands of miles. People from the city pour out into the countryside on week-ends and holidays and exert direct pressure upon lands at great distances from the urban centre. Recreational demands alone may determine the uses to which lands are put on distant seacoasts, mountains, or other areas sought after by people seeking change from the conditions of urban existence. Thus the effects of one modern, metropolitan city, are felt ultimately in areas over the entire world.

The urban and industrial centres in developing countries may extend their influence over a smaller surrounding area, but because they concentrate the demand for such commodities as meat, milk, timber and fuel they may provoke an even more serious threat to the conservation of the local environment. In the arid or semi-arid lands of Western Asia this urban demand has long aggravated the evils that arise from wood cutting and over-grazing. The remedy lies in the more intensive use of those local resources that are best adapted to sustain this level of production, the concentrated demand providing an economic incentive for the greater investment required. In Western Asia fodder crops can be grown under irrigation to support modern dairy industries and fatten cattle and

sheep drawn from more distant ranges, while irrigated forest plantations can better meet the demand for timber if not for fuel. At present, irrigated agriculture often follows an extensive rather than an intensive pattern, making only a partial use of the available water supply and with much of the land under cereals and fallow.

(2) Wild-land systems: Far from the cities, in areas of land that are still little modified by man a similar network of relationships may be observed. A forested mountain area will be influenced by atmospheric conditions determined by the relationships of sunlight, air and seawater in some remote ocean. The build up of convectional currents in the local atmosphere can result in lightning that strikes dry forest fuels. Fire may spread and destroy the forest cover. Habitats that supported a rich variety of forest wildlife will be destroyed and forces that will create a different kind of habitat for other species of animals set in motion. Vegetation-soil relationships will be upset. Rain falling upon the previously forested watershed can remove soil and cause both flashfloods in the valleys below and the deposit of silt and debris in reservoirs intended for urban water supplies. Insects that breed in the dead vegetation left by fire may spread out to damage forests in areas many miles distant. Wildlife populations of species adapted to the kind of vegetation that will replace forest on burned areas could increase to high numbers and perhaps descend upon agricultural crops in valleys below. Thus local conditions are determined by factors operating in remote areas and can in turn have their effects upon regions well removed from the boundaries of the forest originally involved.

Man's activities increase the degree of interaction. No area of land serves only one human purpose. A decision to use a wild land area for a specific human objective in turn affects other possible human uses of the land and may in turn have effects upon natural processes that extend far beyond

comprehension or intention of the local land users. Thus, in planning for human use of the land, it is essential to consider not just the immediate costs and benefits involved in harvesting a timber crop (for example) but all of the indirect costs, benefits and values that become involved in that decision: the effect upon the scientific values represented by an undisturbed natural area, the effect upon possible recreation uses of the land, the effect upon wild animal life and a recognition of its many values to mankind, the effect upon soil stability and fertility, upon the hydrology of the watershed, and so on. Any less comprehensive evaluations can result in major errors in land use decisions. Each area of land involves many strands of a complex web of environmental relationships. The cutting of any strand can affect the entire network.

III. ECOLOGY AND RATIONAL USE OF THE ENVIRONMENT

A. ECOLOGY DEFINED

Ecology is an integrating science concerned with the study of living things in their relationships with their environment. In particular it is concerned with populations and communities of living organisms. Their environment includes both other living things and the physical environment of energy, atmosphere, water, soil and rocks. Since the conservation and rational use of biotic resources requires an understanding of their environmental relationships, ecology forms a scientific basis for these human activities. Since man must coexist with and is himself an integral part of a physical and biotic environment, ecology forms one kind of scientific basis for understanding man's rôle on earth.

Ecology takes no precedence over other scientific disciplines. Since it is by its nature an integrating science it depends upon other disciplines for basic data and principles to be applied to the interpretation of environmental relationships. Ecologists necessarily use the techniques and theories of physics, chemistry, the earth sciences, biology and behavioural sciences in their studies of the interactions between organisms and environment. The laws of thermo-dynamics, for example, derived by physicists, provide a basis for interpreting energy flow through the biotic communities that are the concern of ecologists.

B. THE BIOSPHERE CONCEPT

1. Definition

All life on earth is confined to and dependent upon a thin film of air, soil and water known as the biosphere.[1] This outer shell of the earth, composing the upper few feet of soil and rock surface on the continents, the waters of the land and the oceans and the lower levels of the earth's atmosphere, is the region in which interactions occur between the energy provided by sunlight and the chemical materials of the earth. These interactions make possible the existence of life and determine the nature of the many kinds of environments that exist on the surface of the earth.

2. Man's changing rôle in the biosphere

A review of human evolution reveals man starting with a small and inconspicuous rôle in the biosphere as one of several primate species occupying a limited area in the old-world tropics. His effects upon his environment were no greater than those of other wild animals. His dependence upon it was complete. He required oxygen and water derived from the atmosphere, energy from sunlight transformed by green plants into states suitable for human capture and assimilation. He was a predator upon certain other animals and a prey of larger or more capable carnivores.

As human evolution proceeded, however, the rôle of man in the biosphere increased. With the discovery of the uses of fire he was able to modify vegetation and thus affect the conditions of life for a much wider array of plants and animals. With the development of domestication he emerged from being simply another kind of omnivorous animal to become a factor determining the conditions of life

(1) It should be noted that some ecologists restrict the usage of "biosphere" to include only organisms and not their physical environment.

for all other species of life inhabiting the same geographical area. With civilization and the gradual development of technological skills he became a minor geological force, affecting that portion of biosphere in which his numbers were concentrated. With the industrial revolution and the channelling of new energy sources into the production of materials useful to himself, he became a global force, and assumed a position of ecological dominance over other living components and much of the inorganic material of the biosphere.

Despite this, however, man remains basically an omnivorous animal dependent upon the oxygen and water from the atmosphere and energy from sunlight transformed by green plants into states suitable for human capture and assimilation. Although in a position of dominance, he cannot for long modify conditions within the biosphere beyond the limits of tolerance for himself and the animals and plants upon which he still depends for life. Where he does so, he perishes.

3. Interactions in the biosphere

The interrelationships within the environment that man occupies have been described in part in the first section of this paper. The total extent of these interrelationships is something we have only recently begun to understand. It is generally agreed among scientists who have considered the origin of life on earth, that before life evolved the earth's atmosphere was devoid of oxygen. Oxygen is a product of photosynthesis, carried on by green plants, and is only added to in insignificant quantities by man's industrial production of it. The vegetation cover of the land and soil and the algal population of the upper layers of the ocean maintain the oxygen balance of air, water and soil. With any reasonable level of human population, such oxygen production would hardly be interfered with to any serious degree. Continued human population increase combined with vegetation disturbance and the burning of fossil fuels would create such a dangerous

interference. Without better knowledge of global rates of photosynthesis and oxidation we cannot predict when a danger point would be reached.

Present levels of human population and industrial activity have significantly increased the carbon dioxide content of the atmosphere at a rate of .7 ppm per year. This is believed by some to create a "greenhouse" warming effect within the earth's atmosphere, which will expedite the melting of the world's glaciers and icecaps, cause a rising of sea levels and a submergence of coastal lands upon which a high percentage of the present human population of the earth is now concentrated. Although there is no immediate danger, man's ultimate occupancy of the biosphere may well be greatly influenced by the care he takes to maintain the necessary ratio of gases within the atmosphere.

Interrelationships within the biosphere have been illuminated by man's misuse of atomic energy through the detonation of nuclear explosions. Fallout from atomic and hydrogen bombs kills small organisms and damages tissues of larger organisms at distances half-a-world away from the sites of the explosion. Although present fallout levels create no immediate danger to man, radioactivity is inimical to life and, the consequences of any major discharge of radioactive materials into the atmosphere are apparent and well-known. No nation would be immune to the consequences of atomic warfare.

Studies of both radio-isotopes and of pesticide chemicals have increased our awareness of the ability of biological material to concentrate chemicals to a degree that would be unpredictable from the consideration of simple physical laws alone. The movement of air and ocean currents and the migrations of birds, insects and other animals make it possible for chemicals that are released in one area to have their ultimate effects through biological concentration in areas quite removed from the source. DDT, presumably released on another continent, appears in the tissues of Antarctic animals. Radio-cesium, derived from

atomic explosions, although occurring at low levels in the atmosphere or soil, appears in dangerous concentrations in the tissue of Arctic caribou, thousands of miles from the area of origin.

Studies of urban air pollution further reveal environmental pathways within the biosphere. Automobile exhaust fumes released in the urban concentration areas of coastal California have their effects upon crops in the Central Valley of California, hundreds of miles away. Smog from these urban centres damages pine trees growing in the distant Sierra Nevada mountains.

As our knowledge of the biosphere increases, our realization that we live in "one world", not in a political sense but in a realistic biological sense becomes more certain.

C. THE ECOSYSTEM CONCEPT

1. Definition

The fundamental unit of study in ecology is the ecosystem. This is defined as a living community and its non-living physical environment. It is impossible to separate except for purposes of discussion the two components of an ecosystem. Thus the atmosphere, air, could be considered as non-living. Nevertheless air is constantly being used by all living organisms in a biotic community. In the process of use, its chemical composition is being modified through additions or substractions of oxygen, carbon dioxide and water vapour. Thus the atmosphere in the immediate vicinity of a biotic community provides both part of the environment and part of the community. It is different from the atmosphere that would exist were the biotic community to be removed, since it would contain different percentages of CO_2, oxygen, water vapour and nitrogen and undoubtedly have different temperature characteristics.

The term ecosystem is flexible in its usage and can describe any combination of living things and physical environment that are integrated, interact and

achieve some degree of stability. The value of the concept is the emphasis it places upon interactions and upon the realization that no living thing exists apart from other living things or from its environment.

2. Kinds of ecosystems

For purposes of study the world is divided into major categories of ecosystems and various subdivisions of these. In the terrestrial environment, major categories include the major types of world vegetation: tundra in the Arctic and Arctic-alpine regions, boreal forest in the sub-arctic and sub-alpine regions, various categories of temperate zone forests and shrub, grasslands and deserts, various categories of tropical and sub-tropical forest and savanna. Within each of these major vegetation regions, or biomes, certain types of vegetation represent relatively stable and permanent communities known as climax communities. Other types of vegetation, more transitory in their existence, are known as sub-climaxes or successional communities. Given time and freedom from disturbance these change into the more stable climaxes.

Within each major vegetation region is a characteristic animal life; including among its ranks herbivorous and carnivorous species each adapted to occupy a certain place in the environment, or ecological niche; each depending upon other species for its existence and in turn supporting the existence of still another group of species. Each major vegetation type will provide niches that are occupied by ecologically equivalent animal species. The small deer of the Asian rainforests have their equivalent in the small antelopes of the African forests, or in deer of different species in the American rainforests.

Each major ecosystem may be subdivided into smaller, but still distinctive communities, each with a different array of plant species occupying a different kind of soil and often characterized by a different kind of microclimate, each supporting a different array of animal species. These communities in their

aggregate, including both climax and successional stages, represent the greatest degree of biological complexity and diversity that the earth has produced and supported during recent geological times. Each species supported represents a stage in an evolutionary process that may be traced back to the beginnings of life on earth. Each in turn may give rise in future time to new species adapted to changing conditions on the earth's surface.

3. Relevance of the ecosystem concept

The ecosystem concept helps to explain both the success and failures in man's attempts to modify the natural environment for his own uses. In general, a land use practice developed in one ecosystem may be transferred to a geographically separate, but similar, ecosystem with hope for success. Thus agricultural practices developed in the temperate deciduous forest region of Europe were transferred with good success by certain groups of careful farmers to the temperate deciduous forest region of eastern North America. Attempts to transfer them, however, to the humid tropical forest regions of the world have been marked by failure. Grazing systems adapted to the humid pastures of Europe have failed completely when applied to the arid steppes of Australia. Forest practices acceptable in temperate America have been poorly adapted to the American tropics, but successful in temperate forests of eastern Asia.

Since ecosystems differ from one another in soil, micro-climate, vegetation and animal life, each presents a different problem in land use. Understanding of the relationship of native species with their environment can greatly assist in achieving stabilized and productive use of domesticated species. Thus studies of soil-forming processes under native grassland vegetation have helped in the improvement and maintenance of grassland soils devoted to cereal-grain agriculture, through demonstrations of those factors that contributed originally to fertility and physical structure. Studies of the rôle of nitrogen - fixing

trees such as alders (Alnus) have demonstrated their importance in forest succession and the enrichment of forest soils. Comparisons in Germany of soils created through forest monocultures with naturally occurring forest soils have led to a more balanced and sustained production from commercial forests.

Ecosystems differ also in their adaptability and tolerance to change. Those of northern and western Europe have adapted and adjusted to a long process of trial and error in land-use that has finally evolved into a highly stable agriculture. Those in Mediterranean Europe, less tolerant and adaptable, have broken down over extensive areas under similar pressures. In arid or cold areas, where life exists in delicate balance with a hostile environment, land-use blunders can have long-lasting ill effects. In more humid and warmer areas, similar mistakes are more readily absorbed and corrected.

4. Importance for maintaining reference types of ecosystems

All of man's advances in culture have been associated with new and improved ways of using the biosphere to produce things necessary or desirable to mankind. The products of naturally occurring ecosystems may be harvested or cropped. A natural ecosystem may be drastically modified to create an artificial one yielding a greater supply of useful products. Under certain circumstances improvements may be made upon natural conditions, as for example in western Europe and eastern Asia. Many of the agricultural soils in these areas are apparently superior in fertility and stability to the soils originally formed under forest cover. Under other circumstances deterioration may take place, either rapidly or slowly, as in many grassland areas of both the old and the new world where productivity has declined under continued grazing use. Progress or loss, however, can be best measured if representative samples of the original ecosystems are maintained for study and comparison. Such samples must represent the

full range of systems being used for commodity production if the comparisons are to have value.

Ecosystems also provide a reservoir of genetic materials, a spectrum of organisms adapted to a particular range of soil and climatic conditions. If preserved, these may provide, in the future, species directly useful to man's purposes, perhaps for domestication, for biological control, for medical research, or a variety of other uses.

Apart from immediate practical values ecosystems have an enormous value to basic science, to developing an understanding of living processes, evolution, comparative biochemistry, physiology and so forth.

The aesthetic and recreational value of undisturbed wild areas grows also in importance as the percentage of the earth's surface modified by man is extended.

These then are some reasons for the maintenance of unmodified areas of naturally occurring ecological systems. Wild species cannot be recreated if once lost. At little or no economic cost to mankind, however, they can be maintained.

IV. ECOSYSTEMS AND MANKIND

A. ENERGY FLOW AND ENERGY NEEDS

1. The energy cycle

The dependence of life upon solar energy is complete. This includes not only the dependence on sunlight in supplying warmth and illumination to the earth's surface, but also on its rôle in providing the energy contained in food and in the fuels that are burned to operate our industrial civilization. Much research is directed today toward the important question of greater efficiency in the capture and storage of solar energy. Basically, however, mankind will always depend mostly upon the most widespread process for energy capture and storage - that provided by photosynthesis in green plants.

Man requires approximately 2,000 calories of energy from food each day to maintain his metabolism and to function efficiently. The actual requirement varies with individuals and the amount of work performed. All of this energy was captured by green plants and stored in chemical bonds in carbohydrates, fats, proteins or vitamins.

Energy flow through the ecosystem is an inefficient process. Seldom is more than about one per cent of the total solar energy impinging upon extensive areas of vegetation actually captured and fixed as stored potential energy in plants, although higher efficiencies are reported from some agricultural crops, small areas of productive natural communities and algal cultures. It is unlikely that a high degree of efficiency will ever be reached in any large-scale food

production endeavour. However, the efficiency of solar energy fixation is seldom an important limiting factor in food production.

Energy captured by green plants becomes available to higher organisms in an ecosystem and is said to flow through the various energy levels, or trophic levels, of a food chain. A food chain consists of a series of organisms, one feeding upon the other. Because of the inefficiency in energy transfer and loss of energy at each transfer in the manner to be described below, food chains are usually short.

In the transfer of energy from green plants to herbivores that consume green plants, most of the energy stored by the plants is lost through dispersal as heat in the processes of digestion and metabolism or through elimination as undigested wastes. The energy actually stored in the tissues of a herbivore usually represents only a small percentage of the energy originally available in its food. Thus the hog, a relatively efficient energy converter, will supply in its tissues only about 20 per cent of the energy in the corn that the hog feeds upon. When carnivores feed upon herbivores there is still another loss of energy and most of the energy contained within the tissues of herbivores does not appear as energy stored within the body of the carnivore. Thus, in any ecosystem, the relative amount of energy available to a species that fed exclusively upon other carnivores would be quite small compared to that originally available in green plants.

The inefficiencies of energy transfer within an ecosystem are examples of a long-recognized physical law, the second law of thermodynamics, which states, in effect, that in any spontaneous transformation of energy some will inevitably be lost to the system, dispersed as unavailable heat energy. It is a law that humans have learned to live with. In over-populated areas, few can afford the luxury of energy transfer from green plants through herbivores. Plant foods

must be consumed directly by man to achieve the caloric intake needed to sustain life. Quality of diet, the luxury of feeding upon meat-animals or fish, must be sacrificed to caloric quantity. However, while caloric quantity may be adequate to sustain life for a short period, a sacrifice in food quality results in serious consequences to health, reproduction, vigour, growth and other metabolic processes. Protein hunger is far more widespread in the world than caloric hunger.

2. Man's changing rôle in the energy cycle

Before man or his ancestors had fire, his energy supply came almost entirely from the food that he could consume and fluctuated perhaps from 2,000 up to 3,000 or more calories per day depending on the availability of edible materials. Any excessive use of energy by the body, as in keeping warm in cool weather, or cool in hot weather, fighting or fleeing before foes, or escaping hostile forces in the environment, had to be compensated by increased food consumption. The environment of man was necessarily restricted to areas without extreme cold, with adequate shelter from excessive heat and particularly to those with a relatively abundant supply of accessible food and water.

The discovery of fire both increased man's basic level of energy consumption and extended his environmental range.

The next major step upward in the rate of energy utilization accompanied the industrial revolution, when fossil fuels were first harnessed on a large scale to do man's work. Use of nuclear energy (derived from the sun during the period of the earth's formation) is a recent development and still does not contribute greatly to total energy consumption. Thus food is only a small part of the energy consumed by an industrialized society, but it remains a basic, essential part for which no substitutes will be available. Its continued production

in quantities adequate for human needs remains a first priority in conservation planning.

The use of fossil fuels, hydro-electric and nuclear power to accomplish work has a sparing action upon biotic resources. Were it possible to run an industrial society on food-supplied energy and wood fuel alone, it is doubtful if the biotic resources of the earth would be adequate to meet today's energy needs. Substitution of machines driven by power from sources other than food or human muscle power decreases the demands placed upon our agricultural resources. Substitution of fossil fuels for wood makes possible today's programmes for forest conservation. It is ironic therefore that South West Asia, with a large share of the world's fossil-fuel resources, has placed some of the heaviest demands upon its limited supply of vegetation suitable for burning in campfires and cooking fires and today suffers the severe consequences of widespread deforestation.

Despite the massive consumption of energy in industrialized societies, all societies must meet the basic food energy requirements of man through dependence upon the annual storage of energy by green plants. The flow of energy through natural or modified food chains remains the process most vital to continued human occupancy of the earth.

3. Food for the world's growing population

For man, as for the larger animals, demographic changes are necessarily slow and to be measured by generations rather than in years. For many centuries the overall growth in world population must have been extremely slow and uneven as between different communities according to their mastery of their environments and the incidence of disease and disaster. In the two thousand years before the Seventeenth century the world population may have doubled. It doubled again in the next two hundred years, this demographic change reflecting mainly the new technologies of the now developed countries. Since then, largely through

advances in medicine and hygiene, a demographic transition has been even more pronounced in the developing world which includes the majority of the human population. At the present rate it may double within 40 years and the rate of increase is itself increasing. Any limitation of population growth will require yet another wholesale demographic change in succeeding generations.

Technology in the developing world has lagged behind advances in medicine and the majority of the race does not now enjoy a sufficient or sufficiently balanced diet. Other material needs are even more unequally met, as between the developing and the developed nations. A vast increase in productivity from land and water resources will be required to satisfy the reasonable needs of the present population and to provide for its inevitable growth.

There has in fact also been a continuing but uneven increase in agricultural production in developing countries, the production of food crops having risen by some 3 per cent per annum over the past decade. This is more or less in step with the growth of population but not with the growth in <u>per caput</u> income which measures the effective demand for a more satisfying diet. The unsatisfied demand, largely by urban populations and the uneven increase from year to year and from one country to another has led to substantial imports of cereals and other food products in place of former exports. The volume of these imports is rising at some 6 per cent per annum and is now of the order of 10 per cent of total consumption, including some 23 million tons of cereals a year in the period 1961-1963. The projected demand for food in the developing world will be from 50 to 60 per cent higher in 1975 than it is now and, since the foreseeable increase in local production within a decade is limited, food imports will at least be doubled. The short-fall can no doubt be met from the farm lands of the temperate zones but, with the limited purchasing power of the consumers, hardly on commercial terms.

The dilemma arises from the failure of developing countries to modernize their agriculture, in fact to appreciate the ecological necessities of their situation, as rapidly as they have attempted to develop their industries and improve the health of their peoples. The tendency has been to extend the limits of cultivation and reproduce, often in less suitable environments, the existing technology of production - a more serious encroachment on the biosphere than any threat arising from the introduction of well chosen methods of intensive agriculture.

The biological phenomenon of population growth is as much an element of the dynamic ecosystem as any of its "natural" biological elements. To feed, house, clothe and generally provide for the material needs of the future race is not beyond man's technical competence. The challenge lies in deploying technology in a manner which will not overtax natural resources or utterly destroy irreplaceable elements of the flora, fauna and habitat.

B. THE CYCLE OF WATER

1. The hydrologic cycle

Water flows through the biosphere along pathways that are described as hydrologic cycles. Solar energy acting upon the surfaces of the globe raises water vapour into the atmosphere and through differential warming of the atmosphere generates the major atmospheric movements that bring moisture-laden air to the earth's land surfaces. Falling as precipitation water enters into terrestrial ecosystems in many ways, determining local climates, regulating temperature in living organisms, entering all of the various metabolic processes of plants and animals, running off vegetation or ground surfaces to enter stream flow, or percolating through soil and rock to enter underground storage areas. At every stage in the process water may be lost once more to the atmosphere

through evaporation and must be replaced in the ecosystem by further precipitation.

Precipitation and temperature combine as the most important environmental factors that determine the kind of ecosystem that will develop in a given locality. Acting along with vegetation and animal life to modify the rocks of the earth's surface, they determine the kind of soil that will form, its physical structure and its fertility. The importance of water to man is obvious. It is regarded by some as the earth's most critical nature resource and one likely to be a factor limiting human population increase. The importance of understanding the hydrology of the earth has been emphasized by the institution of an International Hydrological Decade under the auspices of Unesco.

2. Water in the ecosystem

Water falling upon a paved surface will either run-off or evaporate. Water falling upon a vegetated area may follow many pathways. Some will be intercepted in vegetation and evaporate from the leaf canopy, some will evaporate from the soil surface. Under circumstances where the rate of precipitation exceeds the rate at which soil can take up water, some will run off. Water entering the soil may be held within it, occupying air spaces or held by various tight or loose bonds to the soil particles. Water may penetrate through the soil and enter underground channels through various openings in rock surfaces, or if the soil is built from highly porous materials such as sand or gravel may flow through these to lower levels, to emerge in some other place as seeps or springs, or to be held in underground artesian basins. Some water that is held temporarily in soil will move to the soil surface through capillary action, as water evaporates from the surface. Much of the water that is in the soil will be used by the vegetation, passing through roots and stems to be transpired into the air. Some will be held within the vegetation in chemical combination or to

maintain cell turgor. Water within plants may be consumed by animals and satisfy, in part or entirely, their normal water requirements. Similarly, water held in soil or on the surface in streams, ponds, springs, etc. may be consumed by animals.

3. Use of water

Where man wants to make direct use of water that falls upon the land he may seek to modify various aspects of the hydrologic cycle in order to obtain a higher water yield. Such modifications, however, usually involve losses of other values within an ecosystem. To obtain maximum yield of water from a watershed, losses through evaporation or transpiration need to be minimized; and a system by which water goes directly from precipitation into underground aquifers to emerge at the point of human use must be approached. Most naturally occurring watersheds, however, defy such simplification. If the source of transpiration, vegetation, is removed, the soil-holding qualities of vegetation are also removed. Frequently, the soil will then erode from slopes and choke streams and reservoirs and the soil that remains may become relatively impervious to water, forcing all water to flow over ground surfaces with consequent increases in evaporation. Thus, maintenance of vegetation cover and consequent soil structure and porosity is often necessary for the best practicable sustained yields of water. Disturbance of vegetation and creation of bare soil, or compacted soil will often lead to disturbances in the production of a sustained yield of water. Thus, the relative importance of water supply from an area can have a determining influence upon other uses made of the land. A high priority for water in areas susceptible to erosion can rule out any uses that disturb soil or vegetation.

Many examples can be found of watersheds that once produced a year-round stable flow of water and now are in a cycle of seasonal flashfloods followed

by long periods of aridity. Such conditions reflect persistent misuse of vegetation and soil within the area often resulting from fires or uncontrolled grazing.

The demands placed upon the watersheds of the earth by man are heavy and varied. Water is required, first of all, for drinking and must be present in both adequate quantity and in a quality that will not impair human health or vitality. Equal in importance, but many times larger in quantities required, is the use of water for the growing of food crops. Rated below these in importance are uses of water for cleaning purposes, industrial processes of all kinds; for the transport of wastes, for transportation of people or their possessions; for fire suppression, for recreation and so on. Some of these uses are consumptive. The water used in the production of crops for example cannot be re-used. Other uses are non-consumptive, transportation, hydroelectric power and recreational uses are examples. Others are intermediate, water used in drinking may be in part re-used, if wastes are removed from it after it passes through the body; water used in transporting industrial waste products may be re-used if purified, although some water will be consumed in many industrial processes.

The existence of useful water in an environment determines the presence or absence of human cultures. The pressure upon the world's freshwater resources calls for great care in the management of watersheds and the uses of water. Where human density is high water must be used and re-used for many purposes. Under proper care a single water source may supply most human wants and needs - providing multiple-purpose approaches are taken to its development and pollution is minimized.

4. Irrigation

In the dryer parts of the tropics and sub-tropics, agriculture without irrigation, if possible at all, gives only a scanty and uncertain yield and half or more than half of the land that has been converted from its natural state and

vegetation must be left fallow each year. Even in wetter areas the seasonal concentration of rainfall often limits production to a single and possibly precarious harvest. Except in the most favourable climates irrigation or supplementary irrigation may, therefore, be a prerequisite for the economic application of such agricultural improvements as the use of fertilizers, higher yielding varieties and crop rotations.

The simplification of the ecosystem characteristic of monocultures can be avoided where rainfall or irrigation and the temperature in the growing seasons allow a rotation of crops throughout the year. Major irrigation systems in the valleys of great rivers may transform an entire country; smaller systems create islands of productivity and add to the ecological and human stability of an otherwise harsh and over-exploited environment.

In comparison with the use of water in industrial processes the volume required for irrigation is immense in relation to the quantity of the end product. In an arid climate as much as 10,000 tons of water may be needed to maintain one hectare of land in cultivation throughout the year. Over and above the moisture required for transpiration there must be sufficient drainage to prevent the accumulation of salts in the soil and to maintain the water-table at a suitable depth.

Because so much water is needed to produce a crop and because water for the dry season must often be stored in dams or pumped from wells, the unit capital cost and annual charges must be modest and the water must be used to the best advantage. This considerably restricts the choice of areas suitable for irrigation development. Research is also urgently needed on the real water requirements and responses of crops, to make possible a carefully regulated supply and an optimal cropping pattern. In Western Asia, for example, fallows are usual even on irrigated land because the supply is largely uncontrolled and salts

accumulate in the soil through inadequate drainage. In India the water allocation for the same crop in similar environments shows astonishing and presumably arbitrary variations. Related to irrigation, flood control is another necessary modification of the agricultural environment; they may well go together in projects for multi-purpose river basin development.

In the light of future needs for food and other agricultural products a required, and feasible, increase of at least 50 per cent in areas under irrigation by 1985 may be estimated, together with a significant improvement in irrigation efficiency.

5. Inland fisheries

It is beyond the scope of this paper to discuss marine fisheries; inland fisheries, however, may contribute some 15 per cent of the world catch, or about 7 million tons, without taking into account the considerable volume of subsistence and sport fishing throughout the world. Their relative contribution to the human diet is even greater for much of the marine catch is diverted to other uses. The world-wide distribution of inland fisheries makes them the sole source of fish and a major source of protein in many developing countries.

Inland fisheries are seldom incompatible with other uses of the water and involve no significant consumption of the water itself; as a stabilizing element in the ecosystem the fish improve its quality. Nor does the establishment of a fishery usually involve any modification of the physical environment. Some uses of the water may, however, be inimical to the fish, as with the effects of industrial pollution. River basin development and land drainage may interfere with the migratory phase of the life cycle and introduce fundamental changes in the environment to which the fish are exposed. On the other hand inland fisheries are often improved or even brought into existence by man-made structures such as dams and river control works.

Natural and man-made areas of fresh water, rivers, canals, lakes and swamps, may cover a total area of 500 million hectares. In addition there are vast areas of coastal lagoons and brackish swamps and estuaries equally capable of supporting a fishery. Only locally are these resources fully used, with improvement in boats and gear and better accessibility a much higher production is certainly possible without modification to the environment or the ecosystem. More intensive systems of management, involving restocking with preferred species, the elimination of predators and the use of fertilizers, are generally only applicable to limited areas and are unlikely to affect the ecology of major water bodies. The most intensive systems are fish cultures, in artificial basins or enclosures in open water. Yields of several tons per hectare per annum are often obtained in South East Asia and elsewhere and fish culture might be more widely developed to improve human diets where meat is scarce and there is little surplus potential for livestock.

C. NUTRIENT CYCLES AND NUTRITIONAL NEEDS

Finally, the ecosystem possesses a nutrition cycle, linked to the energy and water cycles. If life is to continue on earth, there must be constant exchange and continuous return of nutrients, with wastage kept to a minimum. The sources of nutrition are soil, atmosphere and water. The return of nutrients to the soil is dependent on agricultural methods. Knowledge of the soil, of its management and of its behaviour is thus of capital importance. If this cycle is to remain stable, rational exploitation must ensure a balance between extraction and return of nutrients. This is the problem of scientifically grounded fertilization.

1. Sources of nutrients

Nutrients important to life are derived from the rocks of the earth's crust, from the atmosphere, or from water. Among these elements, nitrogen has

a main importance. A great variety of other chemical elements must be present in the soil for plant growth to occur. It is not enough, however, for them to be present, they must be present in available form, which usually means either dissolved in water in the soil solution, or loosely attached to clay or humus particles within the soil. A porous, friable soil structure in which air and water can circulate, but containing sufficient clay or humus to provide a steady supply of chemical nutrients is most favourable to plant growth. Agricultural practices which either break down soil structure, or lead to excessive drains on soil fertility disrupt the nutrient cycles essential to proper functioning of the ecosystem.

2. Soil nutrient supplies

In some ecosystems, such as prairie grasslands, the rate of turnover of nutrients from soil to plant and back to soil through the action of decay organisms is rapid. These soils themselves are developed under low-rainfall processes and often contain a relative surplus of nutrients over and above the annual needs for plant growth. Lack of moisture, rather than lack of nutrients, provides an annual limitation to the growth of these grasslands. Such soils, when cleared of grass and seeded to cereal grains will remain productive for decades even without addition of fertilizer providing reasonable care is given to maintenance of the soil structure.

In other ecosystems, however, the soil-forming processes are such that many nutrients are in relatively short supply. Tropical forest soils developed under high rainfall régimes, are often heavily leached and oxidized. They contain an excess of iron and aluminium salts but a deficiency of other elements. Most of the nutrients are tied up within the living matter of the ecosystem, the plant and animal life. As soon as these nutrients are released, through death and decay, they are picked up again by plants and returned to the system. If

vegetation is cleared and burned, nutrients once contained within it are released in quantity to the soil, but since the soil lacks absorbing clay particles to hold nutrients near the soil surface they are quickly leached away by rainfall. The parent soil, because of leaching and oxidation is in itself relatively sterile and consequently unable to sustain an extractive form of agricultural use for long. Relatively high production may follow the initial clearing, but it cannot be long sustained. The soils respond poorly to fertilizer since they lack the structural compounds that will hold and make available to crop plants the elements supplied.

Permanent agriculture, in such tropical soils, where it can be achieved at all, needs to duplicate as closely as possible the soil forming and soil-holding action of the native vegetation. A garden-type agriculture that utilizes trees, shrubs and root crops, provides permanent cover for the soil and returns nutrients to it, and reaches through a variety of root systems into many soil layers, seems best suited to permanent production, particularly where manuring and mulching provide for a return of nutrients and humus. At best, however, these humid tropical soils are generally deficient in nitrates and produce crops high in calories but low in protein. Under agricultural systems that leave the soil bare to the action of sunlight and rain, such soils can undergo laterization - develop an almost indestructible iron-aluminium laterite layer - and become almost useless for further production of any kind.

3. Soil surveys and soil management

Although the soil and its properties are basic to all agriculture, millions of farmers throughout the world now work soils that have never been examined scientifically. With a far reaching agricultural revolution now so necessary for man's survival the execution and interpretation of soil surveys is a prime necessity. Even long established and stable systems of primitive agriculture have

their stability threatened by the need to take up more land and grow more food. Meanwhile the gap between potential sustained production from the soil and current production continues to widen as new agricultural methods are devised; well managed and adequately fertilized soils are intrinsically more productive than the soils of the original natural environment.

High crop yields, if they are to be maintained, require the application of fertilizers but their use is only economically effective if they are the right kind for that soil and the right farming practices are adopted at the same time and if the crops grown are suited to the soil and the environment. Advances realized elsewhere can only be transferred to new sites when the soil properties have been determined. Soil surveys on small scales for large areas are needed in planning the strategy of development and on larger scales for operational planning on selected sites. The Soil Map of the World at a scale of 1:5,000,000, jointly promoted by FAO and Unesco, aims at pooling the knowledge of the world's soil scientists to produce this strategic map; not the least of the technical problems involved in its preparation are the correlation of analogous soil types in widely separated regions and the interpretation of their agricultural affinities.

4. Steady states and human use

Under natural conditions a relative steady state develops in ecosystems. Energy flows through the system in one-way paths, but is utilized to perform the work essential to life at every level along a food chain. Water flows through in cyclical paths from atmosphere to land to water bodies and back to atmosphere. Nutrients flow from soil to plants to animals and back to soil and the relatively slow rate of loss from geological erosion is balanced by the rate at which new nutrients enter from rock decomposition, bacterial production, or by atmospheric additions to the system.

When primitive peoples, including those living permanently at a village agricultural level, enter such a natural ecosystem they may create little change or disruption. Part of the energy, water and nutrients is channelled through man rather than through another species of animal, but the process of turnover continues as people die and their remains enter the soil.

As higher, more mobile, cultures engaging in trade or supporting urban centres enter the ecosystem, however, a different, extractive pattern emerges. Nutrients are removed and not returned to the soil that yielded them originally. The steady-state condition is disrupted and fertility can become exhausted. The process is accelerated if widespread destruction of natural vegetation, accelerated soil erosion, or laterization enters the picture. An ecosystem can go, as some have gone, from a high level of productivity to one near zero. Examples of such change may be readily observed in Mexico in the hills north of the Valley of Mexico where lands described by Alexander von Humboldt as beautiful pin-oak forests are now barren hardpan, or in the Valley of Oaxaco where red, gullied badlands have replaced the productive scene described by Cortes.

Rational use demands a balance between extraction and return. Fertilizers and organic materials must be returned to the soil to balance those removed by crops or shipped out in the form of domestic livestock. Efforts must be made to duplicate or improve upon the soil-forming and soil-maintaining function of the natural vegetation to keep channels of nutrient flow and water movement open. Cover, either natural or artificial must be provided to check direct soil loss through erosion. Particularly unstable sites must be kept under natural vegetation to maintain the hydrologic cycle within the region. If these things are done, as they have been successfully in some areas of the world, ecosystems can be used to produce commodities useful to man on a permanent basis.

5. Nutritional needs

This report has emphasized earlier that a central world problem is food, and considerable effort is being expended to increase world food supplies. It is essential to bear in mind, however, that man's nutritional needs are not simple and even a large increase in a few kinds of food crops may not satisfy them.

a. Caloric needs

Nutritional needs are of two categories. First is the relatively simple problem of meeting caloric needs, of providing food energy at a level of 2,000 or more calories per day, to keep body metabolism functioning and maintain life. Such needs can be met by food supplies of a carbohydrate nature which can be produced under a wide range of ecological conditions. Root crops such as the taro and yams of tropical regions as well as the cereal grains can supply this necessary energy. Nevertheless, food supplies measured only in sheer quantity of caloric usefulness, remain inadequate in many parts of the world and a report on the FAO Indicative World Plan for Agricultural Development states that approximately half the world's people are underfed, ill-fed or both.

b. Nutritional quality

Beyond the simple quantitative food needs, the nutritional requirements of man include proteins, some fatty acids, minerals and vitamins. Foods that can supply energy may not have sufficient nutritional quality to maintain growth, health or strength. Protein-deficiency disorders, resulting in illness and decreased vitality have long been widespread in most tropical areas. Meat, milk, eggs, fish, or high-protein vegetable crops are required to meet human requirements for protein. These are most difficult to produce in quantity on leached and minerally unbalanced tropical soils. Beyond caloric and protein needs, the provision of adequate supplies of the wide range of minerals and vitamins that

man requires in greater and lesser amounts demand soils that are themselves minerally rich, or that can retain and supply chemicals provided by fertilizers. The areas of greatest human food deficiencies are often those tropical areas most poorly adapted, ecologically, to provide high quality human foods, because of soil deficiencies and are also the areas in which high rates of population increase seem to defy efforts to improve food supplies.

Over and beyond nutritional requirements, there is a further psychological need for foods that meet the tastes and demands of various human cultures. The body can be kept alive and physically functioning on a diet that soon, if not immediately, becomes tasteless and unattractive. People have, and hopefully will be able to retain, food preferences that lead to demands for diets that are varied, interesting and appealing. Meeting such demands seems at times almost an idle hope in areas where too many people crowd into too little food-producing land and all efforts are being bent toward providing a bare minimum of food to eat. It is, however, a goal of conservation, as an important factor contributing to the "quality" of living.

D. STANDING CROP AND PRODUCTIVITY

1. Standing crop biomass

At any point of time, any ecosystem will contain a total quantity of living material that is referred to as the standing crop and usually measured in terms of weight or "biomass". The total standing crop will vary from one ecosystem to another depending upon past conditions for growth in each ecosystem and the longevity of the organisms that live within it. Generally speaking, a forest made up of a dense stand or long-lived trees will have a higher standing crop of plant biomass than will a grassland made up of relatively short-lived herbaceous plants.

a. Variations in biomass

Gradients in the standing crop of vegetation will be found to correspond with gradients in temperature or rainfall. There will be a lower standing crop in the cold, dry arctic tundra than in warmer and wetter biomes. There will be a lower standing crop in an arid temperate zone desert than in a humid temperate zone area. The complexity and variety of vegetation tends to vary along the same gradients as the standing crop, with greater complexity and more species in warm, humid areas than in either cold or dry areas. There are some possible exceptions, however. The most complex vegetation, with the greatest number of species is to be found in humid tropical regions. It may be, however, that the highest standing crop biomass will be found in relatively less complex, but long-lived, humid temperate zone forests where individual trees reach great size. We know as yet of no comparative measurements of the weight per acre of vegetation in a redwood or douglas-fir forest in the cool, temperate region compared with that of a humid tropical rain forest.

b. Biomass and agricultural production

Considerable confusion results from equating a high standing crop with a high potential for good quality agricultural production. Humid temperate zone ecosystems with well-developed soils have a high potential for carbohydrate production. The standing crop, of trees, shrubs and other woody plants will constitute a great bulk of carbohydrate material but a relatively low percentage of protein and of many elements essential for animal life. The much lower standing crop in a semi-arid grassland will have relatively much less carbohydrate and far more protein per unit of area, along with a greater variety of essential minerals. Those biochemical relationships are reflected in animal biomass. Humid tropical forests in Africa support a great number of animal species, but the total biomass of animal life per unit of area is reported to be relatively low.

By comparison the drier tropical savannas will support fewer species of animals but a much higher animal biomass per unit of area. Similarly the maximum standing crop biomass of wild animals in North America was to be found in the dry plains grasslands. The humid forests, with more species of animals, had a relatively low animal biomass.

2. Productivity

From the viewpoint of human use, standing crops are of less significance than productivity, the rate at which new organic material is added to an ecosystem. There is no necessary correlation between high standing crop biomass of vegetation and high plant productivity. A heavily cropped pasture may have a low standing crop but a much higher rate of productivity than an ungrazed pasture with a much higher biomass. A mature forest will be less productive than a stand of fast-growing young trees of a much lesser biomass. Productivity usually varies with the rate at which organisms are consumed, are harvested, or die. Two categories of productivity are recognized, primary productivity, which is the rate at which photosynthetic or chemosynthetic organisms produce new organic material and secondary productivity, which is the rate at which consumer organisms, mostly animal, convert plant materials into animal tissues.

a. Variations in productivity

Productivity varies with the limiting factors in the environment. In the Arctic, cold and lack of moisture limit plant growth during much of the year. During a brief growing period, productivity may be high; but the annual mean productivity is low and comparable to that of deserts. In deserts, water is limiting and in places a toxic excess of salt and alkali exists, so that overall productivity is low throughout the year, although it may be high for a brief period following rain. Where water can be supplied and where soils can supply a good balance of nutrients, productivity can be expected to reach high levels in

desert regions. Productivity of deep, open ocean waters, away from islands and continental shelfs, is at a low, desert-like level. In shallow tropical waters it may reach unusually high levels.

It is believed that the highest annual productivity is to be found in tropical rain forests, where all climatic factors tend to favour plant growth, moisture is abundant and only nutrients are in relatively short supply. The complex biota of the rain forest, however, appear to circulate available nutrients rapidly through highly complex food chains and thus sustain a high productivity. As noted earlier, when the forest biota is removed and the soil is laid bare, productivity rapidly declines. In temperate regions a gradient in primary productivity occurs from deserts through grasslands to humid forests and probably reaches a maximum in moist, relatively warm regions, marshes, estuaries and such.

The gradient in secondary productivity, however, does not appear to follow that of primary, at least among the larger animals, although a different picture would be found if all smaller animals, decay organisms and soil organisms were taken into consideration. These do not contribute much to total biomass, since they have short life spans and high turnover rates; they do, however, contribute to productivity. For animal life, harvestable by man, however, secondary productivity appears to reach a maximum in open woodlands and savannas rather than in moist forests or arid deserts.

b. Productivity and complexity

Secondary productivity appears to increase with the number of species of organisms available to feed upon the vegetation. Each species is adapted to occupy a particular ecological niche. This is its place in the environment, determined by what it feeds upon and what feeds upon it, by the habitat it occupies and its environmental needs. In complex vegetation, where the number of species of plants is high and the size, shape and other characteristics of plants highly

variable, a great number of niches for animals can exist. If these are filled there will be a greater turnover of energy from plants to animals and a higher secondary productivity than where some niches are left open or only partially occupied. The success of native herbivores in the woodlands and savannas of Africa, in achieving high rates of secondary productivity and meat production, relative to that of one or two species of domestic herbivore, is related directly to the greater number of niches that these can occupy and the much greater variety of species of plants and parts of plants on which they are adapted to feed.

It is important to recognize the relative importance of biotic factors in controlling productivity in the humid tropics relative to temperate, arid or cold regions. The number of species in the tropics is enormous, with each making use of the environment in a different way. The greatest percentage of plants are insect pollinated and often each will depend on a different species of insect for its pollination, reproduction and ultimate contribution to productivity. Turnover of nutrients from vegetation to soil depends upon the existence of a great variety of consumer organisms from birds and mammals, through insects to soil micro-organisms. To a large degree the community creates its own physical and biotic environment, the vegetation sheltering the soil from direct sunlight or impact of rain, changing temperature and humidity conditions from canopy to ground level, altering rates of air movement and so on. Destruction of the community destroys the environment and completely disrupts the complex networks needed to maintain nutrient flow and energy flow. It is little wonder, therefore, that such ecosystems in the humid tropics break down quickly when an effort is made to convert them to simple agricultural systems.

E. STABILITY AND ADAPTABILITY IN ECOSYSTEMS

1. Complexity and stability

Gradients in complexity and in productivity appear to be matched by gradients in community stability. Arctic and desert regions not only have fewer species and a lower average productivity, but also have wide fluctuations, normally, in the relative abundance of species and their productivity rates. In some years Arctic regions may appear to be virtually devoid of animal life, in other years the tundras teem with animals. In deserts, rainfall is not only low on the average, but highly variable. Following a high rainfall year plant production may be great, but the excess will disappear as dry years follow. Plague years of rabbits or locusts, of mice or game birds, serve to compare great abundance with the normal relative scarcity.

In the humid tropics, where biotic controls replace climatic controls, such instability is virtually unknown. A slight increase in a given prey species will be removed by the efforts of any number of preaators adapted to feed upon it. A decrease in abundance in one predator will have a gap filled immediately by other predators and prey will be kept under control. The diversity in species in plants prevents an increase in the level of insects, diseases, or parasites specializing on one species of plant. By contrast the single species stands of trees in the boreal forests of the sub-arctic encourage increases of insect or disease pests to proportions where they can wipe out large areas of forest.

2. Simplification and its consequence

Man has succeeded in his agricultural systems through simplifications of naturally existing systems. A natural grassland will have a great number of species of plants and a relatively high productivity. Most of the energy and nutrients, however, will be unavailable to man. The same area, cleared of grass

and planted to a single species of cereal grain, could have a lower total productivity, but the energy and nutrients will be harvestable by and useful to man. Unfortunately such simplification encourages the kind of instability characteristic of naturally simple ecosystems. Pest organisms, adapted to the cereal grain species, can increase to plague proportions. Unless some method of control is devised or resistant strains of the grain are developed, the crop will be lost.

Recently man has turned increasingly to various pesticide chemicals to provide this control. Such chemicals, however, can serve to further simplify the system by not only reducing the pest organism, but also its natural enemies. With the natural enemies removed the pest species are often able to recover from the effect of pesticides more quickly and return to plague proportions more rapidly than previously. Further applications of pesticides can result in further simplification. Meanwhile, genetics will have operated to favour pest organisms most resistant to the pesticide. Finally, an unstable system consisting of crop plant and its chief enemy can result, and new pesticides must be sought, each capable of bringing new problems.

Such an ecological upset can be disturbing in temperate regions, but it is there alleviated by climatic controls which operate to prevent pest increases in some years. In the humid tropics, where biological controls predominate, the indiscriminate use of pesticides can, and probably will in many places, have disastrous consequences. In the tropics, also the practice of monoculture is most likely to be permanently in trouble, since it diverges most greatly from natural systems and encourages the emergence of new pests from the ever present, always abundant list of species of potential pests, diseases and parasites. The destruction of Costa Rica's banana plantations along the Caribbean coast by the Panama disease is an example of what can occur when a new disease strikes a vulnerable monoculture.

3. Adaptability in ecosystems

a. Recovery from disturbance

The ability of an ecosystem to tolerate human use and to recuperate from human abuse varies greatly with climate and biological factors. The recovery of communities from fire serves to illustrate this. In humid regions, for example, naturally occurring fires are rare. In unusual dry years, fires may burn and produce disastrous immediate results, since the volume of fuel will be large. Such results, however, are seldom long-lasting. Following normal pathways of succession, forests will grow back. In extremely arid regions naturally occurring fires are non-existent, since the fuel to carry them cannot be produced. In sub-humid and semi-arid regions, fires are most frequent since both fuel and dry conditions are present. Vegetation recovers from fire most quickly in the areas with the higher rainfall, deeper soils and greater variety of species. In semi-arid regions recovery may be slow and at times may not occur at all. Forests growing near the climatic limits of their range can be eliminated by fire as has occurred in California's pine forest growing on the eastern slopes of the Sierra Nevada. Similarly in the colder regions of the earth, the effects of fire are long-lasting. Tundra fires in Alaska and Canada destroy the lichen vegetation and recovery of this normal climax growth takes many decades, if it occurs at all.

b. Biological versus climatic controls

It would appear that the system most tolerant to disturbance would be found in the humid tropics. This appears true, however, only when the disturbance is relatively minor and the normal biological networks are not too widely disrupted. Interspecific dependence is too great for major disturbance to be tolerated. Major disturbances can so completely disrupt the interwoven web of plant and animal

food chains, that complete recovery of tropical climax forests can be an extremely slow process.

Tolerance to disturbance seems to be greatest in those areas where climatic and biotic factors operate in more nearly equal proportion, the humid and subhumid forests and grasslands of the temperate zone. Here grasslands hold up best and recover most quickly from grazing pressure; forests recover from fire or clearing in relatively short periods of time. Agricultural soils, with reasonable care for structure and fertility, hold up under centuries of crop production. Where climatic controls become more operative, toward the Arctic or the desert, durability of ecosystems under human use decreases. Where biotic controls become more complete, in the humid tropics, the durability of ecosystems under human use decreases also. It would appear that the world centres of civilization and population of past centuries coincided most closely with the durability of ecosystems. More recent increases in population in other more fragile areas, brought about by the import of medical technology and economic surpluses from more durable areas, may be only a temporary phenomenon. They perhaps cannot be permanently sustained except as they are supplied by the more durable ecosystems. With our present knowledge, at least, there is scant hope for converting the still uninhabited portions of the earth into areas capable of supporting high densities of population. The exception may be those desert areas where the sole limiting factor is water. If water can be made available the climatic controls over productivity would be overcome.

c. <u>Points of no return</u>

Any ecosystem, even the least fragile, can be pushed to a point of no return. At this point, limiting factors become so severely operative that recovery in periods acceptable in a human time scale becomes impossible. Soil erosion on mountainsides can go on to a point where bedrock is exposed. At this point, only

the slow processes of primary succession, operating over centuries or millenia can once more build back soil and vegetation. Such depletion has occurred in the Valley of Mexico and on mountain slopes in Greece, Spain and Italy. Laterization of tropical soils can only be arrested, economically, at certain stages. Once a tough layer of laterite develops, recovery is no longer possible. Communities can repair themselves, with moderate protection, up to a certain point. Beyond that level of abuse or disturbance, biological repair becomes, in human terms, an intolerably slow process. It is an important aim of rational use of environments to prevent areas from reaching these points of no return.

d. Adaptability of animal populations

Animal populations have a potential of productivity known as their biotic potential. This establishes an absolute maximum level above which they cannot be cropped without depletion. Rational management of wildlife or domestic stock keeps cropping levels at or below the biotic potential of the species, thus guaranteeing a sustained yield. It is irrational to crop a species that we wish to preserve at a level above that which it can sustain. It is equally irrational to fail to crop a species that has become too abundant, or has exceeded the carrying capacity of its habitat. Exceptions exist only where other natural processes will remove without disturbance the surplus that we do not choose to harvest. Thus serious problems have developed in some national parks such as Yellowstone in North America or Tsavo in Kenya where wild herbivores were allowed to increase above the level that their habitat could support and where predators, adequate in number to control the numbers of herbivores, did not occur or had been destroyed.

4. Commodity production in the environment

From the point of view of human use, the standing crop is generally itself introduced by man; necessarily so in field agriculture, less so in animal husbandry although the livestock will have been introduced and still less so in

forestry. Food gathering from the natural biome as a way of life is virtually obsolete. The impacts of forestry, animal husbandry and agriculture on the natural environment call for some separate consideration.

a. Forestry

It has been estimated that some four thousand million hectares of the earth's surface remain under forest. Of this area some 40 per cent is considered inaccessible for development although it may not be immune from deterioration at the hand of man. A further 24 per cent is not effectively exploited although accessible. Only about 13 per cent, some 550 million hectares, is under some form of forest management though not always rationally used. Like food, the consumption of forest products, timber, pulp, fuel and a host of minor commodities, is closely related to the gross national product of the economy and to the growth of population. Future needs can therefore be projected and long-term projections are particularly necessary because of the slow maturation and regeneration of forests in comparison with other crops.

Some degree of balance between forestry and other uses of the environment has been established in most developed countries although the hazards arising from an industrial civilization remain; in developing countries the equilibrium is increasingly precarious and it is upon tropical forests that the increased demand will largely fall, both for forest products and for agricultural land. As has been said, heterogeneity of species is a character of the tropical forest and few of them in any given area are of commercial value. It may therefore be more economic and less exhaustive of the natural resource to establish forest plantations, often of exotic or fast growing species, than to work over larger areas that can only be partially utilized. In East Africa it has been found that while exotic plantations may provide an annual increment of more than 20 cubic metres

per hectare, the useful increment in a natural forest may be only 3 or 4 cubic metres.

The most stable forestry system would combine the sustained yield from well managed natural forest stands, possibly with a considerable measure of sylvicultural adaptation, afforestation for watershed conservation, forest plantations and shelter belts on agricultural land. The strategic siting of forest industries is itself an element in conservative management and may provide a good nucleus for human settlement in new areas. It is important that forest policy should be based on a careful inventory and a just appreciation of the total ecology. This will allow minimal interference with the natural habitat or the way of life of indigenous peoples, even where it depends on traditional systems of shifting cultivation and forest grazing.

b. Animal husbandry

While in the equatorial rain forest there are usually too few domestic animals to provide a balanced diet for man, elsewhere livestock numbers may be so high as to overtax the grassland on which they subsist. The frequent specialization of primitive agriculture on the production of cereals as a stable food means that little fertile land remains for pasture and the livestock best cared for are the work animals. Poorly nourished flocks and herds yield little and are prone to disease. The conservation of the resource, while augmenting the deficient protein fraction in human diets, calls for better management both of pasture and livestock.

A first step, towards which considerable progress has already been made, is the control and eradication of disease, but it must be accompanied by a corresponding control of livestock numbers by providing incentives and facilities for disposing of surplus stock at maturity or for fattening off the range. Natural pastures generally exhibit marked seasonal drought and scarcity of feed

which can in some measure be countered by providing water points, conserving hay or silage and supplemental feed from crops grown on agricultural land. In climates where grain thrives better than grass the feeding of coarse grains may be economic if the livestock industry is sufficiently organized. The objective will be to avoid undulating levels of nutrition in the life cycle of the animal.

The improvement of natural or deteriorated pasture will seldom be possible until grazing and stock numbers can be controlled; then it may be economic to apply fertilizers where moisture is not deficient, reseed with local or exotic species and correct deficiencies in trace elements. The value of the improvement is to be measured in the variety and stability of the new ecosystem established, in relation to climate, floral composition and the grazing habits of the stock.

Since the first priority in land use in developing countries must usually be assigned to food crops, the integration of agriculture and animal husbandry in patterns of mixed farming is of the greatest importance and should enhance the productivity of both sectors; by providing fodder and crop residues for feed and enhancing the fertility of the soil. With higher agricultural yields marginal land can be reverted to range to the benefit of the entire environment. In arid lands where no agriculture is possible without irrigation pastoral nomadism will continue to be the best human use of the resource; its productivity can be increased and established by making fodder reserves and water points accessible to the nomads and by providing a ready market for their produce.

Advances in animal husbandry in the developing world call for further research in tropical ecology, the physiology of both the pasture and the animals themselves and the breeding of well adapted species of both. The possible development of new species of domestic animals from species that are now wild also needs further consideration.

c. Agricultural crops

In bringing land under cultivation man necessarily disrupts completely the pre-existing ecosystem and substitutes another that is generally more simple and generally established anew with each succeeding crop. For continued occupation the farming pattern must nevertheless be stable and sufficiently productive to supply his needs. Indeed, for labour to be available for other employments each farm family must support many other workers; the fraction of the population engaged in agriculture is an effective measure of the sophistication and diversity of the community.

Farm crops are all genetic modifications of naturally occurring species; the higher yield, resistance to pests and disease, or adaptation to particular environments of newly developed varieties are the result of further genetic experimentation. The high productivity of modern agriculture in developed countries depends on their introduction and the maintenance of the more exacting soil, moisture, or phytosanitary conditions that such varieties require. Over large areas a single crop may be dominant, as in the temperate corn and wheat lands and in much of the developing world. Higher and more stable levels of productivity are, however, associated with a diversity of crops grown in rotation, including grass and feed for farm animals. In biotic status this may approximate more nearly to the original ecosystem, but nevertheless it is a profound modification requiring large inputs of labour and soil nutrients and furnishing an output of food and other products that is withdrawn from the system to support a larger human community.

A diverse crop pattern involves a carefully timed series of operations on the land which are often beyond the capacity of hand or animal labour and primitive tools, farm power and farm equipment must be adapted to the task.

Some such intensification of agriculture is required to support the growing populations of developing countries and set free labour for other occupations. New man-made ecosystems must be devised for unfamiliar environments and farmers taught to follow new ways. Nor can they put the new methods into practice unless all the required inputs are available to them and they have the economic support and incentives to grow and market larger harvests than are required in subsistence agriculture. Former relationships between the community and the land, expressed in a traditional agrarian structure, can hardly survive unchanged. Their perpetuation under new patterns of production is likely to enrich the few and reduce the farming population to a more servile status without either the incentive or the freedom of action to adopt the required combination of a whole range of new methods and make the best conservative use of the land.

V. THE CONSERVATION OF IRREPLACEABLE LIVING RESOURCES

A. THE LIVING TREASURES OF NATIONS

Whether they be recognized or not, each nation has within its boundaries irreplaceable treasures represented by living species of plants and animals, by natural environments and by areas of unusual scenic value. The protection of these treasures is a duty of each government, that they may be kept available to future generations of people within the nation and the world. Their values are both immense and in part immeasurable. Some of them are described below:

1. Scientific values

a. Potential practical values

Nobody would question today that the wild species of grass from which the domesticated wheat was derived was a species of high value to mankind. It was not possible, however, to describe the value of this species until we had learned to use it. In the 1930's few would have suspected that the bread mould, Penicillium, was of high value. The moth, Cactoblastis, was of negligible interest until it proved capable of controlling the prickly pear pest of Australia. Studies of the eggs of the sea urchin led to new understandings of animal development. We cannot say what innate value a particular wild plant or animal may have. We can say, however, that this potential value may be so great, that we should not carelessly allow a species to become extinct. Some extinctions will be inevitable as part of an evolutionary process despite our best efforts, but these must be deplored. We could benefit greatly from having available for study living specimens of all species that have existed in the past. This benefit is

denied to science. There is, however, no need to permit extinctions to occur needlessly.

b. Value of intact communities

It is easy to catalogue most of the species of birds, mammals and other vertebrates and list the habitats in which they occur. For many of these we can keep a close watch on individual populations and recommend measures needed for their welfare. This is not true, however, of the greater number of species of plants and invertebrate animals. For these smaller, or less well-known organisms, we can offer little in the way of direct care, management, or protection. To preserve them we must preserve the natural communities, of which they are a part, representative samples of all the various naturally occurring ecosystems on earth. By providing protection for the community as a whole, we offer the best safeguard for the species that compose it. Even this will not preserve all species, but it is the best that we can do.

c. Genetic reservoirs

Each nation has a share of the world reservoir of genetic material. Each owes it to its people and to the world to do what it can to protect this material. Each species is irreplaceable. It cannot be created anew by man. Each may contain an organic substance, a genetic combination, or provide an insight of knowledge that could some day be essential for human survival. The importance of saving wild species, of preserving natural communities, reservoirs of genetic material for unknown theoretical or practical purposes in the future can be considered as the "insurance policy" reason for conservation. It is a safeguard against future calamity and an investment in future human welfare. Since our knowledge of the functioning of our own agricultural systems is still limited, and our understanding of our present interdependence upon other species in

the biosphere is fragmentary, we may, through protecting wild species and communities, also be safeguarding against present calamities.

d. Understanding ecological processes

The understanding of ecological processes is very often obtained by studying the causes of amelioration or degradation of the environment. But natural communities have also, however, an immediate practical value through the contributions they can make to the understanding of natural processes. The various land-use systems that we devise in an effort to produce the commodities we need, succeed or fail to the degree that they can adjust to natural processes in the ecosystem. A study of those factors that govern stability or productivity in natural systems produces information that can be used to govern stability or productivity in systems modified by man. An example is offered by the studies carried out in Eastern and Southern Africa on wild mammals which have revealed greater stability and more meat production from natural biological communities than can be obtained if domestic animals are substituted for the existing mixture of wild species.

e. Behavioural studies

There are many experiments that can be carried out and studies that can be made on wild animal populations that are impossible with the human species. Behavioural studies under different levels of crowding and social organization are examples. From these it is possible to determine responses and effects that may be looked for in human populations exposed to similar conditions. Comparative studies of mammalian behaviour, particularly among the primates, are yielding significant information that is useful to studies of human behaviour. Many forms of behaviour, once thought to be socially conditioned among men, are found to be prevalent among related mammalian species.

From the viewpoint of scientific value alone, both theoretical and applied, adequate justification can be found for major efforts directed toward the preservation of wild animal species and the communities that support them.

2. Aesthetic values

a. Beauty versus ugliness

Although ideals may differ between cultures, most people would prefer to live in an environment that is aesthetically pleasing, rather than one that is ugly. Some can find adequate satisfaction from attractively designed man-made environments devoid of the more obvious forms of non-human life. Others, and perhaps the majority, want green plants and living things to give added variety and aesthetic appeal to an environment. Many require some combination of wild and tamed nature, and some find most pleasing landscapes from which man is entirely absent. To provide aesthetically satisfactory environments for all therefore requires planning for diversity including maintenance of natural scenery and the organisms that compose it.

b. Psychological needs

It is difficult to postulate the degree to which man's psychology requires some contact with wild nature and natural landscapes. Man has only recently begun to separate himself from a rural environment in which he was surrounded by other living creatures, wild or domesticated. It is not possible to know how well he will survive physically and psychologically without more contact with open spaces and natural things than many of our present cities can provide. It is obvious that some feel a strong psychological need for such contact. The future may show that full realization of an individual's psychological potentials depends on such contact. To satisfy the needs of those who require wild country would be adequate reason for preserving an adequate amount of natural, open space.

c. Recreational needs

Apart from psychological needs, there is an obvious desire among many, if not all, urban peoples, to seek open space for outdoor recreation. All of those countries that provide national parks or other outdoor recreation space and have transportation facilities by which people can reach them find these areas crowded by city dwellers who seek the open space and natural scenery. The desire for outdoor recreation is almost universal among people who have risen above a subsistence level of existence. The space, however, is most easily provided before the need for it has become acute. Were there no other reason to preserve natural areas, this would be sufficient.

d. Cultural records

All peoples, save the most primitive, have passed through stages of cultural evolution leading to gradually increasing separation from natural environments. An understanding and appreciation of a nation's cultural past, however, can be increased if the environments that supported the earlier cultural activities have been preserved. A city dweller who has not seen a farm or a domestic animal can hardly be expected to understand the rural history of his people or his own dependence upon the land. A person who has not experienced wild country and animal life can hardly fathom the difficulties through which pioneers have lived and fashioned the more advanced culture to which he belongs. Thus, if only to provide an understanding of man's long history and an appreciation of cultural evolution, it would be worthwhile to save some of the landscapes in which it took place. Particular settings of a wild or rural nature often have unusual value to a culture: the mountain on which a saint once lived, the tree under which a treaty was signed, or a battlefield where a nation's fate was decided. Such religious or historical monuments provide specific backgrounds for appreciation of a nation's history. The preservation of archaeological sites

such as Macchu Pichu in Peru or Angkor in Cambodia is recognized as worthwhile. It is also desirable to preserve the natural setting for such cities or monuments.

3. Ethical values

To some people all life is sacred and must not be destroyed by man. To others there is an ethical imperative governing man's relations with nature. These have been factors leading to the past preservation of wild species and places and to some are adequate justification for future preservation.

a. Eastern religions

To the followers of certain Hindu religions life is sacred. This belief may be carried to the point of complete vegetarianism and the avoidance of killing any form of animal life. The troublesome "sacred cows" of India are a result of the particular reverence extended to this animal. On the positive side, many wild animals that might elsewhere have become extinct have been preserved. The belief in the sacredness of life becomes even more rigidly adhered to in many forms of Buddhism and had its effects upon the preservation of species in many of the nations of eastern and south eastern Asia. Unfortunately, the protection offered to animals seldom extends to their habitat. Since the two are interdependent, the widespread destruction of habitat has led to the serious depletion of animal species. Exceptions may be noted, however, in sites protected for religious reasons, temple gardens for example. In such places species have been preserved that have elsewhere become extinct: the Ginkgo tree from the temple gardens of China and Japan is an example.

b. Western religions

Reverence for non-human life has not been a characteristic of the Western religions, Jewish, Moslem or Christian. A belief in man as separate from other animals, the only species with a soul, may have had some relations with the widespread abuses against nature in Western societies. There are, however, religious

leaders and their followers among Western religions that have been inspired by a belief in the sacredness, or value to God, of other living things. Saint Francis of Assisi is an early example among Christians. Albert Schweitzer, with his doctrine of "reverence for life", is a recent one. Religious beliefs, such as the avoidance of pork by Jews and Moslems, have had some sparing effect upon wild creatures. The over-abundant boars of West Pakistan are as much a consequence of religious belief as are the cows of India.

c. Modern philosophies

Aldo Leopold, a leader in American conservation thought, has spoken of the need for development of an "ecological conscience" and a "land ethic" to govern man's relationship with his environment. In such an ethic one would recognize the rights of other species in the way that social ethics recognize the rights of fellow humans. The development of ethics toward man's dealings with his environment and of a conscience governing his relations with other species are desirable goals not yet widely achieved. Perhaps an adequate expression is to be found in the statement of a Nigerian chief: "I conceive that land belongs to a vast family of which many are dead, few are living, and countless members are still unborn." If the consequences of this conception were accepted in our relationships with our environment, destructive use of land and nature could be halted.

4. Economic values

a. Direct commodity use

Natural communities and wild species have a direct commodity value in addition to the non-commodity values that have been previously expressed. Thus the higher commodity value of wild animals as meat producers, compared to domestic stock, has been demonstrated in Eastern and Southern Africa. The higher commodity value of a combination of wild and domestic species has been shown in the

United States and Australia, along with other areas. The high commodity value of a single wild species, the saiga antelope, has been shown in the USSR, along with the possibility for domestication demonstrated by the previously wild eland. The fur trade is an example of a long established commercial use for wild species, particularly those occurring in arctic regions where fur production may be a principal economic use of the land. Ivory from elephants, musk from musk-deer, oil from whales, plumes from birds-of-paradise are all examples of valued commodities produced by wild animal life. In places these may be the most beneficial commodity use that can be made of a particular environment. Elsewhere, some combination of wild with domestic commodity production may be most desirable. Unfortunately, through ignorance, as in some parts of Africa, the higher commodity value of wild species is often sacrificed for a lower, but more familiar value for domestic species.

b. Indirect economic use

In some countries and in portions of all countries high economic values are derived from tourism. Nations with magnificent scenery or wild animal wealth such as East Africa gain significant increments of national income from international tourist trade. The value of this trade alone justifies considerable national expenditures toward the protection of those resources that encourage it. The national parks of Kenya, Uganda and Tanzania are examples of this. Within a nation the movement of resident tourists serves to transfer wealth from urban centres to rural areas, benefiting local economies and permitting the development of the services and amenities that the people in rural areas require or desire.

Wildlife and fisheries resources have high potential value, apart from their direct commodity use, as means for providing recreation for those who wish to hunt or fish. In some countries these are popular pursuits and like tourism

can attract international sources of funds for their development or pursuit. Within a nation sport hunting and fishing can serve to transfer wealth to local, rural economies for the overall benefit of the entire nation.

c. Contributions to productivity and stability of commodity-producing lands

Through providing ecological diversity, the presence of natural areas, large or small, can be of benefit to lands used primarily for crop production. For reasons described earlier, such areas of natural vegetation contribute to the stability of watersheds and help to guarantee sustained flows of useful water. A variety of wild species in an area through the operation of biological controls can be an aid to the prevention of local outbreaks of pest species. A diversity of vegetation in an area will be less favourable to the development and spread of plague proportions of pest organisms. There is a need for long-term studies to compare the sustained productivity of agricultural and forest crops between areas with highly diversified land-use and vegetation and areas entirely cleared and used for extensive monocultures.

B. A CLASSIFICATION OF PROTECTED AREAS

Once the decision has been made to protect the irreplaceable elements of landscape and biota, it is essential to determine a programme for conservation and management. The programme will vary with the resource being protected and the purpose for which it will be protected. Thus a rocky peak, famous for its scenic value, may require no specific conservation or management measures save prevention of quarrying or development and perhaps some measures to protect its visitors. An endangered species, on the other hand, may require the maximum degree of legal protection along with a programme of habitat restoration. Some resources, for some purposes, are best protected by reserves or parks. Others need only a degree of reasonable legal protection to prevent over-exploitation.

In the following presentation, resources requiring the strictest protection will be considered first:

1. Natural areas

Natural areas include those completely or relatively undisturbed by man in the sense of wilderness or primitive areas and also areas in sub-climax, disclimax, or successional stages representing communities created by various levels of disturbance. Thus it may be desirable in some areas to preserve, for example, a climax broadleaf, deciduous forest; an area of sub-climax pine forest created in the past by widespread fire, hurricane, or other disturbance; a meadow stage and a shrub stage of successional vegetation developed on abandoned farm land. The protection of the first would require complete freedom from disturbance, for the others it would require maintenance of whatever level of disturbance is necessary to guarantee their perpetuation, the use of fire, land clearing, ploughing, etc. Natural areas are best protected in various types of reserves, parks, management areas, or public forests:

a. Scientific reserves

(1) Strict natural reserves: Purpose: The preservation of representative areas of undisturbed or climax biotic communities for scientific study. Disturbance of all kinds will be prevented in such areas, such as that resulting from logging, grazing of domestic livestock, hunting, fishing, tourism, development of water resources, commercial or urban-industrial development and agriculture. Scientific uses will be restricted to observations or surveys that require no significant disturbance or establishment of permanent installations. Educational use will be carefully controlled and of kinds that involve no disturbance to the area. All uses will be on the basis of permit. This type of reserve must be subdivided into two categories:

Class A. To be kept free from all human interference other than that described above, including that associated with fire suppression, control of insects, or control of other pathogenic organisms

Class B. To be protected against fire, or other major damage through insect or disease organisms in order to maintain the kind of community that would develop as a result of such protective measures.

No size limit is established for a strict natural reserve. Both the desirable size required for protection of the total community involved including all associated animal species and the boundary characteristics needed to eliminate undesirable edge effects should be determined by competent scientific authority.

A strict natural reserve may be proclaimed primarily for the protection of endangered species if the species concerned are those that would benefit from complete protection of an undisturbed habitat. It would not be recommended for a species that would require habitat management, predator control or other forms of management that would involve disturbance of the reserve.

(2) Scientific management area: To maintain representative areas of biotic communities, both previously undisturbed and successional, for the purpose of scientific management and study involving various levels of disturbance to the community. All kinds of scientific research would be permitted under the permit, including those that require disturbance or removal of vegetation or animal life, or the construction of various installations. Limited educational use would be allowed under permit. Other public uses would be special exceptions. Compatibility of varying scientific uses would be determined by the management agency under competent scientific advice. Size and boundaries of the area would be determined from recommendations of competent scientists. The location of scientific management areas adjacent to or near strict natural reserves will be generally desirable, both to buffer the reserves and to provide for study of similar communities under different levels of disturbance.

b. <u>National Parks</u>

Purpose: The preservation for public recreational use and enjoyment of natural areas representing sites of unusual scenic attractiveness or those with unusual or rare biotic communities of great public interest. To be maintained free from disturbance, except for those management activities determined necessary for the maintenance of the desirable scenic or biotic attractions and for those developments necessary for public use and enjoyment of the area, providing that those developments do not interfere with the preservation of the scenic or biotic values of the park. The park will also accommodate those forms of scientific and educational use that do not interfere with the preservation of scenic or biotic values. Generally speaking a national park will be an area of large size and unusual quality. Size qualifications recommended by IUCN are 500 hectares minimum in countries with populations equal to or exceeding 50 persons to the sq. km., and 2,000 hectares minimum in countries with populations less than 50 persons per sq. km. National parks are to be divided into two categories:

(1) <u>Wilderness parks or zones</u>. Those in which roads or other facilities for mechanized transport are not developed. Use restricted to those willing to travel by foot, domestic animal transport, or non-mechanized boat. To be maintained as closely as possible in a primitive state without developed tourist facilities, other than necessary foot trails and lightly developed campgrounds.

(2) <u>Tourist parks or zones</u>. Developed in accordance with the limitations described in paragraph 1 for use by tourists employing motorized transport, including necessary roads or other transportation facilities. Where already existing in established parks, hotels, restaurants and other tourist facilities are permitted; however, every effort should be made to locate these developments outside of park boundaries. The type of development to be found in Banff or Jasper in Canada's parks should be avoided inside boundaries of national parks.

A single national park may be subdivided into two zones, a wilderness zone and a tourist zone. Generally speaking, where conditions permit, a national park may surround or adjoin a strict natural reserve to the mutual benefit of both areas; it may adjoin but usually should not surround a scientific management area because of the problems of restricting use in the latter area.

Because of past ambiguities in management practices in which wilderness preservation was not considered essential to national park policy, a national park not designated as a wilderness park, or as having wilderness zones, will be assumed to lack wilderness attributes.

c. Special reserves

Natural areas not qualifying for inclusion in the system of scientific reserves or national parks may be designated as special reserves. These may be created for the preservation of rare or endangered species where this requires a special management incompatible with national parks or scientific reserves, or for the preservation of historically and culturally valuable sites. Parks not large enough or sufficiently unusual in character to qualify as national parks will also be considered to fall into this category. Special reserves may or may not be open for public recreation and tourism depending upon the compatibility of these activities with the primary purposes for which the reserves are established.

d. Special management areas

Areas under natural vegetation used primarily for the purpose of production of commodity resources, but secondarily open to public recreation are included in this category. The national forests and public domain lands of the United States, managed for the production of timber, range land, water resources, wildlife for hunting and fishing and public recreation are examples in this category. National recreation areas, in the United States, designated as serving a

primary public recreation function, but used also for commodity production would also be included in this category. Areas used exclusively for commodity production and without access or development for public recreation will not be included. In land-use planning it is desirable to buffer national parks and scientific reserves with special management areas to be maintained in natural vegetation, but used for production of wild-land commodities. This avoids the nearly incompatible juxtaposition of parks and scientific reserves with intensively developed agricultural or urban-industrial lands.

Besides the encroachment of cultivation and other uses upon the natural environment a converse trend may often be observed in developed countries, and perhaps to a less extent elsewhere in the world. Changing social and economic values lead to the neglect or abandonment of land formerly more intensively used. Examples of this trend may be seen in some upland pastures of the British Isles no longer an economic base for animal husbandry in competition with a more intensive farming pattern, in the impoverished hill pasture and forest of southern Europe and in abandoned farm lands of the eastern United States.

Abandonment cannot in itself constitute a constructive measure of resource conservation or restore the natural heritage with its scientific and aesthetic values. While limited areas may be suitable for inclusion in nature reserves and parks, it is more important that neglect should not be allowed to diminish the richness and variety of the environment as a whole. Rational planning should seek to assign and promote appropriate uses and provide the transport and other facilities that can make such areas an asset, rather than a liability and an eyesore. Thus, the relative scarcity of meat, milk and forest products in Mediterranean countries could be met in part by better management in the public interest of neglected upland areas. Well planned non-intensive systems of production, which might well cover the cost of management, would enhance rather than diminish

the ecological status of such land as a reservoir for wild species of plants and animals and also their amenity value for the human society.

2. General management of wild species

The ownership of wildlife is herein assumed to rest with the general public. This ownership may be delegated by the State to private individuals under conditions to be specified by the State with full considerations of the public interest. The importance of preserving wild species outside of parks and reserves should be generally recognized. For many species of wildlife, including most migratory forms, it is impossible to establish reserves large enough to provide complete protection. Legal protection, with adequate patrol and enforcement, must be extended by Government to these species wherever they occur. Rare or endangered species of wild animal and plant life must be extended full protection at all times. Cropping for sport, scientific, or commercial purposes normally is permitted for more abundant species of wildlife, except in those parks and reserves where such cropping is incompatible, but this always must be done under licence or permit from the appropriate government authority. The level of cropping must always be compatible with the preservation of the species and the principle of sustained yield. In addition to special protection offered to wild animals and rare or endangered species, land owners or managers should be encouraged through educational programmes to protect natural habitat and wild species wherever this is compatible with the primary use of the land. The goal in overall land management, of maintaining diversity, will require particular attention to the preservation of natural open space and wild species wherever this is ecologically and economically feasible.

Special attention should be given to the rôle of natural areas and wildlife in urban areas and areas of intensive commodity production. For many inhabitants of these areas, visits to wild parks and reserves may seldom be possible. The

psychological and educational benefits of contact with nature and wildlife can only be obtained through an adequate and representative natural area system throughout all categories of lands. These urban parks and greenbelts will not require necessarily the special protection offered to major parks and reserves. The important requisite is adequate care to provide open space, natural beauty and contact with compatible species of wild animal and plant life for all people who desire or would benefit from it.

VI. RATIONAL USE OF THE BIOSPHERE

A. GOALS FOR MANKIND

There seems little disagreement that the scientific knowledge and technology developed during the Twentieth century hold out a hope for mankind that was never before justified. The prospect of meeting the needs of the existing world population for food, fibre and other essentials for living is brighter than could have been foreseen a few decades ago. The prospect of meeting the needs of an ever-expanding world population, however, is as remote as it ever has been. The availability of scientific techniques does not guarantee their application to human problems. The existence of a technology capable of providing benefits to all mankind does not necessarily imply that it can or will be used to improve human welfare.

In many areas we see evidence that technology is lop-sided and out of hand, that urban-industrial development and the extension of facilities to serve urban-industrial centres is destroying the amenities that make living worthwhile, and even threatening the continued existence of human life in areas of extreme population congestion. Thus the air in places such as New York City, London, Los Angeles, or Tokyo receives such a high level of pollutants that massive morbidity and mortality only await the fortuitous combination of meteorological events that will prevent normal air movement across these cities. To a surprising degree we have allowed our technology to dictate the conditions under which we must live, rather than using it to create a better environment. To a degree

we have allowed our knowledge of what is technologically possible to influence our predictions of what is economically and socially probable. Thus we hold out false hopes of prosperity and abundance. It is important that humanity analyse its goals and direct its means, its technology, toward achieving those goals.

1. Choices for the future

We have basically three choices, or various modifications of these, to select from.

a. Minimum subsistence for maximum numbers

We can channel all available resources and use all available space to provide a subsistence existence for the maximum number of people that the earth can keep alive. All of us would consciously reject this as a goal. In practice, however, humanity is behaving in many parts of the world as though this were indeed the goal. The hundreds of millions of people in parts of Latin America, Africa and Asia existing at the edge of famine are evidence enough. The ultimate consequence of pursuit of this goal is the recurrence of catastrophes.

b. High material standards for maximum numbers

We can channel all available resources and use all available space to provide a high material standard of living for the greatest number of people that can be accommodated at such a level, with disregard of natural values in favour of an artificial existence. Although not stated as a goal, this is a consequence, perhaps unforeseen, of the "religion of growth" that is widely accepted by industrialized, technological societies. In these, natural values are usually sacrificed in favour of increased production of those commodities that enter the market-place and show up in indices of economic gain. The daily life of a middle-class apartment dweller in downtown Tokyo or New York could exemplify the relatively high material standard of living, high level of consumption of economic goods and almost complete lack of contact with things that are not

man-made, that would characterize the continued pursuit of economic gain at the expense of natural values.

The results of continued emphasis upon ever-increasing commodity production and population growth at the expense of the natural environment are predictable: increasing pollution of air, land and water; disruption of natural ecosystems to the point where productivity and life is threatened; a constant war to control pests and plagues; and ultimately perhaps the evolution of a different type of human being, able to tolerate such an existence, along with the elimination of all those who cannot. Continued emphasis on economic growth at the expense of natural values, along with the inequities in distribution of material goods that appear to accompany such a pursuit could increase the probability of international conflict through growing competition for markets and raw materials to a degree that the continued existence of mankind would be in doubt.

c. Quality of living for optimum numbers

The human goal that is implied in the concept of rational use of the biosphere is one that would seek a combination of a high material standard of living with a retention of a maximum variety of natural and man-made environments, including protection of non-human species and the values of wild nature. In such an environment, there would be the retention of opportunities for change of direction, for the creation of different ways of living, since all resources would not be channelled or utilized and an abundance of living space would be available. Attainment of this goal would be possible only for a human population held at a compatible level, perhaps a level that could be described as an optimum abundance of people. The actual numbers involved in such an optimum population cannot be described in general terms, since they will vary with nations, cultures and levels of technology. From an ecological point of view this concept corresponds with that of an optimum density for an animal species, one

at which we seek to maintain those animals that we manage. From an ecological viewpoint also, this appears to be the only realistic goal for humanity, one in which the survival of free, psychologically whole individuals remains possible. Indeed, whether or not it is accepted as a goal, this orientation toward quality of life in place of quantity of people and of economic production is the only chance for retaining permanency of human civilization with full opportunities for individuals to develop their human potentials.

2. <u>Orientation of means toward ends</u>

That our technology and our behaviour is not oriented toward acceptable goals for humanity is a result of numerous factors. To a degree it represents a lack of knowledge, a failure to understand the consequences of our own behaviour, to a degree an inability or unwillingness to look ahead and plan effectively for the long run, and at times it represents an unwillingness of individuals to concern themselves with the fate of their fellow men or of future generations, through the desire to gain wealth or power for themselves.

a. <u>Ecological ignorance</u>

Ecological ignorance is still widespread. Thus the effects of broad-spectrum, persistent, pesticides upon the environment could have been predicted by ecologists. The pesticides, however, were developed and tried without adequate ecological knowledge on the part of the users. Their continued use reflects, however, not only ecological ignorance, but a willingness to sacrifice the welfare of all and to ignore future consequences in an effort to achieve short-term gains for a few. Ecological ignorance has often been involved in the overstocking of semi-arid rangelands, in the abuse of watershed cover, in the removal of productive forests, in the building of dams that are never filled to irrigate lands that soon go out of production, or in the pollution of air by the by-products of internal-combustion engines. Where the ignorance is overcome,

however, the practice may still continue because of the failure to place the welfare of the nation or humanity above the economic gains of some individuals.

b. A failure to plan

In general, the long-term effects of man's activities are not adequately considered. A failure to plan is still prevalent. A failure to take all identifiable factors into account in planning is more prevalent. The need for consideration of conservation values and of ecological principles in economic-development planning is widespread. To a large degree, engineering, economic and political considerations enter into such planning as is done, but seldom is adequate attention given to ecological factors that will determine the long-range success or failure of a plan. Planning is often short-range, based on immediate economic gains and local political cycles. Budgets for many government agencies must be approved annually. Long-range programmes approved by one legislature are vetoed in a few years by the next. Political expediency demands immediate results, at any cost to the environment, to justify future financing of a programme. Economists prefer to plan for no more than five years and never for more than twenty. To be rational, in the long run, planning must be long-range and consider the realities of the biosphere. Planning in itself can mean little unless effective political, economic and social means for its implementation are devised. Many Utopian worlds exist in the literature of planning. None is to be found on earth.

3. The limitations of space

We are now sufficiently aware of our solar system and the universe to know that we dwell on a small planet of a minor star in a planetary system that is apparently generally inimical to life. Our continued existence depends on our ability to cope successfully with our population and our environment. We are condemned to live on this earth and cannot migrate in numbers to other planets.

We can continue in ways that must ultimately destroy mankind, or we can adjust to the limitations of our planet.

Our predicament is not unlike that faced by the inhabitants of a small island, cut off from contact with the outer world. It was faced by many primitive peoples in the past and most of them adjusted to it well. The discoverers of the more remote islands of the earth found commonly that the primitive islanders had managed to maintain moderate numbers of people in environments that were kept amenable to man. The impact of advanced civilizations and later of the industrial revolution completely disrupted the ecology on many islands and has brought some near to the brink of disaster. Relatively unchecked rates of population increase, the destruction of natural environments and often their replacement by a precarious monoculture, have combined to bring excess human misery to islands such as Santo Domingo, Reunion and Mauritius. Whereas the limits of the environment appeared obvious to many primitive peoples, modern technological society, with its promise of abundance and its too frequent delivery of suffering, has shown an unwillingness to recognize such limits. If we cannot notice the relation between richness of the environment, optimum levels of population and human well-being in relatively simple island ecosystems, there seems scant hope that we can see it for the planet as a whole. One can suggest only that an international effort directed toward rational use of island ecosystems might help to point the way for the earth as a whole as well as provide better conditions for the islanders.

B. THE LAND-USE SPECTRUM

In all nations a spectrum of land-use exists, ranging from the most intensively used urban or industrial areas to the lightly used wilder lands. All parts of this spectrum need consideration in land-use planning. No part should be developed without consideration of the effect on all other parts. It is

essential in the long run to obtain the highest value, commodity or non-commodity, from each area of land. It is essential that uses be both compatible and capable of being sustained. To accomplish this it is necessary to classify lands and waters according to their capabilities. When this has been done, priorities must be developed for use that recognize not only the capabilities of the land, but the adaptability of the kind of use to the sites that are available. High priority must be given to those uses that are necessarily fixed or limited, lower priority to uses that are more flexible in site requirement. There may be only one reasonable site choice for a harbour development or a national park, but great numbers of potential sites for highways or housing.

1. Multiple use of land

The concept of multiple use implies that land may serve more than one useful function. A timbered region may be growing wood products, producing wildlife, providing space for recreation, stabilizing soil and regulating water yield at the same time. When an area, through proper management, can serve several functions at the same time, it may be of benefit to society to have it do so. However, priorities in use must be recognized and related to the values and capabilities of the site. Incompatibility of some uses must also be recognized. A site best adapted to the growing of commercial timber would not normally be used simultaneously to support intensive grazing, since the uses are largely incompatible. The use of an area as a scientific reserve or wilderness park is incompatible with commodity production or intensively developed public recreation.

The concept of multiple use is more applicable to a region than to a particular site. Since sites will differ in their capability the region will best be used when it is serving the many purposes to which the sites within are best adapted. A scientific reserve or wilderness park will often benefit if the surrounding lands in a region are developed for such uses as public outdoor

recreation or commercial timber production, since these uses can provide a buffer against other more intensive and incompatible uses. Use of an area as a factory site necessarily rules out its use for other purposes. However, industrial use of an area will benefit if the industrial sites are buffered by greenbelts or other space use that prevents encroachment of incompatible neighbouring uses such as residential housing. Thus multiple-use concepts are adapted to the proper planning of the development of a region, but limited in their application to any specific plot of land.

2. Sustained yield

The concept of sustained yield is basic to the management of land and living resources. Land should be capable of sustaining the uses to which it is put. Uses that are extractive and cause deterioration of the useful capacity of the site should normally be avoided. The demands placed upon soil or biotic resources must not, in the long run, exceed the capacity of the land or biota to supply them.

For agricultural lands sustained yield means the avoidance of uses that cause impairment of their productive capacity by loss of fertility, breakdown of soil structure, or other forms of depletion. For forest lands, sustained yield implies management in such a way that production of forest products is continuous. Wildlife populations must be cropped at levels that do not exceed the reproductive capacity of the species. Management on the basis of sustained yield is applicable to all living resources and helps to guarantee their continued productivity. Determination of the yield that can be sustained, which varies from one site to another, remains for many areas an object of research.

3. Land classification

A first step toward rational use is the classification of land and living resources according to their capacity to sustain use. The techniques for

classifying land for commodity production in temperate zone areas are now widely known and used, although always subject to improvement and will not be discussed here. In the tropics much more research is needed before land classification techniques can become highly reliable. However, in land classification, there are certain criteria which are never normally taken into account and which should be given particular attention. For example, two criteria should be considered:

(a) Does the site have any special or unique qualities of scenery or landscape? If these are outstanding the site should be designated for uses that will be compatible with preservation of these qualities, even though the site is otherwise capable of being used for more economically profitable purposes.

(b) Does the site support a biotic community of special interest? The presence of rare, unusual or endangered species, or of outstanding examples of plant or animal communities will indicate that the site should be used only for purposes that will preserve these special biotic qualities.

For sites that do not have special qualities of scenery, landscape or biota requiring special measures for conservation, the usual land-capability criteria will be considered in classifying it for other uses. These include the climate, soil, geology and hydrology, biota, slope, drainage, stability under use and so forth. Classification will specify the usefulness of the site for sustained agriculture, pastoralism, forestry or other uses and land-use planning and control will be based upon this classification. The agro-climatological surveys that have been conducted in the Middle East and in Africa under the leadership of Unesco, FAO and WMO represent an effective step toward such land classification for commodity production. However, in overall land-use planning the following additional point needs full consideration:

(c) The skills of landscape design and architecture need full consideration in any plan. The arrangement of people and land uses should favour diversity and beauty in the environment as well as practical goals. To preserve environmental quality the monotonous development of uniform uses or repetitive patterns need be avoided even at the cost of commodity values. Diversity provided primarily for aesthetic purposes will have benefits in human welfare and can be expected to pay ecological dividends in sustained regional productivity. Particular attention need be given in the design of towns and cities to the development of new and diversified patterns of residential, commercial, industrial, transportation and recreation space to create an environment attractive to those who must live within it, and to provide distinction and identity to each community.

4. Water-use principles

The same criteria used for establishing broad land-use classification and principles need also be applied to water. Since water, unlike land, moves through ecosystems and affects all parts of them, special care must be given to its use. In general, the concepts of multiple use and sustained yield apply as well to watersheds and water production as to the use of land. In classifying water areas for use, special consideration should be given to principles that are often, today, ignored:

(a) Water areas with unusual quality for scenery, or possessing unique biota or high recreational potential should be considered first and if possible reserved for uses compatible with the retention of these values.

(b) Since water pollution can ultimately destroy the usefulness of a water resource and seriously impair the quality or health of an

entire environment, every effort must be made to avoid excessive dependence on waterways for waste disposal. The development of techniques for recycling and reusing potential pollutants needs to be given high priority in every nation. The sanitization of urban sewage for ultimate return to the soil requires special attention in all nations.

(c) The development of water for power, irrigation or other uses through constructions of dams and other installations needs to be viewed with consideration of all values to be affected by such development. Where such development leads to serious impairment of environmental quality, a full exploration of alternate sites for development and of possible relocation of the people or facilities for which the development is needed must be undertaken.

5. Air-use principles

Air, like water, moves through ecosystems and life depends equally upon its quality and purity. The care of water quality and of air quality are of equal importance. Every effort must be made to avoid excessive reliance upon air for the disposal of waste products created by oxidation of fuels or other chemical processes. Recycling and reuse of potential air pollutants needs full and detailed study. Development of transportation and industrial processes that do not result in air pollution deserves a high priority. Careful design and planning of transportation networks and urban-industrial sites can help minimize pollution of the air.

C. PLANNING AND CONTROL

Parks, reserves and wild species cannot be maintained without adequate attention to the overall question of land-use and resource planning. Uses must be adjusted to and compatible with the capabilities of the land in all areas of any

nation. Destructive use in one area will influence the future of all other areas. Excessive population pressure on any category of land, whether it be a national park or agricultural land, will in the long run defeat the purpose for which the land has been designated.

1. Priorities for use

In the past land-use planning has usually proceeded by designating first the areas to be used for those purposes with the highest economic value, usually measured over a short period of time. Urban-industrial use thus normally received a high priority, whereas other uses were considered secondary. Within cities, industrial, commercial or residential use received high priorities along with transportation. Future priorities need take into account a longer-range and broader view with full consideration of ecological realities and conservation values. With such consideration the areas necessary for scientific reserves, special reserves and national parks would be given the first priority in planning, since these are fixed resources that cannot be accommodated except on the sites to which they are by nature bound. One cannot create a Grand Canyon National Park without a Grand Canyon, nor a Serengeti Park without the plains and the game herds. Similarly, in the planning of cities, the open spaces, natural areas and greenbelts should be designated first, since these give form and design to the rest of the city and will determine in large degree whether it will be amenable to human occupancy or to a degree inimical. Admittedly in established cities or settled lands such priorities cannot readily be asserted. They should nevertheless be taken into account in the guidance of all future development.

Again, because of ecological necessities, such as the nature of terrain, soils and climate, the protection of high-quality agricultural land should receive high priority in planning, so that unwarranted encroachment for incompatible

uses, residential, industrial, transport, etc., can be limited and controlled. Highly productive forest sites, also determined by soil, terrain and climate, require a similar high priority in planning. Uses that are more flexible: highway and rail routings, locations of residential areas, certain categories of commercial and industrial sites and the like, should be adapted to lands not required for specific and largely fixed uses, even though immediate, short-term, economic returns may be greater from the more flexible uses.

The changing land-use pattern in the developing world must be planned with equal care if the irreplaceable inheritance of nature is not to be impoverished or destroyed in man's attempt to deploy his technical knowledge to improve his material existence. The growing demand for food and other consumer goods requires an agricultural revolution to bring more land under cultivation and at the same time increase productivity per unit area and per head of the agricultural population. Whereas in developed countries it is at present less urgent to extend the agricultural area than to protect the remainder of the environment, in developing countries the environment must be protected while agricultural production is rapidly increased.

Agricultural development must be selective, for everything cannot be done at once. A large increase in production from a relatively small area of good land, to be obtained by applying a combination of technical measures and inputs, will relieve the pressure on a much larger area that would otherwise deteriorate through our exploitation and also make it possible to continue for the time being simple and less exhaustive traditional patterns of land use, or to protect less accessible areas, or areas of special scientific or aesthetic value, from further human interference.

In the more populous countries of Asia it may be that little cultivable land or accessible forest remains unused. The emphasis must therefore be on an

improvement in agricultural and forestry methods, with a diversification and intensification of production in areas where stable ecosystems can be established. Irrigation, the use of fertilizers and the introduction of better varieties of crops and breeds of animals will be among the most constructive modifications, together with a prudent allocation of land to different uses. Elsewhere, as in much of Africa and Latin America, the overall pressure of man on the land is less acute, but the same selection of sites for development and changes in method are required to prevent the destructive exploitation of wider and wider areas of the natural environment to increase, or even maintain, the volume of production. New patterns of land use must be paralleled by changes in social and economic organization, to provide the infrastructure for an agricultural industry not tied to local subsistence and to make available to the agricultural population the amenities of civilization.

The Indicative World Plan for Agricultural Development, now being formulated by FAO in collaboration with the countries concerned and with other international agencies, attempts to quantify and elucidate the agricultural, forestry and fisheries aspects of this urgent problem of expanding production to meet the reasonable needs of the rapidly growing and increasingly articulate populations of the developing world.

Taking an analysis of production, consumption and trade in the period 1961-1963 as a basis, projections of the future demand are being prepared for 1975 and 1985 which will reflect both nutritional requirements and economic growth. Production targets and an economic frame within which future development can be accommodated are then formulated for these two epochs. The production targets are based on a close study of the physical potentials for increased production and on the rate at which innovations can be introduced and effectively adopted, alternative assumptions being made as to the rate of population increase

and the level at which international aid can be made available for agricultural development.

While the ground work of the Plan is closely linked with a rather detailed analysis of physical, economic and social factors, the presentation will be regional. The broad regions for analysis are the Near East, the Mediterranean Basin, Africa south of the Sahara, Latin America, Asia and the Far East. It is intended that provisional plans for these regions and an integrated plan for the world as a whole should be available for presentation at the forthcoming World Food Congress in 1968.

Since the expansion of agricultural production bears so directly on the natural resources of the developing world, the findings and policies proposed in the Indicative World Plan will be extremely relevant to the conservation of natural environments. As has been said already, agricultural development must necessarily be selective in its use of natural resources since both the feasible rate and economic pace of development are limited. The plan seeks to relate rational development to the needs of the next two decades; it will also provide a measure of required environmental changes, both in the exploitation of new areas and in the introduction of new methods.

2. Survey and inventory

Overall agro-ecological surveys, land capability and use, soil, vegetation and other resource surveys and mapping, are essential in the long run to sound land management planning. New techniques of aerial or space-satellite surveying will eventually shorten the time and expense involved in these tasks. However, these will never entirely substitute for the ground-based surveys, which need therefore be started as early as possible in all parts of the world. Knowledge of the distribution and abundance of most wild animal species must often be derived from time-consuming, expensive ground surveys. These must both be started

early and maintained permanently, since populations and distributions change rapidly from year to year.

The interdisciplinary and the integrated types of surveys recently carried out in different countries are of particular interest here. The method for Integrated Resource Surveys recently developed in Australia and New Guinea, afford an excellent example of such an inventory. Each survey team included a geomorphologist, a soil scientist and a plant ecologist, other specialists being included as required. Making extensive use of air photography and ground transects, the object of the survey was to distinguish "land units", of similar genesis and definable in terms of topography, soils, vegetation and climate; and within each unit "land systems" separated by geomorphological or geological factors in the landscape pattern. This classification, together with the field data collected makes it possible to assess the ecological status and potential use of the environment in considerable detail. The Training Centre for Integrated Surveys recently established in Delft, Netherlands, under Unesco's auspices provides excellent opportunities for training key personnel in such methods for the developing countries.

It follows from the above that a first step toward sound land-use planning will involve the location, definition and mapping of the irreplaceable natural communities and wild species. This will require a programme of ecological surveys and inventories, which in themselves could be elaborate and time-consuming, and in the long run must be. However, time runs out fast on most world conservation issues. It is essential to take initial steps toward preservation on the basis of incomplete and perhaps inaccurate information. This may involve making use of the best-informed local opinion combined with quick surveys by qualified experts. Nations that are poorly staffed by people with the necessary skills and training may take advantage of the facilities provided by international and

extra-national agencies and combine the skills of outside advisers with the first-hand knowledge of local people. Early action toward preservation is the essential first step. It must be carried out with the understanding, however, that boundary and legal revisions will follow after detailed surveys and studies are completed.

3. Planning and control

It has been stressed that planning for rational use is essential but becomes meaningless without land-use controls. Planning and control must operate locally, regionally, nationally and to a degree, internationally. In so far, however, as governmental and economic systems will permit, a maximum degree of planning and control may be best concentrated at local levels in the hands of those most cognizant of local conditions and needs. There is no generally accepted best method for integrating social and economic considerations with ecological requirements for long-term planning. The decisions regarding the land-use pattern are the result of a choice where political, economic and social considerations intervene. Planning not only fixes objectives and priorities but the means to attain them. Regional and national review, integration and legal authority, however, have generally been essential to prevent local special interests from prevailing against the public welfare and long-term national interests.

VII. ACCOMPLISHING RATIONAL USE AND CONSERVATION

A first step toward accomplishing rational use of the biosphere and conservation of its resources lies in achieving an awareness of the absolute necessity of moving toward this goal among those who are in positions of power and authority.

The imperative need for accomplishing rational use and conservation arises from existing human pressure upon the environment. As this pressure increases the biosphere will be affected accordingly and the problems will grow worse. The need for food will increase, the needs for living space will increase and unless appropriate action is taken the quality of the human environment will deteriorate. Mankind must reconsider its goals and objectives if an equilibrium is to be maintained between human needs and the resources of the biosphere.

Rational use and conservation of the resources of the biosphere must be based upon scientific knowledge. It is, therefore, imperative that this knowledge be assembled and evaluated so that deficiencies that still exist may be remedied through further research. To this end it is essential that we examine the nature of the biosphere, its structure and its function and thus determine the ecological basis for its rational use. In particular, we need give attention to the following areas:

(a) Biological productivity in wild and tame environments including studies of the adaptation of species to their environment and their interactions with it.

(b) The nature of land and soil, including survey, analysis and classification of soils and landscapes with a view to determining their values and uses.

(c) The characteristics of aquatic environments and water resources with a view to determining their availability, values and uses.

(d) The ecology of modern man with a view to his environmental requirements.

In a consideration of the scientific basis for rational use of the resources of the biosphere the problems that have resulted from various human practices must be given attention. These include the disappearance of fauna and flora, the deterioration of soils, misuse of water resources and aquatic environments, and pollution of the environment. The human attitudes and traditions that lead to these problems must be fully considered.

Because of the availability of scientific knowledge and technology it is now possible to analyse the resources of the biosphere and determine ways of achieving their integrated utilization. The potential for better and more rational use therefore emerges. In particular, it is important to consider more effective approaches to accomplish:

(1) Improvement and increase of yields in agriculture and sylviculture.

(2) Conservation and improvement of aquatic environments.

(3) Control of pollution of air, water and land.

(4) Preservation of natural areas and ecosystems.

(5) Protection of rare or endangered species.

(6) Management of wildlife and its habitat.

(7) Enhancement of the aesthetic quality of the total environment.

(8) Planning for integrated management of the resources of the environment to augment environmental quality.

To promote the rational use and conservation of the resources of the biosphere it will be necessary to define principal lines of action at the national and international level. These must necessarily include:

(1) Survey and identification of the resources of the biosphere, including increasing support for those efforts already under way and initiation of new programmes. Among those programmes already started are:

(a) The whole of the programme of the Food and Agriculture Organization, which aims at increasing agricultural production on a rational basis and assuring sustained yields. The World Food Plan endeavours to assess and clarify the agricultural, forestry and fisheries aspects of the urgent problems of increased production necessary in order to meet the growing needs of a rapidly expanding world population.

(b) FAO and Unesco have jointly undertaken an inventory of the soils of the world through the Soil Map of the World on the scale of 1:5,000,000.

(c) Unesco has particularly developed multidisciplinary studies of the natural environment and its potential resources, particularly in the arid zones; through the launching of the International Hydrological Decade, it makes an essential contribution to the study of water resources. Furthermore, Unesco supports the International Biological Programme and the activities of the International Union for the Conservation of Nature and Natural Resources.

(d) The International Biological Programme (IBP). This represents a major step toward scientific identification of the living

resources of the earth and research needed for the conservation of these resources.

(e) The International Union for Conservation of Nature and Natural Resources (IUCN). This agency has long been engaged in programmes intended to identify and protect irreplaceable natural areas and wild species. It collects data and information and acts as a clearing house for knowledge of the status of wildlife, natural areas and activities related to them.

Among programmes that have been proposed for initiation the following two may be quoted as examples:

(a) The establishment of a Trust for the World Heritage. This was first called for by a Washington Conference on International Co-operation held in 1965. It would act to establish effective protection for outstanding examples of natural areas, wildlife areas and scenic and cultural resources throughout the world, including such areas as the Grand Canyon, Serengeti Plains, Angel Falls, Mount Everest and habitats occupied by such endangered species as the orang-utan, Indian rhinoceros and mountain gorilla. Such a trust would stand for and speak for the principle of a paramount international interest in the protection of significant natural environments and would work in close co-operation with IBP, IUCN and other international agencies in establishing effective identification and protection of such areas. The co-operation of international agencies and their member nations is required if such outstanding areas are to be dedicated to the future enlightenment and enjoyment of all mankind.

(b) Demonstration Islands Programme. The XIth Pacific Science Congress, at its meeting in Tokyo, Japan, in 1966, urged the establishment of protected island reserves in the Pacific region, to preserve for the future a series of unique and undisturbed islands habitats. Full support for this proposal is strongly urged because small islands present ecological situations which do not exist on continents and the experience gained on continents is not easily applicable to islands. It is further urged that an additional step be taken by the United Nations agencies and their Member States, the establishment of a demonstration islands programme. On islands to be selected for demonstration, a major international programme using all available knowledge and skills would be initiated to establish rational use and achieve the highest possible environmental quality. Such efforts directed toward improving island environments would provide not only a superior life for the island inhabitants, but would provide models to show what could be accomplished on larger areas.

The expenditure of international technical assistance funds for the establishment of such model environments could well produce much more meaningful results than an equal expenditure disseminated widely over continental areas. Many such expenditures in the past have gone toward short-term programmes aimed at a variety of unrelated environmental problems and development efforts. An island programme could provide an opportunity to put the best available knowledge to work on ecologically integrated areas of sufficiently small size to enable

full evaluation and appreciation of the results within a relatively short period of time.

(2) Many data necessary to the rational utilization of resources of the biosphere are still lacking. Scientific and technological research are therefore needed. This research involves not only the general level of surveys and identification of problems, but the more fundamental levels of soil science, forestry, range management, wildlife biology, plant and animal ecology, human behaviour and other fields. It should lead, within the framework of a programme of action for the development and management of the resources, to interdisciplinary and integrated studies. The establishment in each nation of a research organization or organizations oriented toward studies related to environmental quality is essential. Research organizations of Australia and New Zealand provide good examples, although a number of other nations have equally adequate research agencies.

At the international level further support for those aspects of the International Biological Programme related to fundamental research should be increased. The research being conducted by the United Nations agencies needs continuing and additional support. Amongst these could be mentioned the regional agroclimatological studies undertaken jointly by FAO, Unesco and WMO; the activities of Unesco in the field of natural resources research, with the object of providing the necessary scientific basis for their utilization; the studies carried out by WMO on problems of pollution, etc. Other long-term research programmes at the international level will be required. Inter-agency co-operation will be essential for the success of these efforts.

(3) One of the most important steps to be taken is in the area of education and publicity. Public acceptance of the need for a national programme of rational use and conservation depends upon this. Time is too short to allow any nation to start its educational programme only at a traditional school level and wait for a new generation of informed citizens to reach maturity. Instead a major programme for informing adults needs immediate implementation. This will require the use of modern techniques for public education. Establishment of a national educational television network reaching every town and village could perhaps be done for less cost than many unwise economic development programmes that have been attempted. The use of radio, newspapers and other printed materials needs full exploration also.

At the school level the teaching of the principles of rational use and of improvement of the quality of the environment needs integration with all school curricula. The social studies and natural sciences provide obvious vehicles for conveying these principles. Establishment of curricula in conservation, as such, is seldom the most useful approach, although integrating courses and programmes that provide a multidisciplinary approach to environmental problems are to be highly recommended.

Underlying all educational programmes must be a realization of the need to inform all citizens, now, in order to accomplish action today. The critical nature of world problems requires an information-action programme equivalent to that which a nation can muster in support of a war. Only such a programme can hope to avert famine in

those areas where population increase is rapidly outstripping the productive capacity of the land.

Unfortunately, all of the goodwill and public support in the world can accomplish little toward achieving rational use of the environment, unless the technical skills and scientific knowledge needed to carry out the job are available. Just as construction of a dam requires the skills and knowledge of engineers, rational use of land and biota requires the knowledge and skills of land-use ecologists. Most countries have supplies of engineering skills, few have ecological knowledge available.

A programme for training ecologically oriented technicians in every country to operate in all areas of planning, land management and resource management, is an immediate essential. This requires establishment of technical schools and the review of curricula in existing schools to guarantee that students are receiving an adequate orientation in ecological principles applicable to their respective disciplines and to the nature of the environments in which they must work.

A programme for training scientists in ecology and the various disciplines related to land and resource use also requires high priority and early implementation. This university-level training will be necessarily more rigorous and time consuming than the training of technicians but is equally urgent if research is to be undertaken and adequate supervision is to be provided for those activities concerned with rational use of the environment.

International organizations should make every effort to provide to those nations requiring immediate assistance teams of ecologically

trained resource specialists. These teams can be of assistance in initial surveys, inventories, allocations of priorities and planning efforts during the period when local personnel are being trained.

(4) Finally it will be necessary not only to draw the attention of countries to the absolute necessity for them to develop a national policy of rational use and conservation, but also to assist them in this task. Development of such a national policy will necessarily precede its widespread implementation. An acceptance at a national level of a goal for maximum opportunity for an optimum population, an agreement to avoid the sacrifice of environmental quality, diversity and natural values for short-term economic gain and a commitment to plan for rational use of the total environment, would represent a major step forward at this time.

In addition to the formulation of a national policy it is essential that effective governmental organizations be formed to implement the policy. There are at present many national parks that exist only on paper and laws intended to protect national resources that have yet to be heard by the citizens engaged in resource exploitation. Conservation organizations are low in government hierarchies and lack money or power. It is necessary, therefore, to stress the need for effective governmental organization to control development and enforce the measures needed to implement rational use. Too often the excuse has been used that a nation cannot afford the expense of effective conservation. A proper evaluation of the respective rôles of rational use and economic development will show that no nation can afford not to implement adequate measures for rational protection and development of the environment. It would be most desirable

that, under these conditions, an institution dealing with Conservation and Development be established in the countries at the highest governmental level with a view to advising the government regarding its policy on national utilization of natural resources. It should ensure that projects related to national development take into account the demands of ecology in the preservation of resources. It should have sufficient authority to permit its point of view to be accepted by those responsible in the government for the administrative and legal aspects and to be able to influence their decisions. Its competence should extend equally to questions of prospection and scientific inventories and to questions of planification and legislation with a view to promoting the rational utilization of resources and to preserving the quality of the environment.

Such boards or commissions of Conservation and Development are required in urban, county, provincial, state or regional governments as well as at a national level.

Only an integration of actions such as those described above will lead the world toward the rational management of the land areas of the planet. The September 1968 Intergovernmental Conference of Experts on the Scientific Basis for Rational Use and Conservation of the Resources of the Biosphere which is convened and organized by Unesco with the United Nations, the Food and Agriculture Organization of the United Nations and the World Health Organization participating, will allow a first detailed analysis of the steps to be taken at national and international levels and establish the basis for a long-term action in this domain.

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