natural resources research X

use and conservation of the biosphere

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use and conservation of the biosphere

Proceedings of the intergovernmental conference
of experts on the scientific basis
for rational use and conservation
of the resources of the biosphere
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Foreword

This tenth volume in the Natural Resources Research series presents the proceedings of the Intergovernmental Conference of Experts on the Scientific Basis *for Rational Use and Conservation of the Resources of the Biosphere*, held at Unesco Headquarters in Paris from 4 to 13 September 1968. This conference was organized by Unesco, with the assistance of the United Nations, the Food and Agriculture Organization and the World Health Organization, and in co-operation with the International Biological Programme and the International Union for Conservation of Nature and Natural Resources. The conference was attended by 238 delegates from 63 Member States and 88 representatives from six United Nations Organizations, seven other intergovernmental organizations, *eleven non-governmental organizations* and *three foundations*.

In the context of this conference, the biosphere was taken as that part of the world in which life can exist, including therefore certain parts of the lithosphere, hydrosphere and atmosphere. Work bore mainly on the terrestrial part of the biosphere, including inland waters and coastal areas, but excluding oceanic resources, which are covered by other international conferences. The resources considered were biological ones, including the soils and waters on which they depend: they did not include inorganic resources, except in so far as *these provide a medium for the support of plant and animal life.*

The discussions of the conference were based on reports presented by Member States and ten review papers which had been prepared and circulated in advance to the participants. The conference adopted a series of recommendations to Member States and international organizations relating to fields of research, education at all levels, and scientific policy and structures.

The present volume includes the ten background papers, as revised in the light of the discussions of the conference, and the official report of the conference *in which will be found a summary of the discussions*, the conclusions and the recommendations. It also includes the texts of the addresses given at the inaugural session by Mr. Malcolm S. Adiseshiah, Deputy Director-General of Unesco, Dr. M. G. Candau, Director-General of WHO, Mr. A. H. Boerma, Director-General of FAO, and Mr. Guy Gresford, Director for Science and Technology, Ecosoc, representing the Secretary-General of the United Nations.

The recommendations of the conference were considered by the General Conference of Unesco at its 15th session, which called on the Director-General to present at its 16th session in October 1970 a long-term intergovernmental and interdisciplinary programme on the rational use and conservation of the natural environment and its resources. The programme will be prepared on the basis of the deliberations, conclusions, and recommendations set out in this volume.

Contents

Contemporary scientific concepts relating to the biosphere

This paper was prepared on the basis of a draft submitted by Professor V. Kovda and his collaborators (U.S.S.R.), with comments and additions by Professor Frederick Smith (U.S.A.), Professor F. E. Eckardt (Denmark), Dr. M. Hadley (United Kingdom), Dr. E. Bernard (Belgium) and the Secretariats of Unesco and FAO.

The needs and requirements of human society are increasing every decade. The population of the planet is growing at an exponential rate. Industrialization is accompanied by a vast exploitation of natural resources and by a profound change in the natural environment. The ploughing of large territories of land (about 11 per cent), its use for pastures (17 per cent), the felling of forests, the construction of dams and canals, mining, fertilization, irrigation, soil erosion and many other results of man's activities, cause considerable changes in nature. These changes are often of destructive character (including nuclear bomb explosions) and what is particularly dangerous for mankind's future, of irreversible character, breaking the established systems and relations in the biosphere of the Earth.

The biosphere is endowed with a marked stability with respect to external influences, that is a considerable plasticity. This plasticity represents an important asset for man, as it enables him to use and to transform the components of it to a large extent, according to his needs. This transformation, however, cannot be carried beyond certain limits, otherwise it may imperil the established relationships of the dynamic equilibrium of the biosphere. In some large areas of the globe these limits have already been transgressed, resulting in the deterioration of considerable parts of the biosphere as well as of the disappearance of numerous plant and animal species, freshwater basins and soils. Man and his society live within, and constitute an important part of, the biosphere and use the resources of the biosphere. The protection of the biosphere is of great importance to him.

It is therefore urgent that countries of the world should work out programmes of joint activities aiming at:

1. Preserving and improving the biosphere.
2. Further developing the rational use of its resources.

The recommendations on the preservation and use of the resources of the biosphere should be based on the knowledge of the origin and structure of the biosphere, the interrelationships of its components and the mechanisms maintaining its functions in nature.

THE BIOSPHERE OF THE PLANET EARTH AND ITS PECULIARITIES

The surface of the planet Earth is continually exposed to the influence of flows of energy coming from space. For billions of years this energy has been pouring onto the surface of the Earth, causing processes of immense intensity, bringing about most complicated changes of the structure and permanent evolution of matter. The result has been a diversification within the 'mineral realm' as well as the creation of an immense variety of different forms of organisms, interrelated in the most intricate ways with the environment and with each other.

The Earth as a planet has existed for about 4.5-5 $\times$ 10^9 years (most probably not more than 6 $\times$ 10^9 years). A distinct manifestation of life occurred some 2.5-3 billion years ago, though primitive forms of life may have existed before, and about half a billion years ago life started to conquer the land. Since then radical changes have taken place in the structure, condition and processes of the Earth. The complex structures of living organisms so different from those of inanimate matter appeared on Earth. In the course of the evolution of life, about 3 million species of animals, plants and micro-organisms came into being.

Among the living organisms a special place was taken by green plants capable of synthesizing organic substances with the aid of the radiant energy of the sun.

The development of life resulted in the formation on Earth of a new structural unit known as the 'biosphere'. The biosphere is one of the outer parts of the globe in which life developed in the form of a large variety of different organisms inhabiting land surfaces, the soil, the lower layers of the atmosphere and the hydrosphere. Basically, the biosphere is a product of the interaction between biotic and abiotic substances. Due to the activities of the plants, the biosphere stores and distributes energy coming to the Earth from space.

Living organisms represent important biogeochemical agents that transform the planet's crust. The migration and differentiation of chemical elements on the surface of the Earth, in the soil, in sedimentary formations, in the atmosphere and in the hydrosphere occur either with direct participation of the living matter (biogenic migration) but also take place in the media, the characteristics of which (pH, redox, O_2, CO_2, H_2S, H_2O, etc) are, or were, influenced by living matter.

For the billions of years of existence of life on Earth, living matter has converted an immense quantity of radiant energy from the sun into effective chemical and mechanical work. The atoms of almost all the chemical elements have passed through living matter innumerable times in the course of complex cycles. The appearance of the planet has greatly changed and it may be considered that it is living matter that has determined the composition of the atmosphere, sedimentary rocks, soil and, to a great extent, the hydrosphere.

However, V. I. Vernadsky noted that the definition of the concept of the biosphere to include only a space which holds life is incomplete and insufficient. The biosphere includes three main components, the first of which is 'living matter' (totality of organisms determined quantitatively by the 'biomass'). The second biosphere component is 'biogenic matter', i.e., organo-mineral and organic products created by living matter. They include coal, bitumen, combustible gases, probably petroleum and, in particular, peat sapropel, and soil humus and litter. The third biospheric component is 'biocosnic matter', a term used by V. I. Vernadsky to designate the mineral materials formed by the association of living organisms and dead nature, as for example, the gas composition of the lower layers of the atmosphere, sedimentary rocks, clay minerals and water (Vernadsky, 1926, 1934).

Solar energy is fixed and utilized by the green plant in the form of organic substances, and then conserved for a long time as biogenic and biocosnic substances. Geochemically speaking, these substances have for a geologically long time been moving with flows of air and water to depressions of the land, to the seas and oceans, where thick layers of sedimentary rocks containing biocosnic and biogenic substances and organic remains are being built up. All this resulted in a considerable 'biologization' of the planet, its lithosphere, atmosphere and hydrosphere.

This provides a basis for considering the biosphere of the Earth as an ancient, extremely complex, multiple, all-planetary, thermodynamically open, self-controlling system of living matter and dead substance, which accumulates and redistributes immense resources of energy and determines the composition and dynamics of the Earth's crust, atmosphere and hydrosphere. For this reason, the biosphere has stability and plasticity, mentioned briefly above.

One of the most important peculiarities of the biosphere is the extreme diversity of living organisms, which has developed in the course of a long evolution, and which results in its stability and dynamism in time. In nature, living organisms are in constant interaction with the environment and each other, both within a single population and within biocenoses.

Another peculiarity of the biosphere is the irregularity and the mosaic pattern of its structure and, so to speak, its absolute asymmetry. The distribution and ratio of the continents and oceans is asymmetric. The distribution of mountain chains, great alluvial plains and the world hydrographic network is asymmetric. The distribution of life and living matter on the land and in the ocean is uneven. The largest concentration of living matter is characteristic of shallow waters and of the surface layers of water basins (including the horizons of plankton in seas and oceans). The concentration of living matter in the soils of humid temperate, subtropical and tropical zones is high. The smallest concentration of living matter is typical of cold polar and subpolar areas, arid countries and deserts, high mountains and ocean depths. The concentration of life in the atmosphere is, in general, low. On the continents, living and biogenic matter is particularly concentrated in the flood plains and deltas of rivers, in shallow lakes, in humid forests, in prairies and in meadow plains.

The biosphere, considered from the historical standpoint, that is its evolution from its appearance to its present state, is the result of the long-term evolution of organisms and the interaction and interrelationship of astronomic, geophysical, geochemical and biological factors. The atmosphere of the Earth, of favourable gas composition and density, which can be retained by a considerable planetary mass, is associated with a not fully regular orbit and with the inclination of the Earth's axis. These create, with the energy of the sun, the light and temperature conditions essential and favourable for life.

The main structures of the Earth's surface are the world oceans, which occupy two-thirds of the Earth, the continents, the fresh-water reservoirs of the land, the glaciers of the Arctic, Antarctic and the high mountains. The continents are not similar in their structure, and differ in climatic zones and geochemical facies. On each continent there are regions of denudation and geochemical outflow with poor acid crusts of weathering and poor soils (areas of eluvium). They are bordered by areas of transit and accumulation situated on the foothills, plains and plateau slopes, on the inlands or coastal plains with fertile, rich soils.

In the areas of transit and accumulation, when the humidity is sufficiently high, as well as on the continental shelves, the most favourable conditions are created for the development of life and for the formation of living matter (e.g., meadow steppes of the Russian Plain, the pusts in Hungary, the prairies of America, the Far East, the pampas of Argentina, the lowlands of the Amazon, etc.). From the point of view of geochemistry, such widespread areas are characterized by a definite stability of the composition of migrating and accumulating compounds, the level of which may be below or above the biological optimum for certain organisms, including man. These areas, involving an unusual level of concentration of chemical elements in the environment are called, by Vinogradov, biogeochemical provinces (Vinogradov, 1938, 1946). In Asia, Europe, Africa, North and South America, there are provinces of contemporary or ancient accumulations of chloride-sulphate salts or soda, as well as provinces with excess of boron (Kovda, 1953). Some of these provinces, as for example the acid podzol soils of Eurasia, are characterized by a deficit of iodine, magnesium, calcium, copper and sulphur. The excess or deficit of important biophilic elements often leads to specific illnesses of man, dwarfing, and low productivity of animals and plants.

The elementary primary structural unit of the biosphere is the 'biogeocenose', that is, genetically, geographically and trophically linked local combinations of vegetation, animals, soils, relief, climate and hydrology (V. N. Sukachev, 1948, 1964). In some countries the word 'biogeocenose' is used to designate similar units. The biogeocenose (ecosystems)[1] are parts of land or water surface, homogeneous in respect to topographic, microclimatic, botanical, zoological, pedological, hydrological and geochemical conditions. In this system, the circulation of matter and energy is put into being with a characteristic direction and certain intensity. The starting point of the circulation of matter is the photosynthesis carried out by plants. The actual dimensions of the biogeocenose-ecosystem on the planet vary within a wide range from a few metres (micro-depressions in the steppes and semi-deserts, sand dunes, etc.), to kilometres (saltmarshes, takyrs, homogeneous parts of steppes, forests, etc.). The vertical dimensions

1. There is unfortunately some confusion regarding the synonymy of the words 'biogeocenose' and 'ecosystem'. Ecosystems are subdivisions of biogeocenoses, the latter including a broader concept, but this appreciation is not shared universally. In a Unesco symposium on the 'functioning of terrestrial ecosystems at the primary production level', held in Copenhagen in 1965, the proceedings of which were published by Unesco in 1968, the two terms were used as synonyms. This has been maintained in the present paper.

of the ecosystem also vary considerably: from a few centimetres on rocks to some tens of metres in the taiga or a tropical forest.

The ecosystem (biogeocenose) is a system relatively stable in time and thermodynamically open with respect to the inflow of substance and energy. This system has an input (solar energy, mineral elements of rocks, atmosphere, ground waters) and an output of energy and biogenic substances into the atmosphere (heat, oxygen, carbonic acid and other gases), the lithosphere (humus compounds, minerals, sedimentary rocks) and the hydrosphere (dissolved biogenic substances of subsurface, river, lake and other waters).

The self-controlling aspect of the biosphere results from the auto-catalytic property of living matter, its ability to absorb substances, to grow and reproduce. Organisms actively seek and capture their needs. Thus, the flow of energy and matter from plants to herbivores depends very much on the number and biomass of herbivores present. By contrast, the change from living to dead organic matter is not greatly influenced by the amount of dead organic matter present. The dead organic matter passively receives material at a rate determined by other factors.

At present, biology distinguishes the following levels in the organization of living substance on the Earth.

The first level of the organization of living matter is the existence and the activity of biologically active macromolecules (macromolecular level). The second level of the organization of living substance is the cell (cellular level). The third level should be considered as the level of the organism (species). The fourth level of the organization of living matter is the population. But the ecosystem level is a still higher manifestation of life organization in its stability in geological time. The biosphere as a total combination of ecosystems is the highest level of the organization of living matter on the Earth.

Ecosystems were formed in the process of a long evolution and adaptation of species and populations of organisms to the environment and to each other. They are adjusted, stable mechanisms capable of resisting, by self-control, changes in the environment as well as rapid modifications in the number of organisms.

But there are limits to self-control in populations, ecosystems and the biosphere as a whole. If the changes in the environment (soil, ground water, atmosphere, tectonics, climate) are more extreme than the periodic oscillations to which organisms are adapted, the harmony of the ecosystems is irreversibly disturbed. Still more profound consequences occur in landscapes when, under the influence of natural phenomena (forest fires, shifts of rivers and deltas, etc.) or erroneous activities of man (erosion, immoderate use of pesticides), one or several elements disappear as a whole or in separate trophic chains in the ecosystem. In these cases the ecosystem suffers catastrophic changes and undergoes a radical reorganization.

Ionic radiation of the planet is known as a normal ecological factor to which almost all the organisms inhabiting the Earth are adapted. Local or general increase of ionic radiation caused by nuclear tests and other radionuclear activities may increase the number of new mutations of various types among living organisms (monstrosities, hereditary diseases, loss of valuable hereditary characteristics, etc.).

The knowledge of relationships between populations of organisms of different types in ecosystems (symbiosis, parasitism, allelopathy, competition, predatism, etc.), makes it possible to manipulate ecosystems by using biological methods both for the extermination of certain groups of organisms such as destructive insects and for the support of others, e.g., insect pollinators. The use of chemical toxic substances should be, as a rule, carefully controlled and minimized.

In modern industrialized society, based on scientific planning and expedient use of the laws of nature and means of science, technology and industry, the biosphere can be manipulated as a man-controlled system, which will provide the most favourable conditions for the welfare of mankind. Any manipulative measures must of course take account of the limits of tolerance and plasticity of the biosphere.

LIVING SUBSTANCE, ITS COMPOSITION AND FUNCTIONS

The notion of 'living substance' was developed in detail by Vernadsky. It implies the totality of organisms inhabiting our planet at some moment or another. The living substance of land is quantitatively determined by 'phytobiomass', this including living plants with roots, by the 'zoobiomass' of animals (including insects) and by the 'microbiomass' of bacteria and fungi. According to recent calculations, the total biomass of the whole land surface is about 3×10^{12} tons, and not more than 1×10^{13} tons. The zoobiomass of the land is usually less than 1 per cent of the vegetational biomass. The main part of the zoobiomass (95-99.5 per cent) is attributable to invertebrate organisms. Especially high is the proportion of invertebrates in the most fertile chernozems, in meadow soils, and in soils of old, highly developed farms (99.8 per cent of the zoobiomass).

The biomass of arborescent communities constitutes the major part of total biomass on land. It is, however, the herbaceous vegetations, not the arborescent perennial vegetation, that contributes most significantly to the formation of soil fertility. The biomass of herbaceous vegetation and invertebrates in combination with micro-organisms stimulates the synthesis of considerable masses of humus in the most fertile chernozems and soils of meadows, prairies and flood plains.

The fixation and accumulation of enormous quantities of energy in organic matter is the most important phenomenon introduced by life on the planet. This potential energy is later on used by an endless chain of associated organisms and biochemical and chemical reactions.

The formation of plant organic matter due to photosynthesis corresponds to a conversion of solar energy into chemical energy. According to Duvigneaud (1967), an enormous quantity of energy is fixed annually during land photosynthesis, equivalent to 21.3×10^{16} calories. About the same quantity of energy is fixed by oceanic vegetation. The energy accumulated in plant matter then affects activities of animals and bacteria. Organic remains in soils and soil humus are a source of energy, the supplies of which are constantly renewed and at the same time are continuously used by soil micro-organisms and biochemical reactions in pedogenesis in a most effective way.

Taking into account the ideas of V. I. Vernadsky, it is necessary to distinguish the following forms of influence of organisms upon the environment in evaluating the role of living substance:

1. There is a gradual but continuous process involving the evolution of life on Earth, including the formation of new species and their disappearance; on the average, each independent species, for example a plant, exists approximately one geological period or about 30 million years.
2. There is a change of types of ecosystems in connexion with the multiplication of organisms and the occupation of the surface. Such a change is connected with tectonics and modifications of the relief, the climate and the soils. Examples are found in the interrelations of forests and tundra, steppes and forests, deserts and steppes, flood plains and ancient terraces, etc. These changes last about 3,000-5,000 years and often are of periodic character, reflecting tectonic rhythms.
3. There are consecutive generations of certain plant and animal species and cycles of migrations of substance, caused by the birth and the death of each single living individual.
4. There are exchanges of substance between the organism and the environment during a lifetime, This type of exchange of substance involves solid, liquid and gaseous phases and has very important repercussions in geology, hydrochemistry and pedogenesis.
5. There are trophic and symbiotic relations of various organisms among each other, such as food chains, redistribution of energy, mineral and organic compounds.
6. There is a considerable post-mortem influence of the products of biolysis and those of mineralization of organic substances on mineral formation and processes in nature.
7. During their lifetime, organisms influence the processes of disintegration of rocks, and intervene in the formation and destiny of minute soil particles which form the soils.

The role of living matter in the processes of weathering, pedogenesis and sedimentation, and in changes of water and gases in the past, has been growing constantly due to the fact that the number of species with different biogeochemical functions has gradually increased. The upper and lower limits of the biosphere have expanded and solar energy has been playing a more and more important role in the Earth's processes. The deeper layers of the Earth's crust, hydrosphere and atmosphere are affected by biological cycles.

At any given moment, living matter includes billions of tons of organic compounds. Organisms return billions of tons of substance to the environment (to the soil, to the atmosphere, and to natural waters) and take them up again. The close interdependence of different animal and plant organisms, as well as the lower organisms connected with them, results from the fact that mineral compounds taken away from geological cycles as part of the process of nutrition and growth have a tendency to be retained in biological cycles, preventing them from being carried away by natural waters from the land to the ocean.

The greatest percentage in the composition of living substance is contributed by oxygen (65-70 per cent) and hydrogen (about 10 per cent). The rest (20-25 per cent) is represented by various elements, the total number of which exceeds seventy.

In the composition of living substance there are also dispersed rare trace elements totalling not less than fifteen by number.

Certain specific organisms are capable of accumulating certain elements in quantities of more than 10 per cent. At present such a specific accumulative role is well known for Si, Al, Fe, Ca, Mg, Ba, Mn, S, Sr, and P. As regards the composition of plant organisms, the average content of certain groups of elements is much higher when compared with that of the Earth's crust and lithosphere. This involves, for instance, an increase in content for H and O of several tens of per cent, while it is thirty times higher in N and one hundred and eighty times in C.

The content of Na, Ca, P, N, S, F, Cl, Zn is much higher in the composition of animal organisms than in that of plant organisms. But in animal organisms there is less O, Si, Al, Mn, B, Pb, As, than in plant organisms.

All this points to the need of distinguishing and differentiating the so-called biogeochemical functions of living matter which play an exceptionally important role in atmospheric, hydrological and soil processes.

These functions are as follows.

GASEOUS EXCHANGE FUNCTION

The metabolism of organisms, their respiration and exchanges with the environment all involve a vast combination of various gas reactions resulting in the absorption and discharge of O, CO_2, NH_3, CH_3, water vapour, etc. Ultimately, the history of the atmosphere, the air in the soil, the air dissolved in the waters of rivers and oceans, are all connected with the gaseous functions of organisms.

All the carbon dioxide of the atmosphere could pass through the photosynthesis of the Earth's plants in about ten years. Vernadsky assumed that in one year organisms bring into circulation gases in various forms and in quantities exceeding several times that of all the gases existing in the atmosphere. In the course of their history, oxygen, nitrogen and carbon dioxide of the atmosphere and soil air may all have passed many times through living matter.

The oxidizing processes of organisms constitute a part of the gaseous exchange process which is a combination of photosynthetic reactions resulting in the appearance and accumulation of free oxygen in the atmosphere.

OXIDIZING FUNCTION

The oxidizing activity of organisms plays an important role in the process of weathering, in the migration and sedimentation of substances, in the chemical composition of water and the atmosphere, and in the evolution of pedogenetic processes.

The appearance of autotrophic micro-organisms side by side with green plants has radically changed the conditions of oxidation and reduction on the surface of the Earth's crust. The predominance of a reduction régime, caused by a relatively high percentage of carbon dioxide and a relatively low content of oxygen in the atmosphere of the earth in the most ancient geological eras of the distant past, was changed by a predominant influence of an oxidation régime, connected with activities of oxidizing bacteria and an increase of oxygen in the atmosphere.

The fate of such elements as Fe, Cu and Mn, as well as compounds of C, N, S and P, was essentially changed after the appearance of bacteria, algae and, especially, higher plants and animals.

REDUCING FUNCTION

The appearance of micro-organisms capable of existing and developing in anaerobic media has introduced important changes in reactions leading to the reduction of mineral and organic compounds. Reducing functions are mainly performed by bacteria and fungi leading to the development of reactions of desulphurization and denitrification with the formation of hydrogen sulphide, nitrogen oxides, sulphurous metals, methane and hydrogen. The formation of sedimentary rocks under water and pedogenesis under anaerobic conditions is usually accompanied by a distinct, increased influence of micro-organisms causing reduction reactions.

CONCENTRATION AND SECRETION OF CALCIUM SALTS

Processes leading to the concentration and secretion of poorly dissolving calcium salts in the form of carbonates, phosphates and some organic salts (oxalates and others) are particularly important in biogeochemistry and soil formation. Numerous species of bacteria, protozoa, algae, mosses, higher plants and animals, are capable of concentrating and secreting calcium salts in the form of insoluble precipitates. Enormous quantities of calcium are accumulated by organisms in limestones and chalk.

At the earliest stages of geological history, only chemical processes involving migration and accumulation of calcium salts took place. With the evolution of life on Earth, however, these gave way to biogenic forms of circulation and accumulation of calcium salts in the hydrosphere and in soils. This is also true for iron and manganese.

CONCENTRATION OF ELEMENTS FROM DISPERSED STATE

The permanent presence of a great number of chemical elements in animal and plant tissues and, in particular, the selective absorption of certain elements by some types of organisms, leads to the accumulation of these elements in biogenic sedimentary layers and humus horizons in a distinguishable form.

Soil fertility, as far as the chemical aspect is concerned, is linked with the presence of the elements that are involved in the mineral nutrition of plants (P, K, B, S, Ca, Zn and others). This is due to the ability of organisms to accumulate these elements in their tissues and to transfer them to the upper soil layers. The development of life on Earth contributes to a permanent increase of biogenic concentration of biogenic elements in soil horizons, in silts, sapropels and in sedimentary rocks.

SYNTHESIS AND DECOMPOSITION OF ORGANIC MATTER

The continuous circulation of biological substance is connected with constant and successive processes of synthesis and destruction of organic matter. Up to 55×10^9 tons of plant organic matter is formed and destroyed every year on land surfaces.

This enormous and continuous activity involving the destruction of organic matter, its resynthesis and mineralization is performed by herbivores, carnivores, fungi, bacteria and especially worms and insects. Ultimately more than 90 per cent of the mass of organic matter is gradually converted into the gaseous phase and the rest into different mineral and intermediate organic compounds.

In the course of geological history, large masses of peat, coal, bitumens, petroleum and dispersed organic matter were buried in sedimentary deposits. Carbon and hydrogen, being integral parts of this matter, constitute 'geochemical accumulators' of solar energy fixed at the surface of the earth. Being oxidized at depth, these accumulators discharge and give back their energy. Oxidation processes may be carried out by micro-organisms living in subsurface waters.

It can be supposed that, in subsurface waters, the development of highly reductive conditions, as well as the appearance of H_2S and the sedimentation of sulphides of metals, are all geochemical consequences of photosynthesis and the development of highly oxidizing conditions on the earth's surface. It is possible that sulphide ores of the biosphere (cupreous sandstones and others) appeared at a certain stage of the evolution of the Earth's crust in connexion with the development of life (Perelman, 1968).

Sedimentary rocks, the products of the biosphere, repeatedly descended into greater depths in geosynclines, and by melting, turned into metamorphic rocks and granite. These, after being taken by orogenesis to the Earth's surface, were destroyed and in turn produced the materials for new sedimentary rocks. In this way the great circulation of matter and energy in the earth's crust occurred. For this reason many scientists share the opinion that the granite layer of the Earth's crust is made of smelted sedimentary rocks from 'former biospheres'. The conception of the 'great geological circulation of matter' linking magmatic and surface processes to each other is receiving ever more attention. The elaboration of all these complex questions has just started and the problem is still at the stage of hypothesis. Nevertheless, these ideas are tempting. They promise to establish the enormous role of solar radiation as a source of energy, not only for surface processes but also for the processes of magmatic and tectonic cycles.

Until recently, the earth and life sciences had developed in isolation. For instance, the study of magmatic processes and tectonic evolution of the Earth's crust was hardly linked with the study of evolution of life on Earth, or the geological activity of living organisms of the biosphere. In the elaboration of the general theory of geology and biology, it is necessary to take into account the possible existence of deep and reversible dependencies between the evolution of life on Earth and sedimentation, tectonic phenomena and magmatism.

The impact of living matter on the course of geochemical, atmospheric, hydrological and soil processes appears in the form of circulations of matter. These circulations are not closed and are not reversible. True, some small biological cycles of matter linked with living activities of short-lived organisms appear as closed and reversible. This is particularly true for cycles involving O, C, N, P, S, H. Nevertheless, when chemical elements continuously circulating in living matter and in the environment are taken up by new organisms in the course of nutrition or mineralization, a certain part of these elements is excluded from biological circulation and is carried away by geochemical processes into sedimentary deposits and into the ocean. Such is the case of Cl, Na and a considerable part of C, Si, P, K, S, Mg, Ca. Gradual accumulation of oxygen in the atmosphere, and slow but nevertheless distinctive decrease of the content of carbon dioxide in the air during the past, is of irreversible character. The formation of biogenic deposits of lime, silicon and phosphates was also irreversible in the evolution of living matter.

The predominance of oxidation conditions in the Earth's crust became irreversible after the appearance of green plants. In connexion with these changes, the conditions of migration and accumulation of compounds of Fe, Mn, N, S and P were also changed. Deposits of coal, petroleum, bitumes, peat, oil shales, sapropel, were formed in the Earth's crust after alteration of the carbon cycle. The ratio of isotopes of oxygen, carbon and sulphur also changed.

The soil cover of the Earth is a product of the influence of living matter on the lithosphere. The formation of a more or less continuous humus layer enveloping the surface of the land is the most universal and most significant result of the biogenic transformation of rocks into soils. This layer can be called by a specific term: 'humosphere'. Irrespective of its thickness, this humosphere is the most active part of the natural soil cover, determining the level and potential of its fertility.

The accumulation of specific organic matter within surface horizons of the Earth's crust and the formation of a humus layer mark a definite phase in the history of circulation of carbon and nitrogen on Earth. According to recent calculations, the duration of the cycle of carbon circulation, subsequently involved in the formation of phytomass, zoomass and microbiomass in soils, including the mineralization of soil humus, should be 200-600 years on the average and not longer than 1,000 years. These calculations are based on estimates that the total biomass of the land is $n \times 10^{12}$ to 10^{13} tons and the amount of annual synthesis of terrestrial phytobiomass of the land is about $1.5\text{-}5.5 \times 10^{10}$ tons.

A certain part of organic matter is used in the formation of permanent deposits and in addition is excluded from the pedogenetic process, being taken away into sedimentary rocks and utilized for the formation of sapropel, peat, etc. Thus, the formation of the humus layer of the land is a part of a more general planetary circulation of carbon that involves photosynthesis, food chains, pedogenesis and mineralization of organic matter to give carbon dioxide.

The synthesis of plant biomass entails not only the absorption of carbon, hydrogen and oxygen to form organic matter but also the transformation into this organic matter of a considerable number of mineral elements.

The average content of ash elements in plants is 5-8 per cent of the total by weight, but this may range from 1 per cent to 40-45 per cent (in halophytes). Terrestrial plant biomass fixes annually enormous amounts of different mineral substances—in total about 10^8-10^9 tons. The final destination of the mineral substances and nitrogen compounds of the biomass is entirely different from that of carbon, oxygen and hydrogen. In the process of decomposition of organic matter, the mineral compounds enter the soil where they accumulate, together with humus, in the upper horizons. The biogenic accumulation of elements in pedogenesis is the second aspect of the transformation of rocks into soil through the influence of organisms. The amount of mineral compounds involved in this circulation is far from being equal in different plant associations. Grass vegetation of steppes and meadows brings into circulation up to 500-700 kg per hectare per year of ash compounds, whilst in coniferous forests only 70-200 kg of ash compounds per hectare per year are brought into the biological cycle. Vegetation of semi-deserts and deserts involves even smaller amounts. Man can change such biological circulation of mineral substances by changing the structure of cultivated vegetation and by the introduction of fertilizers.

In Table 1 data are given which characterize terrestrial biomass and which compare the cycling of ash elements with the dissolved and solid particles carried by rivers (outflow). All the figures given have a similar order.

TABLE 1. Biogeochemical agents in the biosphere

Biomass of the land	3×10^{12} — 10^{13} tons
Annual organic photosynthesis on land	$1.5\text{-}5.5 \times 10^{10}$ tons
Annual return of ash and nitrogen as litter	$n \times 10^{8}$ — 10^{9} tons
Total dissolved outflow of rivers	3×10^{9} tons
Total solid outflow of rivers	1.6×10^{10} tons

Both living substances and soil humus accumulate and redistribute solar energy, thus bringing about the chain of mechanical and chemical activity, and biochemical reactions, which constitute the essence of pedogenesis. Without this energy the activity of soil organisms is inconceivable and pedogenesis and bioproductivity are impossible.

BIOLOGICAL PRODUCTIVITY OF THE MAIN ECOSYSTEMS OF THE EARTH

The most important function of the biosphere is the continuous planetary reproduction of living substance (biomass), accumulating and conserving energy. This process is becoming more and more important in the life of the planet and in the use by man of its resources.

The study, both quantitative and qualitative, of the mass of organic matter actually synthesized in the biosphere makes it possible not only to estimate more precisely the biological productivity which may be attained, but also to understand the nature and the laws governing the biosphere, its energetics and geochemistry. Such an estimation will therefore constitute the scientific basis for the conservation and development of the resources of the biosphere, that is for the increase of productivity in general.

In the processes of photosynthesis, leading to the formation of phytobiomass, only a very small amount of incoming solar energy is used, about 0.2-0.5 per cent on the average and not more than 1 per cent (up to 3-4 per cent in the best farms).

The total incoming solar energy on Earth is approximately 5×10^{20} kcal/yr. About $1.1\text{-}1.7 \times 10^{20}$ kcal/yr is received by land surfaces and the rest, $3.3\text{-}3.9 \times 10^{20}$ kcal/yr, is received by the oceans.

According to Duvigneaud, plants annually photosynthesize up to 3.0×10^{10} tons/yr of organic substance in oceans, and 5.3×10^{10} tons on land.

In total, therefore, up to 8.3×10^{10} tons of organic material are photosynthesized annually on the planet. Of the 5.3×10^{10} tons produced on land, forests account for 2.84×10^{10} tons. The rest is synthesized by herbaceous and cultivated vegetation.

Duvigneaud distinguishes the following main levels of productivity:

1. Deserts and deep oceans characterized by a minimal productivity of 0.1 g of carbon per square metre per day.
2. Meadows, steppes, fields and shallow waters with a daily productivity of 0.5-3 g of carbon per square metre.
3. Prairies, forests and cultivated fields with a daily productivity of 3-10 g of carbon per square metre.
4. Tropical forests, intensively cultivated fields, landscapes derived from flood plain and estuaries, with a daily productivity of 10-20 g of carbon per square metre.

The estimation of the productivity of particular phytogeocenoses is difficult, but should nevertheless be undertaken, To enable this, the following parameters should be estimated: (a) total standing crop (including both aerial and underground parts) of the phytocenose; (b) total annual dry-matter production (aerial and underground parts); (c) chemical composition and mass of food elements involved in biological cycles (ash elements and nitrogen); (d) average ash content in annual phytomass production; (e) the number of metabolites (based on the study of balance of food elements) involved annually in the synthesis of phytobiomass; (f) intensity of decomposition of plant detritus, calculated from the ratio between weight of litter and weight of litter fall (green parts).

Let us consider new data obtained in the Union of Soviet Socialist Republics on the distribution of phytobiomass on the land. The lowest amounts of phytobiomass are characteristic of subtropical and tropical deserts (less than 2.5 tons per hectare). Polar deserts, subpolar cenoses, sub-boreal deserts and salt-affected soils into the next category of phytobiomass (2.5-5 tons per hectare).

The standing crop of phytobiomass is about 12.5-25 tons per hectare in the tundra, 50 tons per hectare in forest tundra and up to 300-400 tons per hectare in the taiga.

For broadleaved and subtropical forests an even higher amount of phytobiomass is observed (400-500 tons per hectare).

The largest amounts of phytobiomass are found in humid-tropical evergreen forests (more than 500 tons per hectare). In Brazilian forests, for example, 1,500-1,700 tons per hectare have been recorded. Steppes, mountain meadows, pampas, xerophytic park forests and savannahs, as well as mangroves, have a phytobiomass of 12.5 to 150 tons per hectare.

The data of N. I. Bazilevich and L. E. Rodin (1967) give the basis for arriving at a number of important conclusions about the production of terrestrial phytocenoses. Knowledge of this phenomenon is still scanty, however, and calculations and figures so very approximate that much work needs to be done in the future.

The highest standing crop of phytobiomass occurs in forests but a high annual production of phytobiomass is characteristic not only of forests but also of grass communities such as savannahs, prairies, pampas, steppes and landscapes derived from flood plain. It is worth while to point out that entirely different phytocenoses, situated far away from each other, may produce a similar amount of phytobiomass (for example, tundra and dry steppes). Annual yield of phytobiomass is similar for broad-leaved forests and pampas, for northern taiga forests and dry steppes, etc.

The chemical composition of organic matter is quite different, however, in different phytocenoses. The lowest percentage of ash, 1.5-2.5 per cent, is characteristic of tundras and forest-tundras, coniferous and conifer-broadleaved forests; a medium percentage of ash, 2.5-5 per cent is characteristic of alpine and subalpine meadows, steppes, some sub-boreal deserts, broadleaved, subtropical and tropical forests, wooded flood terraces with grass of the 'tugai' type, open woodland and savannahs; a high percentage of ash, 5-8 per cent, is typical for subtropical, tropical and sub-boreal deserts, as well as for mangroves; the highest percentage of ash 20-30 per cent, is typical of solonchak vegetation. The consumption and release of ash compounds and nitrogen in grass cenoses will always be higher than for broadleaved forests with the same annual dry-matter production. Consumption and release of these elements in broadleaved forests is higher than in coniferous forests. Of course there is variation in the chemical composition of plants as a result of different rates of productivity, selectiveness of mineral uptake and different geochemical composition of the environment.

The ratio between litter mass and mass of annual litter fall (green parts) constitutes a measure of the speed of decomposition of the litter and the release of chemical elements; thus it gives an idea of the intensity of biological circulation. The higher the index, the lower becomes the intensity of biological circulation within a given ecosystem (Bazilevich and Rodin, 1967).

The index is highest in swamp forests (more than 50) and in dwarf shrub tundra (20-50), Circulation within these communities (according to the 10-grade scale) can be considered as stagnant. This index is considerably lower (10-17) in dark coniferous taiga forests, where biological circulation is slow. In broadleaved forests the index is 3-4. The decomposition of the organic matter of the litter is very active in steppes where the index is close to 1-1.5 and where biological circulation can be thought of as intensive. In subtropical forests it is even lower, about 0.7, and in savannahs, the index is not more than 0.2. Almost no dead plant remains are accumulated in humid lowland tropical forests where the index is not higher than 0.1 and biological circulation can be considered to be very intensive.

During the transition from one trophic level to another the loss of biomass may be in the order of 100-1,000 in natural biogeocenoses (Table 2). The ratio between the phytomass and total biomass of herbivores is as follows: tundra: $n \times 10^4$; taiga: $n \times 10^5$; coniferous-broadleaved forests: $n \times 10^5$; wood steppes: $n \times 10^3$; steppes: $n \times 10^2$ and deserts: $n \times 10^2$.

TABLE 2. Gross biomass (dry weight-kg/hectare) of vegetation cover and population of vertebrates

Trophic level	Tundra	Taiga	Broadleaved forests	Steppes
Vegetation (above ground, according to Basilevich and Rodin)	$n \times 10^3$	$n \times 10^5$	$n \times 10^5$	$n \times 10^2$
Phytophagous animals	$n \times 10^{-1}$	$n \times 10^0$	$n \times 10^0$	$n \times 10^0$
Predators	$n \times 10^{-3}$	$n \times 10^{-2}$	$n \times 10^{-2}$	$n \times 10^{-2}$

Table 2 shows that three types of ratio may be distinguished: tundra, forest and steppes. However, in all these biogenocenoses each kilogramme of a herbivore corresponds to an annual plant biomass production ranging from several hundred kilogrammes to several tons. This is considerably higher than the annual fodder consumption.

Evidently, therefore, the plant resources are only slightly used by wild herbivores. The reasons for this and the mechanisms of the regulations of the above-mentioned interrelations are not clear. One of the main problems involved in increasing productivity is to change this ratio, that is, to increase the index of utilization of plant resources by animals.

It must be pointed out that in recent literature there is a widely held opinion of the necessity of re-evaluation of the role of the vegetation of oceans and seas in the total productivity of the biosphere. For many years it has been considered that solar energy per unit area is utilized more efficiently by water than by terrestrial vegetation. However, there are indications that in the most productive (eutrophic) oceanic waters plants assimilate on average 645 g of carbon per m^2 annually, in less productive waters 91 g/m^2 and in the central parts of oceans (which occupy the greatest area) only 36.5 g/m^2.

These figures correspond to the following values in percentage of utilization of total energy of solar radiation: 0.33, 0.11 and 0.02 per cent. It is of interest that very similar figures are known for the main types of land ecosystems according to Duvigneaud, namely: 0.33 per cent for forests, 0.25 per cent for cultivated lands, 0.10 per cent for meadows and pastures and 0.01 per cent for deserts and glaciers. The forests occupy, however, more than 40 per cent of the area of the land surface while eutrophic oceanic waters, mainly limited to the coasts, cover only a very small part of the total ocean area. On the average, the utilization of the total energy of radiation for the whole sea surface is about 0.04 per cent, taking into account the distribution of the energy of radiation and the areas covered by waters of different productivity. For total land surfaces the efficiency of solar energy utilization is about 0.1 per cent, or 2.5 times higher.

SOME IMPLICATIONS REGARDING INCREASE IN PRODUCTIVITY

Many countries of Asia, Africa and Latin America face a situation where most of the population is living in poverty, with a contemptible income, insufficient food or starving in a direct or indirect sense (shortage of calories, deficiency of proteins). In order to close the world gap in protein deficiency, about 42 million tons of protein should be produced annually instead of the present 20 million tons.

Better animal husbandry, poultry farming, wildlife management, fishery and fish breeding, should permit the solving of the problem of increasing the protein content of man's food. In this connexion, a better knowledge of the processes involved in secondary productivity (production of zoobiomass) will open enormous possibilities.

Animals differ greatly in their efficiency of protein production. In order to obtain 1 calorie in cattle meat protein, 7 calories of vegetable carbohydrates must be fed to cattle. To obtain 1 calorie in chicken meat protein, only 3.5 calories of vegetable carbohydrates are required, or half as much. Poultry farming is one of the most efficient and cheapest ways of obtaining highly valuable proteins for man, though fish breeding might become an even more efficient protein source in the future.

Installations for the production of animal protein by microbiological synthesis, utilizing products and salts of nitrogen, phosphorus and potassium, have recently been set up in different countries.

In time, plant genetics and higher density of plants in the fields should guarantee a considerable increase in the efficiency of photosynthesis in new varieties of agricultural plants. In photosynthesis the present efficiency of the conversion of solar energy by cultivated plants is, on average, very low (0.2-1.0 per cent). The rise in efficiency of photosynthesis up to 5 per cent or even to 10 per cent is a seemingly solvable problem that is being investigated by geneticists, physiologists, irrigators, ameliorators and agronomists.

Mankind as a whole can make a more efficient use of the resources on Earth by basing the production of food and other raw materials on the principles of scientific planning and management of the biosphere.

Approximate data on the global synthesis of organic substance reveal that an insignificant part (only 2-3 per cent) of the phytobiomass formed by photosynthesis on land is presently used directly or indirectly by man as food. The major part of the phytobiomass of the land is not used by man as a source of food. Only 25 per cent of the phytobiomass of the Earth is produced in fields and pastures for food production, but of this only 360 million tons, or about 9 per cent, is annually utilized by man.

The losses of photosynthesized organic substance in agriculture, in the food industry and in animal husbandry are therefore extremely high (80-93 per cent) and not at all rational. Furthermore, very little use is made of the mass of organic matter of the ocean although this appears to be a very important resource for man's future food industry.

To increase the efficiency of utilization by the biosphere of incoming solar energy, an important part can be played by cultures of some micro-organisms yielding a high percentage of protein. Under optimum conditions, the cultivation of micro-algae *(Chlorella, Ocenedesmus)* shows an efficiency of photosynthesis of 5-6 per cent with a protein content totalling 50 per cent of the biomass.

The use of 'closed' ecological systems based on a complete cycling of substances may greatly and effectively contribute towards solving the food problem in the future. The analysis of this problem indicates that the basis for solution should involve biological methods of resynthesis and regeneration of gases, water and food in closed ecological systems, rather than concentrating essentially on physico-chemical methods.

The unprecedented technological, economic and social progress of mankind in the twentieth century is being accompanied by profound changes in the composition, structure and energetic resources of the biosphere which is leading towards an entirely new situation and a new relationship between mankind and the biosphere. It is not only perfectly natural but absolutely essential that man should influence rationally this outstandingly important phenomenon in the modern history of the planet by using scientifically justified methods and acting with utmost care and expedience regarding the exploitation of the resources of the biosphere.

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Impacts of man on the biosphere

This paper was prepared on the basis of a draft submitted by Dr. F. Fraser Darling (United Kingdom) with comments and additions by Professor Vladimir Sokolov (U.S.S.R.), Professor Frederick Smith (U.S.A.), Professor François Bourlière (France) and the Secretariats of Unesco and FAO.

INTRODUCTION

The manifold effects which the physical presence and activity of man have had on the face of the planet Earth through the relatively short period of man's history tend to be dynamic and interlocking yet it is worth while attempting to classify them for a clearer understanding of temporal and spatial factors. The world as it existed before man used tools and fire was one of immense riches of natural resources, organic and inorganic. But to say that is to put the cart before the horse; natural resources were not resources at all until man was both present and able to make use of them. The ability to identify, reach and use natural resources has been a continuous process for man, and we have a fair archaelogical and historical comprehension now of the differing rates of exploitation in different parts of the world, the sudden changes of rate and style caused by changes in human condition and the enormously accelerated rate of change within the last century. We are convinced that man's ingenuity is running ahead of his wisdom—that is one reason we are gathered at this conference—but we must not make the mistake of thinking we are wise if we express our notions with the constantly wagging finger and negatively-shaking head of Jeremiah. If civilization is a flower of evolution it could not have grown had not man gained leisure to think and flexibility to act by actively managing to turn some of his environmental wealth to his own advantage beyond that of mere sustenance.

From the beginnings of civilization, man has altered environmental processes as he dug into the organic store of the planet's ecosystems. Even to light a fire of dead wood for keeping warm is to deflect a natural process of decay, which would be humus-building, into the production of inorganic ash. For a long time man may not have been much else than the equivalent of an indigenous animal of limited change-producing activity, but even at the advent of that great thrust, the Neolithic Revolution, hunting and food-gathering man had changed parts of his world more or less unintentionally by the use of fire. This is a point to remember in considering the influence of man on the biosphere: as a species his impact goes far beyond the immediate contact. Fire would run and change vegetational complexes, fires would be used to help drive herds of game animals, a prodigious expenditure of organic matter for momentary expedience, and burning in season would be done to draw grazing animals to new grass, a path of inevitable impoverishment of habitat. Man was controlling the behaviour of wild animals to some extent by these expedients which were slowly altering his habitat and theirs.

Men were so few and the world apparently so large that it would have been strange had man dwelt philosophically on his own numbers and the fate of natural riches. Even in the present century we have seen men speaking proudly of their duty and their success in pushing back the wilderness. The student of the human condition, however, albeit he may hold to the philosophy of conservation, will accept the price of civilization which has been the loss of much natural wealth. When was the moment critical that man should have arrived at consciousness of that fuller kind that would have led him to call a halt to bald exploitation and to match exploitation with rehabilitation ? It is possible we have reached that moment now, though over-all the planet is still losing out. The fear now is whether we can rehabilitate, or are causes and consequences setting up their own percussive oscillations to an extent we cannot control.

It is worth while attempting some classification of man's impact on the biosphere, possibly in developmental and qualitative order which could be flexible and capable of being redistributed as an ecological diagram of interconnecting factors. It can be much expanded and given change of emphasis. Man's impact is not to be thought of as being wholly to the detriment of his ultimate welfare though it may be preponderantly so. Certain man-modified habitats may represent ecosystems of equal or greater production and wealth-building power than the natural condition. Wealth-building in this connotation means the storing of organic capital as in a tropical forest or in a prairie soil or chernozem.

An attempt has also been made to identify the new problems created by accelerated development and also to list the various measures taken until now by man to maintain the quality of the environment.

PAST AND PRESENT MAN'S IMPACT ON THE BIOSPHERE

FOOD GETTING

Animal hunting with the use of fire. Fire has been used for animal hunting, destroying forest incidentally and preventing much regeneration. But production of savannahs as in parts of Africa with a rich spectrum of ungulate species may lead to a rich habitat for organic production. Savannahs of Brazil and Guiana seem definitely to lose out as to their qualitative potential. Is this because of a limited array of ungulates as compared with Africa ? Again, in

North America, the Indians extended the prairie range of bison by burning forest and the resulting humid prairies maintained a very high rate of production, accumulating an immense store of rich soil.

Sometimes the terrain is also being burned intentionally to produce fresh young grass; this leads to impoverishment of the array of plants present originally, which upsets flexibility of the grazing complex in face of seasonal climatic variation. Examples are production of *Molinia* and *Scirpus* swards in the Scottish Highlands; and the gradual elimination of grass, giving way to gall acacia and lantana bush in parts of Africa and mesquite in the south-west of North America. Many important variants originate according to the frequency of burning and, in tropical countries particularly, the time of burning in relation to the dry and wet seasons.

Settled cultivation. Settled cultivation, in opposition to shifting cultivation, leads to soil exhaustion if replenishment is not understood or was impossible, or possible aridity if active counterworks are not used. The English 'brecks' or broken lands are thought to have developed from Neolithic cultivation. The 'Dust Bowl' of the United States in the 1930s showed what continuous extractive cultivation without adequate replenishment could do when a cycle of drought years was encountered. Broadly, cultivation must manage to sustain the level of organic matter, or the soil either bakes or blows away. But many examples can be given where settled agriculture, under various ecological conditions, had been successfully carried out for centuries, namely in the Far East, the Near East, the Mediterranean area and Central America. The ancient Negev demonstrated the efficacy of counterworks for conservation of water; abandonment of these resulted in almost complete degradation of the habitat.

Shifting cultivation. There tends to rise in the collective mind of conservation-minded people an absolute antipathy towards shifting cultivation as being wholly deleterious to habitat. Examples could be given of this practice, however, that produce variety and valuable 'edge-effects' (i.e., creation of ecotones) so long as the human population is low. The *chitemene* system in Central Africa is a good example: the gardens are not larger than an acre or so and being surrounded by bush on fairly level terrain soon return to bush after three to five years of use, and are not used for a further forty years. Immediately after being relinquished these gardens are taken over by colonies of *Tatera* rats while the soil is loose and friable. The rats form a secondary protein crop for a year or two, caught by the small boys. Following this, the bush slowly recovers and replenishes the soil. Another good example of sophisticated and conservative shifting cultivation is given by Hanunoo agriculture in the Philippines.

Increasing human population causes the bush to be broken again too soon and deterioration of habitat follows. Shifting cultivation on steep slopes is almost wholly bad and on some geological formations, e.g., limestone, milpa cultivation may be quickly disastrous. Shifting cultivation is the bane of Central and northern South America and land hunger with rapidly increasing human population a vicious circle from which it is difficult to break. Erosion is having long-term effects on far greater areas of country through interference with the water relations.

Irrigation. Irrigation has a long history and is still a popular line of development, but in large-scale irrigation projects, improvement or maintenance of soil fertility over a long period raises many problems. As they are so often sited in arid areas where a high evaporation rate has kept salts in the soil, irrigation tends to redissolve the salts and deposit them again as a crystal crust. Re-use of irrigation water as from the Colorado River can mean good ground being made saline and useless at the lower levels of operation. This also happens on the Bear River, Utah, and on the great Sind scheme. Wise irrigation, or possibly fortunate irrigation, uses rainwater, and if this is adequate in supply, it can wash the more saline ground of the arid parts where the water is used. The Gezira scheme in the Sudan is an excellent example, where the country's economy has been much strengthened by non-saline water from the Blue Nile (which runs at a higher level than the White Nile) which is taken off and spread over the triangle of the Gezira. The used water drains into the White Nile on the lower side of the triangle, the volume of which renders insignificant any salinization suffered by the Blue Nile water passing across the Gezira.

One increasingly troubling factor in African irrigation is the spread of *Bilharzia*, which causes the debilitating disease of schistosomiasis. The snail acting as intermediate host is widespread and irrigation ditches provide a new habitat. The worm has been spread by human beings who now travel more and are more numerous.

Irrigation by sweet fossil water has much increase. In Texas the oil may outlast the water, but provision of fresh water from the sea may render this remark nugatory. Even in temperate Britain, where there is traditionally so much rain and humidity, irrigation of grass by spraying of fossil water produces increased yields with apparently no injurious sequelae, except that, like all irrigation, it is extremely prodigal of water. Also, Britain is still developing industrially and in standards of living. The latter factor alone means a largely increasing demand for water. Prodigal use of fossil water may be something Britain cannot afford.

Over-grazing and over-browsing by domesticated livestock. Once domestication has occurred, sedentarization limits movements of stock and over-grazing is often inevitable if not constantly then at least in times of drought. Different species of domestic stock cunningly used in different climatic conditions make for maintenance of habitat, but well-understood balances can be easily upset by natural fluctuations of conditions. The technique of successful grazing has to be learned and even when learned may not be generally followed. The sophistication of a modern research station can fall short, e.g., the reindeer era in Alaska, where deterioration outpaced the research, and both the grazings and the reindeer crashed. Modern examples of extractive grazing such as in European Africa, parts of Australia and New Zealand, and the short-grass prairies of North America have been more rapid in bringing about deterioration of the soil than the long-established truly nomadic communities that preceded them.

Nomadism of pastoral origin. This deserves special mention because it can be so easily upset or broken, to the detriment of the habitat. Nomadism is at best a pursuit of the steppe regions of the world and produces least deterioration. It is utterly bound up with movement if habitat is to be conserved. Any undue lingering punishes the vegetational complex, reduces its numbers of species and therefore impoverishes it. The finest nomadic areas of the world were the chernozem plains, like those of the Kuban where the Scythians roamed in the time of Herodotus. Their capacity for and dependence on movement exasperated Darius. Nomads depended on animal products for sustenance and warmth, and as protein consumers were an ecological élite, at the top of the food chain or pyramid; if they increased in numbers, families, clans or tribes had to bud off and move on. We know of these frightening nomadic emigrations in history. Less good steppe was used, forest edges on mountain ranges were used and there was inevitable slow change, usually for the worse.

Conversion of chernozem steppe from protein production, whether of live-stock in the Ukraine and Kuban or bison in the American prairies, to substantially carbohydrate production of wheat and maize, was a relinquishment by the human being of his ecologically aristocratic position. He now converted a complex community of grasses into a monoculture of one annual grass, wheat or maize, the seeds of which he could eat. This allowed a much larger number of mouths to feed from the rich steppe by substituting human mouths for the grass-eating mouths of horses, cattle and sheep. This change meant a loss in reciprocation of the system as it had existed. Organic matter was stripped out as grain, for that commodity was not consumed on the steppe as had been the animal products, so there was profound loss of organic matter. The same thing happened in North America, replacing the Indian-bison continuum. The chernozem soils of America and Europe have stood up well to the extractive agriculture imposed upon them and there is the likelihood that good agricultural methods will maintain them in the future, but a revolution of the plough of this kind always goes farther than those lands best able to bear it. Higher, poorer and more arid steppe has been subjected to 'dry farming' of wheat, with disastrous results.

Wherever sedentary populations have impinged on nomad grazing there has been degradation of habitat for which the nomads are invariably blamed because the sedentary cultures are the literate ones. Yet nomadism as a careful pastoral continuum is the least traumatic of human influences and as a form of husbandry utilizes areas which could not be utilized by man in any other way. It is essentially ecological in structure, relying on movement and seasonal use, a wide spectrum of grazing animals adapted to well-understood differences in habitat and producing much energy without loss of organic matter.

Nomadism is always brittle: apparently small political changes reduce it to habitat spoliation. The Masai in East Africa are a Nilotic tribe moved from a humid homeland into high, dry steppe country. Yet their knowledge was good and accurate and they did not deteriorate their habitat until the white man brought veterinary magic which prevented the full incidence of mortality which formerly kept the herds to a proper level for the stock-carrying capacity of the ground. The Masai and their country are a good example of integration of nomadism with the indigenous animal population. The wild game existed alongside the domestic herds, tolerated and respected. This harmony may well have originated in the Nilotic homeland, as in the Bahr-el-Ghazal, where the Dinka accept giraffes as part of the cattle herd. The Nilotics practise a restricted nomadism seasonally between toich (grass flood plain) and the slightly elevated bush to which the herds repair in the wet season. The Dinka's practical, empirical knowledge and acceptance of the ecosystem approach to living in his rich world is further ex-emplified by his tolerance of a small poisonous snake which inhabits his thatch and keeps insects within bounds. Even in this paradise of symbiotic cattle culture, the march of modernity and the hungry mouths elsewhere are demanding rice culture and the exclusion of game animals; the distended but unsatisfied belly of the carbohydrate eater then appears.

We may close this section with an example of nomadism having become allied with political power and made so powerful by law that much country was devastated. This is what happened with the transhumant society of the Mesta in Spain. Ferdinand and Isabella allied themselves with it for the profit of the crown. The flocks of merino sheep were driven through cultivated areas and it even became illegal to fence against them. It took the folk of Spain nearly two hundred years to beat the Mesta but the bare hills of Castile remain today.

This discussion of nomadism is one more comment on the world approach to human numbers which accepts the rule of numbers as it were, and that habitat must continue to be degraded to produce inferior nutrition for a number of mouths which grow ever faster. When shall we tackle the problems of human conservation and habitat conservation from the other end?

ACTIVE DEPLETION OF RENEWABLE ANIMATE NATURAL RESOURCES

Deforestation. This has taken place from earliest times and is probably better documented than most other types of change of habitat. The earliest effect of restricted deforestation is one of enrichment of the habitat by providing change in a situation of little or no change. Parkland in forest is appreciated by many grazing animals. Primitive and later man, utterly surrounded by forest, arrives at a psychological state eventually when he must push back the forest and not be enfolded. The mediaeval *horror sylvanum* was very real, and we living in a forest-depleted world should remember it in our understanding of history.

The Anglo-Saxon colonizing a Britain which had islands of ploughland and pasture connected by roads in a sea of forest was not only knowledgeable in tools and woodwork, but clever ecologically. To create new arable ground in the long term he used a biological plough or grubber in the oak and beech forest in the shape of the snouts of herds of swine, descendants of the European wild boar. They garnered the pannage and by concentration of effort prevented regeneration. As actual felling took place, grass followed on the cultivation by the pigs and grass parklands or lawns were created, to be ploughed as needed. In temperate, humid England, the changed biological system of forest to grassland with occasional trees made for little loss of organic matter and the output of free energy was probably not far behind that of the forest. Certainly it allowed more of it to be canalized through the gut of the human being.

The tendency of *export* of natural resources to lead to devastation has been documented many times. The oak forests of England did not all fall by the axes of the early Anglo-Saxons. The rise of England as a naval power involved heavy felling and the use of iron demanded more felling for smelting fuel. The opening of the seventeenth century saw prohibitions on the felling of English timber. This drove the iron smelters to the woods of western Scotland where the long sea lochs allowed ships laden with iron ore to penetrate deep into the forests of Scots pine with oak in the glens. Here devastation came quickly because of the high rainfall, acid soils and steep slopes. The Forestry Commission of the present day is concerned with the repair of this damage, but at great cost because the active humus has long gone from the once-timbered slopes.

Perhaps the onslaught on North American forests was the main reason for the rise of conservation thinking. Fairfield Osborn said in 1948 of the United States, 'The story of our nation in the last century as regards the use of forests, grasslands, wildlife and water sources is the most violent and destructive of any written in the long history of civilization. The velocity of events is unparalleled...' This fact of weight and speed of destruction may find its absolution in the rise of the ideal and practice of conservation in the United States. Similarly in Africa, there has grown an awareness of the need to conserve often as a result of destruction and denudation.

On a happier note, it may well be that the African Special Project carried out jointly by the International Union for Conservation of Nature and Natural Resources and FAO, may well have been the turning point in attitudes towards conservation in the rest of Africa: that and the Arusha Conference of 1961.

The felling of tropical forests has been a story of sheer extraction. The massive and impressive accumulation of organic matter presented by this oldest life form on the planet tends to blind us to its fragility. Like most forest forms, the tropical is primarily a photosynthetic factory of cellulose, with any protein as very secondary production. The tropical forest floor has been protected from the sun for thousands of years with the niches for decay and conversion so well filled that nutrition of the trees and the life of the canopy are bountiful. When the forest is felled the tender soil exposed to the sun oxidizes rapidly and disappears:

> 'Like snow upon the desert's dusty face
> Lighting a little hour or two—is gone.'

The mahogany forests of Hispaniola have gone, those of Honduras are going and the results are known.

Many countries, particularly within the tropics, have had their forest resources exploited without any provision for sustained yield management. It can be argued that because of local economics and political structures they had no alternative and a good proportion will likely resort to such expedience in the future. In order to survive they need ready cash to operate politically. Politics are peculiarly bound up with such expedience. We must realize that political decisions are, and have been, a major factor affecting the natural environment.

Drainage of wetlands. In general, wetlands are highly productive of protein in the shape of animal bodies—mammals, birds, fish and invertebrates—but not always in a form acceptable to the human being as food. Drainage has been done throughout history in various parts of the world to create navigable channels and to provide more agricultural land or, perhaps, specially fertile agricultural land. Holland and the Fen country of England are good examples and there are many areas in the United States. Where the soil is alkaline peat it becomes highly fertile when dry enough to manage, but so contracts in volume that diking and pumping become necessary, for the won land is then below the level of the adjoining sea. The situation is vulnerable and the soil itself is so friable that it tends to blow. The question must always be whether the considerable capital works necessary can be maintained and whether the potential fertility of wetland soils can pay for them. Once more the ecosystem is being changed from one of protein production to one of largely carbohydrate grain production. Certainly more mouths can be fed on the 'devaluated' product. The aesthetic loss of beautiful species, especially birds, from drainage in wetlands is considerable. The United States has changed former policy to some extent by allowing wetlands to refill and resume their former land form, for example the Klamath Marshes in northern California. It might be said here that allowing marshes to refill is only possible as a policy in a country affluent enough to be producing grain surpluses and where the proteinous wildlife is beginning to have extrinsic values for recreation.

The Everglades National Park in Florida provides a beautiful example of the complexity of wetland habitats and what can happen when water is deflected from these areas. This is essentially a wilderness and wildlife area on a flat oolite base slightly above sea level and slightly tilting southwards. The Everglades depend on the seasonal passage southwards of large quantities of water moving very slowly. During the wet season all wildlife disperses over the area and in the dry season it contracts to alligators holes. Alligator holes serve as survival reservoirs during the dry season. Drainage north of the park has deflected much of the water which should flow over the Everglades and thereby the water table has been lowered. Further, there has been punched a hole in the bottom of the system in the shape of a canal running up from the sea into the Everglades for the passage of pleasure boats. This both allows quicker loss of water and the occasional invasion of salt water. Last, there has been a long period of poaching of alligators. Failing greater care of alligators, artificial alligator holes will have to be made to maintain many other species of plants and animals. The Everglades constitutes a large national park, but is a vivid example of several thousand square miles being insufficient to be an ecologically independent area. Nothing is simple when playing with water on wetlands.

General reserve on changing the nature of wetlands is not yet apparent. There is a psychological fascination about playing with water and to change a protein-producing system to a carbohydrate-producing one seems to provide ample practical reason for going ahead. Africa has many interior wetlands and one of the most promising lines of development in recent years has been improved management and enlarged use of the fish resources of these wetlands. Zambia is an excellent example of achievement of an improved standard of nutrition for a new industrial population from the freshwater fisheries of the numerous swamps. Yet the projected increase in human population has caused serious consideration of draining such areas as the Kafue and Chambeshi Flats to serve as wheat-growing lands. Not only would fishing be constricted as a result, but the herds of game animals would go also, despite the fact that the red lechwe is an antelope moving in large herds, adapted to grazing inundated lands and potentially capable of management as a meat-producing animal.

Over-hunting of selected desirable species. This history is well known, and we are concerned with it here in so far as the disappearance or decrease in numbers of species has altered the ecosystem and the habitat. We do not know very much about this; our knowledge of niche function is growing but we have much to learn about habitats in which a niche occupant has been removed. The elephant would provide a good comparative study because we have plenty of habitats from which it has recently been removed by over-hunting and others in which it is more numerous than ever because of protection. We have a fair notion what is happening in the latter situation—production of grassland and removal of bush with the tsetse fly being pushed back. The elephant is the agent of change but man's distortion of the elephant's way of life is the instigator of change. Not enough thinking has been done about the influence of reduction of plains game on Africa savannah. The bison on North American prairies was followed by the plough, so we know little of the change which actual reduction would have caused, except that on the fringes of prairie, as in Wisconsin, there is a coincident rise of even-age forest.

Intended extinction or eradication of species. The wolf is perhaps the best example because of its direct challenge to extended pastoralism. The supposed behaviour of the wolf has become a human psychological fiction which can still influence the fate of habitat. In the recent past, bounties were still given on wolves killed in the Alaskan Arctic where human predation of the caribou was quite insufficient to prune the caribou population to safeguard the range which, if overgrazed, might take a century to recover—longer than caribou could wait. There were excellent object lessons in the crashed reindeer populations on the west coast after thirty years of over-grazing of the ranges, but the psychological obsession about wolves had blinded people to the plain cause. These overgrazed ranges can still be seen as different from the sourrounding terrain when viewed from an aeroplane at 20,000 feet.

The necessity for frequent or continuous movement—the brand of Ishmael—was described in relation to nomadic pastoralism. Wild animals conduct their own movements but not entirely of their own volition. There is the curious habit of 'yarding' in several species of deer, treading around as a large herd in one small area in dead of winter. Food may be got farther afield but they do not go to it—unless wolves or other predators stimulate them to move. How far lack of this function of the predator was responsible and how far the sheer lowering of numbers of deer was wanting in the Kaibab plateau crash of mule deer in 1916 will probably not be known now but the fact of absence of predators was immediately understood. Mountain lions were still being killed in the Grand Canyon National Park in 1950, so deep rooted is the aversion to the large predator. We are not concerned in this conference with the fluctuations of deer herds, but we are concerned with the percussive influence on habitat caused by violent fluctuations due to the man-caused absence of predator populations which not only lower numbers but keep the herds of their prey moving. Recent work by Mech on the moose-wolf ratio and equilibrium on Isle Royale in Lake Superior shows how a woodland habitat carrying these large deer can be maintained by man allowing the wolf to do all the necessary culling.

CONSEQUENCES OF MINERAL-GETTING AND OTHER INDUSTRIAL PROCESSES

Toxic fumes and detritus. Smelting liberates toxic fumes which kill plants and sometimes animals. The sterilization of areas by copper smelting in Tennessee is well known. Aluminium smelting at the foot of the Great Glen of Scotland produced fluoride fumes which were blown north-eastwards up the glen by the prevailing south-west winds. The grazings were affected and young cattle suffered. It took a court case and very dilatory action thereafter before scrubbers were installed to remove the hazard.

The lead mines of Derbyshire and the felspar workings left areas of spoil on which the herbage growing thereafter was so far impregnated with lead that young stock could not be grazed on them. This effect remains in the ground even centuries after the mining.

Interference with natural drainage. Coal and shale mining not only create conditions where subsidence occurs, but large quantities of detritus are produced which are in general dumped on the surface near the mine shaft. These vast dumps not only make the landscape an unhappy one aesthetically but serious interference with surface drainage is often apparent in their vicinity. At worst, these dumps are a menace to human communities, as we experienced so tragically at Aberfan. We are slowly emerging into a world of different values in which space is seen to be getting short and derelict landscapes cannot be allowed to impinge on such a scarce commodity. The recent marriage of ecology and landscape architecture has immense promise. The English counties of Durham and Northumberland have initiated schemes of vegetating pit heaps, with a success that promises to enrich and make beautiful the violated landscape. The National Coal Board of Britain has done much opencast mining in the North of England and immense care is being taken to rehabilitate the landscape afterwards, to the extent of 11 per cent of the Board's income. Similar spectacular results can be found in several areas within Germany.

The strip mining and auger mining of the hills of Kentucky are leaving eyesores of dereliction along the faces of the hills, and the effects of watershed erosion which follow are having serious repercussions below these hills on the good soils of the Ohio River country. It is all the more distressing to hear that the coal is being mined for sale at the lowest possible price to that model of rehabilitation policy, the Tennessee Valley Authority. One of our difficulties in much conservation endeavour is to stop different agencies within one nation working to each other's disadvantage, never mind between nations. Once more we lack good legislation: the process of law being so largely by precedent, it can scarcely keep abreast of the types of change quite unimagined in the past.

Dumping of wastes into rivers. This is an obvious and well-documentated way in which we are bringing about change in the biosphere. The trouble arises from the primitive notion that a river is a natural sewer. Paper-making is a modern industry—in terms of centuries—which has been responsible for fouling many rivers of the forest countries. The State of Maine (U.S.A.) has a relatively low human population, but its rivers are polluted to an extent that precludes most of them receiving a run of salmon. Where human population is dense, sewage is the main problem. Knowledge is being gained all the time of how to deal with industrial wastes, but regulation lags. Recent production of pesticides has had a few tragic sequelae in the poisoning of rivers and ditches. In comparison, the carelessness by shepherds in draining out baths of sheep dip is a small thing, perhaps, but indicative of the thoughtlessness that spreads man's deleterious influences over habitat beyond the immediate vicinity. There has not been sufficient realization that much marine productivity on the continental shelf has an estuarine basis.

CONSEQUENCES OF HUMAN POPULATION CROWDING

Losses and gains in plant and animal life. Obviously, with no need to emphasize, there must be losses when man becomes gregarious beyond the hunting food-gathering family. It was by changing ecosystems to a style which passed more of the produce through the human gut that allowed gregariousness and the development of civilization. Certain timid animals keep their distance from human aggregations, others adapt to them, even though they remain timid. The fox in the suburbs of London is an example. Plants, being less mobile, have less choice and many species are stamped out. The large human foot with our upright form above it is much heavier on herbage than many people imagine. This even becomes obvious and to some extent crucial in large national parks such as those of North America where more and more black-top paving is having to be done to safeguard fragile plant associations in alpine, desert and forest areas. A spongy woodland floor will show footmarks for years; the tundras of Alaska are crisscrossed by the tracks of caterpillar vehicles and jeeps, and it is doubtful whether some of these tracks will ever disappear. It may be thought that forest trees are immune to the tread of human feet, but not so. The French find it necessary to fence individually the largest oaks in the Forest of Fontainebleau because impaction of the ground by picnic parties beneath them eventually kills the trees.

The rapid rise of human population in India in a climatic situation of wet and dry seasons illustrates the power of human feet in removing vegetation. Village sites are now bare dried mud where three years ago there was secondary jungle. In these situations where physical building is quite flimsy, sometimes no more than poles, burlap and corrugated iron, it is not definite planned urbanization paving the surface of the earth, but the passage of human feet and of domestic animals. The latter contribute to the general denudation by their own browsing habits and the calls they make on their human owners to cut down branches of trees for the animals' sustenance.

Certain tribes of men in propitious habitats realize the immediate advantage to be gained by cultivation within the forest edge. The Kikuyu of Kenya are an excellent example: these people have pushed back forest to a dangerous extent, especially in recent years since the tenfold increase in the tribe under the *Pax Britannica.*

Man altering ecosystems purposely or unconsciously usually simplifies them and makes possible the invasion of plants and animals of earlier stages of succession. Annual and biennial seeds are good examples. The animal world has ready invaders such as the brown rat and the common sparrow, which has followed man wherever the wheat plant is grown. This is not the place to explore the subject of exotics, but their influence on habitat is worthy of special study in relation to the changes man has brought about in the biosphere. We have a limited field for congratulation in pleasant residential suburbs where gardens express beauty and birds come in greater variety than might be found in the *campagna* beyond. In fact, unconsciously or no, we have here created diversity to which nature has been quick to respond by adding her own contribution of variety and pleasance.

Pollution of air, water and soil. This greatest problem of our age, pollution, has been left till last. No longer can we think of England's industrial north, Germany's Ruhr, Russia's Yaroslavl and Gorky, and a few other places as being the polluted areas where money is to be made, but places not be be lived in if possible: in the last quarter of a century we have polluted the whole planet so that the fat-storing creatures of the remote Antarctic continent, penguins and seals, carry appreciable quantities of organo-chlorine compounds in their fat, the compounds we commonly allude to as pesticides and which have not been used within many hundreds of miles of any part of the Antarctic continent. We have learned now of the virtual cessation of reproduction in some species of birds which have not been the objects of any hard feelings, only of love and pleasure. We carry these pollutants in the fat of our own bodies and as yet do not know of any effects on us, good or bad, but most thinking people are concerned about the possible effect of accumulations of these compounds over the years. Some developed countries have regulated the use of pesticides and cut down dosages, but this has meant the economic dumping of large quantities in tropical countries where there are pests enough and little control over the use of pesticides. The informed among us know that to regulate use in some countries but not on a world-wide basis does not prevent pollution of the biosphere. We are world citizens willy-nilly now.

Much could also be said on radioactivity. In the recent past, the radioactive level has been increased in air, soil, water and living organisms over large areas of the world. Experimental A and H bomb explosions and some other works with radionuclides represent one of the greatest dangers for all living organisms on earth.

What might be the planetary profit and loss account in relation to expenditure and production of oxygen? We believe our atmospheric figure of 20 per cent oxygen has been built up through evolutionary time by the photosynthetic power of plant life, and the slow deposition of organic matter in the deep ocean sediments. The development of animal life must have steadied the advancing proportion of oxygen. Now, we may ask when we hear that a jet plane crossing the Atlantic burns 35 tons of oxygen, is industrial process and combustion dipping seriously into the margin of production over consumption, especially when we think of the rate of destruction of forest growth and other plant life? Oxygen consumption and carbon dioxide production are to some extent linked; we know that the carbon dioxide content of the atmosphere is rising and that this could lead eventually to such raisings of temperature of atmosphere and oceans that there could be a substantial ice melt which would appreciably raise the level of the oceans. Pollution, combustion and destruction are combined here in their ultimate power of change of the biosphere.

The deposition of sewage into rivers is of course age old. Lakes receive this effluent, and eutrophic conditions are being reported from as far apart as Lake Erie and Lake Baikal. Life in some lakes is being asphyxiated by lack of oxygen and too great a deposition of organic matter. Our river banks and lake sides are becoming overpopulated. In order to be able to live at high densities we must process all sewage and wastes. We are definitely trying to mend our ways but not fast enough. London's river Thames is improving by civic action and we must thank the sport of trout fishing for saving from pollution many streams that feed the Thames and other rivers in England.

The wreck of the *Torrey Canyon* focused the attention of everyone to the growing hazard of heavy oil pollution of the sea and the secondary evil of detergents used to combat the oil, the detergents killing more marine life than the oil itself. Responsible oil firms are taking the dangers of oil transportation by sea as a major task of research. Half the world's ocean cargo weight is oil—700 million tons of it last year in 3,218 tankers. Separators of improved design at ports, plastic booms round oil harbours, flocculants for spillage at sea, jelling agents to solidify oil in threatened tankers and new methods of loading and ballasting giant tankers, show a willingness on the part of the oil firms that we would be glad to see more commonly in shore-based industries that are potential pollutors of the environment.

Smoke, smog, sewage and detergents, these are the pollutants produced by modern man. We might also add noise. It is one more addition to bad environment engendering psychosomatic disease, that hidden fifth column in the total of our spoliation of our world. How long will it be before the individual has amenity rights, the burden to be on those offending?

PROBLEMS OF ACCELERATED DEVELOPMENT

Much of what has been said applies to the long, slow changes in civilizations that are characteristic of the past, producing the developed nations of today and the undeveloped nations of a generation ago. The very rapid advances that characterize developing nations today have produced dramatic new kinds of interactions with the environment that were not so evident in earlier history. Nowhere is the problem of accelerated development and its devastating consequences more evident than in many regions of the tropics and subtropics, where two-thirds of humanity now live. Here the relations between man and his environment are changing so rapidly that well-balanced development is seriously endangered and in extreme cases entire populations may be threatened with extinction as some actual examples reveal.

The side-effects of large-scale modifications of tropical ecosystems. Owing to the rapid development of ever greater land areas and the widespread use of powerful technological methods, the various tropical biotic communities are today undergoing radical and extensive changes. Deforestation, irrigation, the introduction of exotic plants and animals, the large-scale use of weed-killers, the eradication of certain pathogenic agencies, etc., have transformed the tropical landscape more profoundly in ten years than the traditional agricultural and stock-raising methods in ten centuries. In addition to economic advantages, immediate and undeniable, this 'reordering' of the tropical ecosystems has sometimes entailed a sudden collapse of the balances, generally going back thousands of years, between man and his environment and given rise to unexpected difficulties. The introduction of live-stock into the savannahs of tropical America has promoted the increase of rabies-transmitting haematophagous vampires. Irrigation of the savannahs of the Sahel in Africa has entailed the spread of bilharziasis. Systematic deforestation has frequently brought about transmission to men and domestic animals of certain arboreal viruses, normally confined to the pathogenic cycle of the forest canopy. Some are capable of causing sickness of little gravity to monkeys and tree-dwelling rodents, but they can be much more dangerous to humans: yellow fever, dengue-fever, Kyasanur forest disease, etc. The abandonment of certain traditional foods, both animal and vegetable, or their replacement by other kinds of food more easily produced has often served to aggravate already existing nutritional deficiencies. Even eradication of a number of tropical diseases may give rise to long-term difficulties. Some of the peoples of West Africa appear to be protected against the effects of malaria by certain abnormal haemoglobins which they possess in a heterozygotic state. Once the parasite has been eliminated, however, only the adverse effects of this genetic adaptation to the environment will remain.

The biological, psychological and social consequences of hasty and chaotic urbanization in the tropics. In Africa, as in Asia and tropical America, the last twenty years have seen the rampant spread of bidonvilles, shantytowns, barrios and favelhas of every description, whose crowded inhabitants are all too often under-nourished and illiterate, and have been frequently ruthlessly severed from their traditional values. The pathology of this situation, which is still little known, is a combination of the effects of malnutrition and poverty, and the physical and psychical effects of manifold stress. It has resulted in the creation of a sub-proletariat in poor physical condition, which deprives agriculture of a source of manpower but, at the same time, is unable to offer skilled labour to industry. As regards public health, sanitary conditions in these shantytowns represent a constant menace to the great urban centres of which they are a part.

The biological, psychological and social consequences of migrations. This lure of new cities and industrial centres involves unprecedented population movements which are the cause of a demographic imbalance that is every way detrimental to the development of many tropical countries. These migrations are, moreover, frequently selective: they tend to leave the less enterprising groups or individuals behind in the rural areas and to condemn the majority of the better elements to chronic unemployment. Populations biologically well-adapted to a special environment (the high plateaux of the Andes, for instance), sometimes find themselves moved by these migrations into areas climatically unsuited to them.

These problems—and there are many of this kind—require urgent study by teams of specialists, including ecologists, medical experts, psycho-sociologists and economists, with a view to finding satisfactory solutions as quickly as possible. Tropical ecosystems are at once so numerous, complex and delicate that nothing could be more detrimental to the interests of the human beings who inhabit them than a pure and simple 'transplantation' to the tropics of techniques (and sometimes even of ideas) which have proved their effectiveness in the temperate latitudes. It is not because the aeroplane has practically done away with distances, or because it is now possible to prevent or cure most tropical diseases, that the fundamental ecological differences between the great biomes have disappeared. To attempt to spread the way of life of the industrialized nations of the temperate zones over the whole planet is dangerously unrealistic. Western 'norms' should be adapted to other environments and cultures and not imported into them just as they are. And this applies not only in the provinces of economics and technology but also in matters of food, housing and clothing.

HUMAN IMPACTS LEADING TOWARDS MAINTENANCE OF ENVIRONMENTAL QUALITY

Irrespective of past and present mistakes and of the new problems created by accelerated development due to demographic, economic and social growth, man has already in the past tried to solve these problems of habitat deteriorations, and new ways of thinking and changing technologies give him the desire and the possibilities to build or rebuild an environment which has the quality required for mental health as well as to provide the necessary goods and services. Some examples are given below.

Plain delight of folk at many levels in organic forms and environmental diversity. There is ample reason to believe in this. There are the great villas of the past, their gardens and the manipulation of water for aesthetic pleasure. We can think of China, Rome, Persia and Renaissance Italy, the architectural gardens of France and the English *jardin intime.* The parks of Capability Brown in England could not be enjoyed by his patrons as we can enjoy them now with the trees at their maturity. Gardening is becoming enormously popular and municipal authorities are gaining confidence in spending money on their public parks. Increased affluence creates a demand for environmental amenity.

Establishment of national parks. This is a major contribution to civilization from conservation-minded people who had a vision of future human aspirations.

The best results of conservancy and the study of wild nature have been achieved through the establishment of reserves and national parks with a staff of scientists working permanently in them.

Establishment of wilderness areas and natural areas. Action here is prompted by both spiritual and aesthetic concern and biological need. There is a widely diffused element of human feeling that wishes there to be wildernesses even if many individuals will never reach the wilderness. There is satisfaction and comfort in the knowledge that it exists. Biologically we need the natural areas as reservoirs; their study shall provide datum lines from which we can more intelligently study other environments.

Conservation agriculture. Some tribes of people in limited or constricted habitats have arrived at conservation practices empirically, but the science of conservation in farming and water relations, together with foresty, has come from change of heart after orgies of exploitation. One would say guardedly that conservation agriculture was fairly firmly established in developed countries, but these same developed countries have made some shocking mistakes in developing countries. This now could be arrested if the necessary preliminary studies concerning sites' potentialities and limitations and the necessary investments for conservation are made. We have now the tools and we must use them correctly.

Interest in sport. Many forms of outdoor sport in developed countries lead to care of the environment. Care of rivers has been mentioned already in the interests of fishing; a diversified agriculture and the maintenance of strategic woodlands and covers has been followed in western countries in the interests of sport. Sometimes sport has removed animals from large areas, but understanding of the ecological place of predators is bringing about much greater tolerance. All in all, farms run by those who like to keep the sporting interest are richer in a variety of plant and animal life than others. Sometimes the sporting farmer progresses to the state of being a definite naturalist enjoying specifically the natural life of no sporting interest.

Changes in industry. This can best be presented by examples. In the United States, agriculture moved from the eastern seaboard to the Middle West. The forests that had never relinquished their hold took over again. Even sixty years ago much wood was being cut for fuel in these eastern forests. Now, oil-fired central heating is fairly general and the woods have grown more beautiful. What is more, the eastern woods have reached a new high destiny, of being the Suburban Forest, the pleasance of the urban communities of the seaboard. Public opinion is now solidly behind maintenance of this pleasing region of the east.

Likewise, in Europe, the concentration of agriculture on the best soils and the consequent abandonment of marginal lands, have opened the way for rural area development based on afforestation for soil conservation, forest management for timber production and recreation, establishment of national parks, and generally speaking, conservation, recreation and extensive management of natural resources.

CONCLUSIONS

To conclude: does this last section imply optimism? Ecologists can scarcely afford to be optimists. But an absolute pessimist is a defeatist, and that is no good either. We see there need not be complete disaster and if our eyes were open wide enough, world wide, we could do much towards rehabilitation. The biggest danger of all is our inability to control the explosive rate of growth of human population. A real damping down of this would lessen the all too frequent policy of expediency, bolstered by technology divorced from the philosophy of science. The scientist as a social entity must eventually establish the necessity for the ecosystem approach to world problems as a safeguard against unbalanced technological action. We have yet to realize that political guidance and restraint is nothing like so operative on technology as on other major fields of human action.

Soils and the maintenance of their fertility as factors affecting the choice of use of land

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INTRODUCTION

The soil is a part of the environment which results from the action of the atmosphere and biocoenoses on the lithosphere over a certain time. Its formation is the result of a series of processes of destruction or simplification, of rearrangements of varying complexity and, practically always, of reorganizations. These processes spring from the exchange or absorption of energy derived from solar energy and from the action of atmospheric agents, mainly the precipitation which controls the humidity of the soil.

Soil is usually a friable and aggregated substance. Owing to its permeable, penetrable and oxidized nature, capable of being hydrated and warmed, it allows microbial life to develop and vegetation to take root and to grow.

The mineral elements of rocks are thus made available to living creatures through various processes among which hydrolysis is particularly important. The intensity of this depends essentially on the temperature to which the environment is raised, and on the degree of circulation of the solution which permeates it more or less deeply.

The coming into being of the soil leads to the development of plants, which allows that of animals at its expense and the development of the human being, the last element in the chain.

Soil thus plays an essential part in all the ecosystems on the surface of the terrestrial globe. It exerts a moderating influence on variations of temperature and humidity conditions in the biotic environment while these, in the atmosphere, are frequently irregular and violent.

In practice, soil is essential to the life of man who, in respect of various activities, depends on the life of animals and plants which, in turn, can only grow thanks to the soil itself. Cases of the prolonged life of man away from a more or less direct utilization of the soil are rare. However, the characteristics of soils do not always allow them to play the complete role that might be expected of them in the general ecosystem, and sometimes make them fit only for certain uses, to the exclusion of others.

SOIL AND ITS UTILIZATION

DIFFERENT POSSIBILITIES IN THE USE OF SOIL

As indicated above, the part played by soil in the development of the general ecosystem is of primary importance, since it enables humans, animals and plants to live on the surface of the earth, but it varies widely according to the use that can be made of it, depending upon the angle from which it is considered.

On a more or less developed soil, vegetation occurs if climatic conditions allow. It may provide food for man directly or indirectly, after being used to ensure the nourishment of animals subsequently used by man to provide for his subsistence.

In its most elementary form, such utilization of soil consists in gathering the produce of natural vegetation or in collecting the wild fauna periodically.

In a more developed form, it consists of the laying down and then the gathering of domesticated plants or animals fairly well adapted to the desired requirements, providing man with reserves of food larger in quantity and better in quality than the natural plants and animals and, also, more homogeneous and more accessible.

If, on the other hand, the indirect use of soil by means of animals is considered, two levels of action are possible: firstly, the use of slightly improved natural pasturage by a wide variety of domestic animals or even wild species, as is still very often the case in tropical countries or, at a higher level, the laying down of very high performance live-stock on grazing made up of very productive species.

Soil can also bear and nourish plants whose products are mainly of industrial interest, either directly as in the case of fibre plants for textiles, oak trees for their bark or the *Hevea* tree for its latex, or indirectly as in the case of so many plants whose cellulose elements can be manufactured into synthetic fibres or pulp for paper, or whose products can provide a great variety of useful substances, by means of the most modern processes in chemical industry.

In extensive areas the utilization of the soil may be by forestry. It may lead to the exploitation either of valuable trees to give building timber and industrial wood or paper pulp, or of trees without special qualities for use as fuel or for the manufacture of panels of reconstituted wood. With regard to building timber and industrial wood, in the humid tropical or equatorial zone, in the dense forest which is generally not organized, activity is limited to collecting trees of specified species and dimensions. Consequently, the output amounts only to one, or even in the best cases, a few trees per hectare, but each unit is of great value. In developed temperate forest, the number and cubic dimensions of utilizable trees cut down per hectare are much greater. In both cases, the soil bearing a forestry plantation established entirely by man would give a more abundant, more homogeneous and more accessible 'harvest'; and this is the trend now followed, more particularly in the tropical zones. The use of land for forestry can also lead to the production of trees or shrubs whose wood, of less high quality, can be transformed by various processes into fibre boards, much used in building. The same trees can also provide wood for heating. It is impossible to overstress the primary importance of this type of utilization for timbered areas or shrubberies of mediocre quality, as in a tropical savannah zone and, similarly, for the soil. Instances can be given of sectors of agricultural improvement by irrigated cultivation, where the failure to keep tree areas or shrubberies to provide firewood has been one of the causes of partial failure, too much time having been spent by farmers in trying to obtain the wood they required for domestic use.

It is essential that the plantations as a whole which the soil can produce should be balanced: this requires a certain proportion of timber-land and cultivated land and also grassland or pasturage. This balance is necessary for several reasons:

1. Maintenance of local climatic and ecological conditions, which appear in particular to depend upon the increase of timber-land in comparison with the total surface of the sector in view.
2. Action on the water balance in each drainage basin, though it is difficult at present to ascertain and calculate the precise effect which the retention or disappearance of a timber area might have on this cycle.
3. Protection of the soil itself against degradation under the action of atmospheric agents (water and wind erosion, violent thermal influences of the atmosphere on the soil).

The very basis of this balance between agricultural, forest and pasture land, which can change moreover according to the development of techniques and investments authorized, are not known with sufficient accuracy, and fresh research is essential to enable them to be defined more clearly.

Soil also plays an important part in supporting vegetation and as a factor in scenery, the value of which to man may be considerable from the psychological, cultural, aesthetic, recreative or tourist aspect.

In any climate, this consideration often enables a reasonable use to be found for soils which are not fertile enough economically to produce useful crops.

In certain cases the soil may also be a source of certain materials, either for the same reason as the rocks from which it is formed: sand, gravel, clay; or for a more particular reason if pedogenesis has allowed the concentration or production of useful elements: brick-clay laterite crusts useful as iron-ore, aluminium, manganese, etc.

Finally over large areas, soil provides support for buildings, industrial plants and factories, and towns.

CONDITIONS OF CHOICE

Faced with so great a variety of possible uses, man must constantly choose, while observing the limitations due to the climatic conditions of the place. The basis for the choice is rather difficult to define. In this case, however, it is possible to retain the criteria of priority often accepted in respect of the use of any natural resources, which are mentioned in a report presented by Unesco and FAO to the United Nations Economic and Social Council ('Conservation and rational use of the environment', document E/4458, 12 March 1968): (a) degree and urgency of the need to which the utilization of the resources under consideration corresponds, whether they are goods or services; (b) satisfaction of the general needs of a group of the population; (c) results to be obtained and probable effectiveness of the operations to be carried out; (d) permanence of these long-term results; (e) cost of the operation; (f) probable effect on other activities of the population concerned or of neighbouring countries; possibility of extension or extrapolation in other countries.

In the choice between the various possible uses of the soil in a specific sector, several factors should be recognized.

Certain uses are very exacting and the required qualities of the soil limit the choice very strictly. The products sought are essential and the corresponding type of utilization is a matter of priority even if a change may occur in the importance of the land to be retained for this purpose.

Such is the case in the production of food. Thanks to better methods of cultivation, the use of fertilizers, insecticides and herbicides, as well as of carefully selected varieties, yields have been considerably increased during recent decades, but the quantities necessary to nourish a constantly increasing population have also increased. In the developed countries, although certain areas which were formerly cultivated are now set aside for tourism or other non-food-producing purposes, the areas used elsewhere to produce food are being constantly extended. New methods of cultivation and the wider use of some which are already known, such as irrigation, particularly with water containing some degree of salt, and the securing of new varieties which are better adapted to local ecological conditions, may facilitate such increase but intensification in the more favoured areas should not be neglected on that account. Such opening-up of new land should be based on preliminary investigation to guarantee its long-term utilization.

The foregoing also applies to the laying down of industrial crops providing such essential products as cotton, sisal or other textile plants, rubber, etc. However, research undertaken in many places for some years enables such products to be replaced by those arising from the manufacture of the plant products of rich crops, from elements not furnished by cultivation (petroleum, mineral oils or certain rocks) or from kinds of plants which require a much lower quality of soil than the first mentioned. Such products therefore tend to be given less priority.

The use of soil for the production of various kinds of trees with a view to obtaining timber for building, carpentry and cabinet-making, pit props or firewood has also long been considered, although to a less degree, as a matter of priority. If in some countries it has been possible to replace timber by metals, concrete, petroleum, motor fuel or many other products, consumption is clearly on the increase, more particularly in regard to wood for paper pulp and fibre board.

Timber production has retained its priority from the economic standpoint in many of the developing countries, either to procure the necessary foreign currency for imports from abroad or for supplying home necessities. Also a matter of priority to some extent and in some countries is that of pit props which it has not yet been possible to replace by any other material having the same qualities of breaking gradually and audibly.

Apart from all purely economic considerations, however, which demand that every country should draw from its own soil at least a part of the food and industrial products that the soil can provide, as being essential for the country to possess, it must be acknowledged that the most important characteristic of these uses of the soil can be seen only at the world, and not at the local, level in view of possible trade between one country and another.

In other cases of soil utilization, the priority nature disappears at each point to be judged at a more regional level; the very qualities of soils are then less important and increases in the areas used may vary a great deal. This is the case in the drawing up of a balanced agricultural-forest-pasture land system, in which allocation of the soils between each may vary rather widely.

The same thing applies in connexion with the use of soil for the purpose of preparing 'landscapes' which are necessary on the spiritual and aesthetic plane and for touristic purposes.

Finally, similar observations apply in the case of the use of soil to support urban or industrial activities. The area used may vary widely in relation to that available. Sites should be chosen in order not to encroach, or as little as possible, for instance on the best land for cultivation in the region.

MAINTENANCE OF THE FERTILITY OF SOILS

THE NOTION OF FERTILITY

A soil is fertile as soon as it can bear vegetation and, in a more practical way, as soon as it can produce crops. A truly unfertile soil is seldom found: soils with a laterite shell or a calcareous or gypseous crust very near to the surface, soils which abound in alkaline salts, certain podzolic or ferralitic soils which chemically are very unbalanced, etc. The notion of fertility is essentially therefore a relative one. In practice, the fertility of a soil is determined by its characteristics and properties as a whole which enable it continually to produce crops if the other conditions of climate, suitable types of plant, methods of cultivation, etc., are taken into consideration.

Productivity is dealt with only in respect of the entire complex represented by the soil in its natural environment and utilized according to the usual methods. A fertile and productive soil is one which enables plants to grow well. It must therefore form a sufficiently oxidized environment and one which permits easy penetration by the root system: consequently it must be penetrable, porous, and with a structure that remains stable. To enable the growth of plants and crops it must provide, in a given volume penetrated by the root system, a sufficient quantity of water and air and at the same time the nutritive chemical substances in a proportion corresponding, at least in respect of some of them, to the balance which allows an energetic interplay of the elements and to which the essential micro-organisms and crops are adapted.

THE BASES OF FERTILITY

The fertility of soils cannot be defined by a single feature but only by a whole set of characteristics, the influence of each of them on fertility, and the possible productivity of the soil, depending often on the value of the others; in other words, there can be compensation.

Thus, in a humid tropical or equatorial zone, the production of coffee-shrub or cacao-tree crops can be the same on two soils, one of which has a total of exchangeable bases lower than that of the other if the first has a higher porosity permitting a better circulation of the soil solution. Similarly, to preserve a given degree of fertility, a soil must have a higher content of organic matter in proportion as its clay content is higher. There are many similar examples in any climatic zone.

Moreover, the effect of the various properties of the soil on its production depends very largely on the ecological conditions of the place where it is found. Thus, in a semi-humid tropical country such as Central Senegal the best groundnut soil will be a very slightly leached, very sandy, tropical ferruginous soil (clay content 6 to 7 per cent); in a slightly more humid region such as Chad (annual rainfall 800-900 mm) a clay content of 10 to 12 per cent will be preferable; lastly, in a humid tropical region, a not very desaturated ferralitic soil, slightly impoverished in clay on the surface, showing 12-15 per cent of clay in the higher level and 18 to 20 per cent at depths below, will give the best results.

Each species cultivated has also its own requirements. Sugar-cane, for instance, will need large quantities of utilizable potash in the soil, while the coffee-shrub has need of phosphoric acid and certain trace elements in addition to nitrogen.

Water

The most essential element that the cultivated plant must be able to find in the soil is water supplied from rain, flooding, irrigation or even a rising ground-water level. It should be capable, if necessary, of being held in reserve in the soil from the time that it arrives so as to be used by the root system of plants when required at last by the latter.

The total possibility of water retention by a soil depends on the value of the 'useful water' at each point in the different layers, that is to say the difference between the quantity of water retained at the maximum of possible humidity 'in the field' and that of the so-called wilting point, practically constant for a sample soil whatever the plant that is cultivated in it. At the same time, it depends upon the thicknesses of soil affected by the calculated values of useful water.

The evaluation of this total possibility of water retention from the surface of the soil down to its base, to contact with the original material, does not present great difficulties. In certain cases, however, two factors may make it difficult to forecast the quantity of water than can be used by the crops during the year, even when rainfall is regular from one year to the next: (a) the material underlying the soil itself may often serve as a 'reservoir' for water if it is porous and if there is no solution of continuity between the two: loess under the chernozem in the Ukraine, chalk under the rendzina in Champagne in France; (b) it is essential, moreover, that the root system of the crop can at the right time reach the level where the water accumulates or is retained. This growth of the root system depends largely on local thermal conditions.

The surveys being carried out in some countries on the evolution of the hydrous profile of the soil and on the growth of the root system of the principal crops during the year should therefore be pursued very much further. They are essential for any research work into a better adaptation of crops (every species, every variety, if not every stock having different needs) to the water supply conditions offered by the various types of soils in each ecological zone.

Although the values of useful water vary rather widely, depending upon the different types of clay, they are not influenced very much by the content of the soil in this element (between 15 and 55 per cent). On the other hand, they depend very largely on the richness of sufficiently decomposed organic matter and especially of organic bodies lying between the plant matter proper and the stable humus. It is still necessary that climatic conditions should allow the soil rapidly to reach and to keep a percentage of humidity higher than the wilting point: in a semi-arid country, for instance, a soil very rich in humus may be a physiologically dry soil, and in an arid tropical zone, like Mali, sandy soils are the only ones to be adapted to a rain cultivation because they are 'agronomically' humid for a longer time than the neighbouring clayey soils.

Water in the soil does not serve only to nourish the plant with water. It serves also to convey the nutritive substances which the plant needs from one point in the soil to another; this process facilitates the feeding of the plant with minerals. To be fertile, therefore, the soil must be porous and well structured. The richness of the soil in well-developed organic matter has a special influence on these characteristics. In this case, also, the intermediate products in the development of plant matter are more 'active' than the stable humus itself.

Physical properties

A clearly defined, medium to fine structure, with rounded particles, and porosity are also two very important properties to ensure fertility in a soil, because they provide for a good circulation of gases, particularly oxygen and carbon dioxide. Although certain crops, such as rice under irrigation of flood water, can grow in a reducing environment, the great majority of plants only develop well in an oxidizing and aerated medium.

Physico-chemical properties

The physical and chemical conditions of the soil (oxidation-reduction as well as reaction) exert a very great influence, not only directly on the growth of crops but also on the development of certain microbial or chemical processes essential for the growth of plants, especially the creation of nitrogeneous organic products, the solubilization and circulation of trace elements, etc.

Chemical properties

Finally, among the bases for the fertility of soils are their content in various elements such as nitrogen, phosphoric acid, potassium, calcium, magnesium, sodium, sulphur, trace elements, etc., and the form in which they occur. It is not enough, however, that these various elements should be in the soil in a form which can be used by the plants, and in such quantity that the crop can easily absorb what goes towards the construction of its tissues. It is essential also, at least in respect of some of them, that various balances should be observed. Very little is known concerning the balances between anions and cations in the soil. That which must exist between potassium and magnesium in an assimilable or exchangeable form has often been observed, especially in regard to the nutrition of banana trees. Another balance has shown itself to be very important: that between nitrogen and phosphorus. As many agronomists and physiologists have shown, it appears essential to define to what extent, in terms of the ecological conditions, types of soil and crops contemplated, this balance between nitrogen and phosphorus should also be extended to sulphur. As far as forests are concerned, the scattering from the air of urea on plantations of Scotch pines in Sweden and of phosphates on pines in Australia, have clearly stimulated growth during the ensuing period. More intensive studies on these relations between characteristics and properties of soils and nutrition of plants, especially cultivated plants, are indispensable. The use of marked elements may facilitate this, as several research stations in the Federal Republic of Germany have demonstrated.

We still have too little knowledge about the influence of trace elements contained in the soil on the growth of plants under cultivation, but there is no doubt, however, that this action is most important. Among the many spectacular effects observed in certain cases, those concerning the application of the following elements to various crops may be cited: *manganese*—cereals, more particularly oats; *copper*—maize; *hevea* spp.; *zinc*—citrus fruits; *aluminium*—tea plants; *molybdenum*—leguminous plants; *boron*—beet; *cobalt*—grasslands.

The trace element-crop relationship depends on the type of soil used and the ecological conditions of the locality. Many studies are in progress on this subject; they must be further intensified, particularly stressing the dynamic relationships of these elements in different types of soils and under different ecological conditions. The practical importance of the results obtained may be considerable.

CHANGES IN THE FERTILITY OF THE SOIL DURING ITS UTILIZATION

Effects of putting under cultivation

The idea too frequently prevails that a soil having a certain level of fertility retains it naturally throughout the period of its utilization and development. This is far from true and, even with cultivation in a rainy climate, the replacement of natural vegetation by cultivated vegetation accompanied by the necessary working of the soil, the contribution of organic matter, mineral improvements, fertilizers, harvesting of crops, etc., changes a number of processes in the evolution of soil. This transformation is still more marked in the case of irrigated cultivation in which, besides, the quantity of water which impregnates the soil and percolates through it is very greatly increased in the periods when the soil was dry under natural conditions.

As a general rule it is necessary, starting with the soil, to manufacture a cultivable earth. One or two years of cultivation on bare soil or cultivation of a cover crop are necessary for the soil to allow re-growths, the root system or the largest stumps of the previous vegetation to be destroyed, and the reconsolidation and restructuration of the soil. In the case of soil that is very little developed (on very recent alluvium, marsh lands, etc.) one to three years of cultivation with a graminaceous cover crop (or with a gramineous-leguminous mixture) with a very deep, very dense and fine root system are also necessary to give the soil the desired structure and to enable microbial life to become established in it.

The first change which results from the cultivation of soil previously ocuppied by natural vegetation is due to the introduction of a new root system. That of the crop only occupies the soil for a relatively short time. It only grows gradually in a soil generally weakened during the first stages of the plants' growth. Nearly always, it penetrates less deeply but is sometimes denser than that of the natural vegetation. This causes a change in the mass and distribution of the residue produced by the death of the root systems, as well as in the influence exerted over the physical properties of the soil. Very great changes also take place in the biotic rise cycle of mineral substances; they may be leached considerably by percolating water (particularly when the soil is bare). This phenomenon is very marked in a very humid tropical region, in ferralitic soil bearing, for example, crops of maize, ground-nuts and tubers, in which this simple substitution of one root system for another causes a considerable disturbance in the water cycle, the organic cycle and the mineral cycle of the soil to a depth of at least one metre. On the other hand, mineral removal by crops is only of limited importance, at least in countries where there is sufficient rain and the soil is well drained.

The application of fertilizer generally compensates wholly or in part for the removals due to harvesting and usually only changes the soil slightly, except sometimes to acidify it (excessive use of ammonia fertilizers). The application of mineral or organic substances may cause a radical and fairly lasting transformation of the soil, especially if it is repeated rather frequently in the course of centuries: in many traditional farming countries, for instance, the repeated use of manure has given rise to very special 'anthropogenic' upper layers, abundant in humus, well developed and bound, and rich in phosphoric acid.

Methods of cultivation, turning over, ploughing, pulverizing the soil can also change its development and its potential. Accompanying the replacement of heath by grassland, such methods in Brittany (western France) have for instance transformed a podzolic or podzolic ochre soil into a soil of which the morphology and the majority of characteristics are those of an acid brown soil.

Too often, also, the putting of ground under cultivation is the cause of very rapid development of catastrophic erosion. It would be impossible to overstress this point, to which we shall revert later.

Finally, the introduction of irrigated cultivation especially causes the most violent changes: the diminution—or, in some cases, the increase—of the content in organic matter, degradation of structure and diminution of permeability, leaching of mineral elements and acidification of the soil, as at the Office du Niger near Bamako (Mali) where, in a few years of irrigated cultivation of rice, the pH of the upper horizon of the soil fell from 6.2 to 4.7.

Development of thickness of the soil

To enable the soil to play its part in any ecosystem, it must be of sufficient thickness. This critical thickness varies according to ecological zones and is the result of two conflicting phenomena: deepening of the soil by the process of pedogenesis and its thinning down by natural erosion.

The first cannot continue indefinitely. It is the consequence of climatic, biotic, edaphic and topographical conditions. It can also be stopped by 'obstacles' such as the formation of a lateritic shell or even of a calcareous crust, or by the presence in the rock itself of a seam which is particularly resistant and roughly horizontal: quartz, aplite, etc.

The second is slow when it is normal, which occurs chiefly under a dense cover of vegetation which intercepts the raindrops and diminishes their kinetic energy, reduces and slows down the flow of water, increases percolation by maintaining good porosity and a stable structure in the upper horizons of the soil and may 'strengthen' the mass of the soil, through its varying depth, by its strong roots.

Unfortunately, the putting of land under cultivation very often causes accelerated erosion. In 1956, the secondary forest at Adiopodoumé (Ivory Coast) lost 2.4 tons per hectare of earth while nearby, in an area that had been cleared and cultivated with cassava, the loss of earth rose to 92.8 t/ha. In 1957 these values were respectively 0.03 t/ha and 28.7 t/ha. In 1955, at Sefa (Senegal) the erosion under dry forest was calculated at 0.02 t/ha while land opened for cultivation with ground-nuts lost 14.9 t/ha.

The numerous works on this subject have enabled the influence of each of these factors of the phenomenon to be assessed fairly accurately. Wischmeyer's formula expresses it well and appears very applicable not only in the United States or Western Europe, but also in tropical Africa and Madagascar. It appears less true for Northern Africa. Future studies on this point should be made in experimental plots, which are now quite standard in type. They should be made mainly using rain simulators which, although not yet perfect, are already giving very good service.

Control of erosion and conservation of soil depend on the use of two sets of methods: (a) 'mechanical' methods, which control the flow of water, and therefore the erosion; (b) biological methods, which give the soil greater resistance against aqueous attack by bringing the vegetation and cultivation practice into play. The latter is frequently the more important.

Control of water flow is effected by modifying the topography by means of suitable methods of cultivation (type and direction of ploughing) or of structures designed according to the gradient of the slope: broad-based terraces for retention (slopes less than 3 per cent) and for diversion (slopes less than 12 per cent), banks and steps (slopes greater than 12 per cent), seepage trenches, etc. It can also be effected by the special arrangement of the vegetation in the space available: cultivation in rotated strips, stop hedges and strips, grassing of banks, wattle-fencing, protective woods. The result may finally be an improvement in the hydrodynamic properties of the soil (role of the organic matter, calcic or ferric saturation of the compound, stabilization of the structure, etc.).

But since man works the soil to produce plants, he also has biological means to control erosion. In effect, he can produce plants in such a way that effectively they protect the soil against aqueous attack and he can, moreover, utilize the plants to improve the qualities of the soil and to give it greater resistance. He is then carrying on a rational agriculture, taking into account the effect of fertilizing the crops, their density, the seasons of sowing and harvesting, associated crops and catch crops so as to leave the soil bare for the shortest possible time, cover crops, manure crops, etc., and lastly rotation. The measure and study of wind erosion, as well as the means to protect against this, still present major problems which must be resolved.

It must be kept in mind that the most effective way to conserve the soil depends mainly on using rational agricultural methods, with regard to their nature, intensity and time of execution. The special operations for controlling erosion should be fully integrated into the agro-technical operations as a whole, which constitute the rational system adopted for cultivation and conservation. The conservation of soil should be carried out on the scale of both the field and the farm as well as on that of the drainage basin.

Development of the physical properties of the soil

The putting of soil under cultivation very often causes a transformation of its physical properties. This may be a degradation due to destruction of the aggregates or weakening of the structure causing a compression of the elements into a solid mass. Thus the 'plough sole' appears and develops. Sometimes, especially in a tropical country with a long dry season, and chiefly on leached tropical ferruginous soils, the degradation goes further and the whole of the upper horizon then becomes very hard, very compact and very coherent as soon as it is dry and rather muddy when it is moist.

The degradation of the structure may be due, moreover, to the action of certain ions such as sodium, and less frequently potassium (the role of magnesium in this sense has not yet been made entirely clear, despite the work done in Canada, in the United States by the Salinity Laboratory, and in France by ORSTOM). They cause the appearance of a loose structure when they are in sufficient quantity in the absorbent complex of the soil. Generally, this change of structure is produced fairly suddenly when the Na/T value is in the neighbourhood of 15 per cent as was shown in the United States, the Netherlands, etc. In practice, it may appear with lower values (down to 8 per cent) when the absorbent complex has a weak exchange capacity (in Mali and Australia), but at other times only appears with rather higher values (18 to 20 per cent).

Acting with an almost contrary effect, putting under cultivation may cause, by desiccation through direct atmospheric action, often after erosion of the surface horizon, a hardening of compounds of iron or manganese already in the soil or liberated by acidification during the process of cultivation (Niari Valley in the Congo, Brazzaville). The superficial soil horizon can then be transformed into a layer of hardened aggregates (pseudo-concretions) or into a true lateritic pan.

Another transformation, very frequently found in an arid zone under irrigated cultivation (Morocco, for instance) or in a moist tropical zone such as Western Africa, is the impoverishment in clay, loam, and sometimes very fine sand, of the upper horizons of the soil through differential erosion in the water-bearing stratum and oblique sub-superficial leaching, after destruction of the aggregates by the cultivation and then semi-homogenization down to medium depth under the action of soil fauna. This phenomenon takes the form of a very considerable progressive textural gradient through the first 50 or 60 cm, without accumulation of clay in depth. Known in practice for a long time, it has appeared increasingly, during recent years, as being very frequent. It may be complicated, it seems—but more detailed study is still necessary—by degradation of the clay in the upper horizons, either by organic products in tropical countries or by hydromorphic effect, for these two phenomena may be accelerated by the growth change in the covering vegetation.

All these phenomena correspond to a lessening of soil fertilities. It is possible to control them and often to prevent their appearance. The most usual method consists of a good working of the soil, sometimes rather superficial. without over-pulverization of the upper layer. A rather lumpy surface is often preferable if the cohesion of the clods is not too great in the dry season, and if the size of lumps is not excessive.

In the case of the cultivation of irrigated orchards or in very rainy regions, methods of non-cultivation may give very good results. They then consist of the frequent cutting and decomposition on the spot of the natural or improved vegetation (leguminous) between the rows of trees, and the clearing of the soil only around the trees.

Sometimes, on the other hand, to improve the physical properties of the soil a complete turning over of the soil may be made as in the case of the chestnut, isohumic, sanded clay soils in the region of Doukkalas in Morocco. Such an operation, under gravity irrigation, increases the yield of beet by 100 per cent and of other crops also in very high proportions.

Finally, degradation of the physical properties of the soil by cultivation is often caused by the ground becoming choked with water or by a rise of the phreatic water level, particularly in irrigated cultivation. Canalization or drainage, used both in the United States and the U.S.S.R., as well as in the Netherlands, enables these to be avoided. An essential condition to limit some of these processes is the maintenance of the calcic state of the absorbant compound against an excess both of hydrogen and sodium.

From time immemorial, farmers have known the importance of organic matter in soils: the use of manure has made it possible to keep the soil fertile for centuries in many countries both in Western Europe and various regions in Asia. More recently, the introduction of a break of buried green manure crop —lucerne, for instance—has given excellent agricultural results in a great number of cases. Numerous works have stressed the great importance of maintaining the organic matter content of the soil above a certain level for a variety of reasons, but particularly to avoid the degradation of its physical properties (structure, water retention, etc.). It is therefore essential that plant matter, essentially cellulose, should be decomposed in the soil, crop season after crop season, by microbial means. If that is in good order, the simple use of crop residue enables a reasonably large quantity of plant matter to return to the soil so as to maintain its organic richness. On the other hand, if it is degraded or has bad physical properties, it is essential first of all to improve the latter, either by applying manure, or by the use of temporary grassland the agriculture-stock farming combination often provides an effective solution to the problem of maintaining soil fertility, as is seen, for instance, in the Sérère country in Senegal or by letting the land lie fallow for a fairly long period, as has been tried out fully in many agronomic establishments, such as for example that at Yangambi in the Democratic Republic of the Congo. Allowing land to lie fallow, like the use of manure, has moreover an important effect on the chemical properties of the soil.

The maintenance of organic matter is particularly important when cultivation involves irrigation, for this often tends to cause a lessening of porosity and a degradation of the soil's structure. By promoting the development of microbial life, it also tends to intensify the decomposition of organic matter in the soil, which increases the physical degradation of the latter.

On the other hand, the organic matter content of the soil can in some cases be increased by simple irrigated cultivation. The reasons for this apparent contradiction lie not only in the type of methods of cultivation used, but also in the initial organic richness of the soil and the climatic conditions under which it evolved. The essential thing to remember is that the function of organic matter in respect to the maintenance of the physical properties of the soil during its use (for agriculture as well as for grazing of forestry) must be regarded as dynamic and not as static.

Development of the physico-chemical properties of the soil

Oxidation-reduction conditions may deteriorate in the soil during its development, either as a result of a diminution in porosity, or through aqueous congestion or the rise of the phreatic water level, particularly in cases where irrigation is used. Especially when land is under this last type of cultivation, fairly extensive black sulphide stains may even appear, particularly with flooded rice cultivation. There may also be a drift of reduced iron or manganese compounds which accumulate at medium depth, thus diminishing fertility, as in certain Far Eastern areas. The maintenance of the physical properties, drainage and canalization, as indicated above, make it possible to avoid such phenomena which might lead to a very appreciable lowering of productivity.

The reaction of soil, when under cultivation, is very often variable. Alcalinization may be produced, especially in connexion with irrigated cultivation. This effect has been observed at Riverside in the United States, in India and Pakistan, Mali and Algeria. Sometimes, if sodium carbonate is formed, the pH of the soil may rise to 10 and over. To avoid such difficulties, here again canalization and draining are the first steps to take. It is often advisable also to apply gypsum, sulphur pyrites or even very dilute sulphuric acid, as has been effectively done in Central Europe and the U.S.S.R.

Neutralization of the reaction is the usual positive result of good cultivation methods in countries with a sufficiently temperate climate.

In other cases, the putting of land under cultivation may produce some acidification of the soil. In rain cultivation, in a moist tropical country, the biotic rise of mineral substances being often weaker under crops than under natural vegetation, the absorbent complex has a tendency to become desaturated and the soil to become acidified. In the Central African Republic, as in Eastern Cameroon or the Congo (Brazzaville), over a few years of fairly extensive cultivation, a fall of approximately one full unit of pH in a ferralitic soil was observed. In the equatorial zone the reverse phenomenon can occur, the pH rising from 3.5-3.8 under forest to 4.5-5 under coffee-shrub cultivation, for instance. The fall in pH can be more rapid and more pronounced in respect of irrigated cultivation with slightly mineralized water. Sometimes also the phenomenon may be accelerated if it is combined either with the use of a large quantity of ammonia fertilizers, as was the case in Rhodesia and Kenya, or with a transformation of the physical properties to allow more effective percolation. The last phenomenon was observed on very clayey ferrallitic soil, very rich in manganese, under ground-nut cultivation in the Niary Valley in the Congo (Brazzaville). In a few years, the pH of the top 15 cm of soil fell from 6-6.4 to 4.5-5. This acidification is all the more serious because at these pH values, 4.5 to 5, large quantities of manganese or aluminium become soluble, which are quickly poisonous for the crops. This fact was observed in various countries of South-East Asia. A particularly serious case of excessive acidification of the soil is that of the organic salt hydromorphic soils, rich in sulphides, the pH of which collapses down to values of the order to 2 when they are drained and become oxidized. They are then practically sterilized, unless the sulphuric acid and acid sulphates formed can be washed out by submersion or neutralized by addition of lime or other calcium compounds.

A slight acidification may not be a bad thing, especially in a tropical country. It is necessary nonetheless to avoid, by using various systems of liming and a judicious choice of fertilizers, too great a fall in the pH of the soil. The use of crushed dolomitique limestone may often give good results.

Chemical properties

The chemical properties which govern the fertility of the soil are changed by all the modes of using it. The uplifting of crops every year removes a certain quantity of mineral matter, essentially taken from the soil. Thus, 3 tons of ground-nuts in the husk contain over 200 kg of nitrogen, 100 kg of lime, 70 kg of potash; 225 tons of sisal leaves contain nearly 250 kg of nitrogen. 100 kg of phosphoric acid, 500 kg of potash and more than 860 kg of lime. In the foregoing cases, however, the larger part of the mineral elements is not found in the crop itself but in the residue which it may leave: oil cake or shredding products. Such residues can and should be returned to the soil. In other cases, the mineral elements taken from the soil are essentially part of the utilized crop. Such is the case of wheat, 5 metric tons of which remove at least 130 kg of nitrogen, 65 kg of P_2O_5, nearly 80 kg of potash and nearly 65 kg of lime; or of rice which, for the same quantity of paddy, contains about 100 kg of nitrogen, 50 kg of P_2O_5, a little more of potash and 50 kg of lime.

At all events, both from the aspect of the organic richness of the soil, as indicated above, and from that of its content in mineral substances nutritive to plants, it is essential that the greatest possible proportion of the residues of cultivation and of the residues of the crop should be returned to the soil. There should be no exception to this rule, whenever the soils are rather poorly provided with organic matter, or burn it up rapidly, and are poor chemically, as are many of the developed soils in tropical regions.

In addition to this form of chemical exhaustion of soils, there is the impoverishment which corresponds to the leaching of the mineral substances by water which percolates through them to below the zone in which the roots are active. In a temperate zone such removals are limited under cultivation. In a leached brown soil on loess in the Paris area, only traces of phosphoric acid and very small quantities of potash and magnesia are lost; however, leaching may remove 25 to 30 kg of sulphur and nitrogen per hectare annually; according to the crops, losses exceed 100-200 kg of lime per hectare per year, but they are much more considerable in the same area on bare soil. In more humid climates, or in irrigated zones, they can reach very high levels, even in cultivated areas.

In a semi-humid tropical country, like Central Senegal, where the environment is sandy, they are considerable under fallow or bare soil. They remain slight in a more clayey environment but become important under heavier precipitation. In the Casamance (southern Senegal) during the first years after a clearance, the quantities of lime or magnesia thus removed are between 12 and 20 times greater than those removed by the ground-nut crops cultivated there; in subsequent years the quantities removed are 2-5 times greater. The removal of potash there is proportionately less.

In the equatorial zone this leaching, very considerable under a crop which is annual, or of short duration, or having a more or less shallow root system (maize, ground-nuts, tubers), is less under perennial tree cultivation (cacao tree) and very limited under wooded vegetation. It especially affects the lime, magnesia, potash, etc.; the Congo (Brazzaville) is typical.

This impoverishment may be very great in the event of excessive irrigation after the use of salt water or in the case of an initially salt soil.

Against these removals, the elements given back during cultivation must be accounted for. The decomposition of additional plant matter in a normally cultivated soil (remains of cultivation, residues of crops, application of manure and mulch, digging-in of green fertilizer crops and cover crops, etc.) may largely replace that lost from the natural vegetation and liberate the nitrate elements, phosphated or phosphorated, or those rich in sulphur, and cations such as those of potassium, calcium, magnesium, sodium, etc. This seems to be, moreover, one of the important functions of the application of plant matter to the soil during cultivation.

The use of fertilizers and mineral additives also assists in maintaining the chemical richness of the soil despite its utilization.

When the soil is very largely deficient in one element, it may be permissible to apply large quantities of minerals so as to improve its fertility and as a real investment for the 'rectification' of the chemical make-up of the soil. In some cases, in areas with little water, or soils which fix the substances (hydroxide soils in regard to phosphoric acid, vermiculate soils in the case of potash) the operation is desirable; it can be carried out and has been done in many countries. In very moist zones and in soil which fixes certain elements poorly, such as potash in a poorly humified ferralitic soil, especially if it is rather sandy, such an operation appears costly and ineffective.

Another frequently important source of enrichment may be supplied by elements contributed by irrigation water, either in solution or in suspension. Those contained in sediment can only be active practically if they are frequently (annually or more often) subjected to desiccation and re-humidification, especially in hot countries. The change in these deposits may then be rapid, liberating the nutritive elements which form part of their minerals. As regards irrigated zones, the water of the Nile contributes 15 tons of sediment per hectare and per year; that of the Amu Darya 36 tons, containing more than half a ton of pure potash and 50 kg of P_2O_5. As to the nutritive substances contained in solution in irrigation water, their quantities are often very high (calcium, magnesium, potassium) but their absorption by the crops is frequently limited by much larger quantities of sodium. Sometimes, excessive quantities of poisonous substances, borates and fluorides are brought into the soil and to the crops by the same means.

Finally, although the change in the original minerals contained in soils only enriches them very slowly and very slightly during their period of agricultural use in temperate countries (though this phenomenon appears to play a large part in keeping up the yield in certain long-term agricultural experiments, as at Rothamsted in the United Kingdom or at Grignon in France, or in certain cases of very intensive cultivation), it has an essential function in the nourishment of crops on the soils of moist tropical countries, as has been shown in the case of the cacao trees on the ferralitic soils of North Gabon.

Nitrogen constitutes a 'special' case with regard to fertility. It is given to the soil, and through it to the crops, mainly by the decomposition of plant matter. The absorption of this element by certain micro-organisms—bacteria, algae—which fix nitrogen directly from the atmosphere, constitutes another source. Nitrogen is also transferred to the soil through leguminous plants by means of the *Rhizobium* which they contain in the nodules on their roots. The use of this process on a large scale enables certain countries (New Zealand) to ensure that nitrogen is fed to their crops, practically without the use of nitrogenous fertilizers. Nitrogen liberated in the soil, however, may also be stopped by reorganization processes. Intensive study of the nitrogen cycle in the various types of soils is essential, as also is the study of the different pedo-climatic conditions created in the various ecological zones by the processes of working the land.

Development of microbial life

It is above all indirectly, by causing changes in its physical and physico-chemical conditions, that the development of the soil changes the microbial life which has so great an influence on its fertility. Normally, if it is possible to regulate these characteristics of the soil as indicated above, microbial activity should help to maintain or improve its fertility. The research already undertaken must be carried on in greater detail and more actively so as to discover the practical means to intensify or to reduce, according to the types of soil, essential microbial functions, such as the bio-degradation of organic carbon or nitrification. The same thing applies in respect of the work concerning the different organisms which fix, symbiotically or not, atmospheric nitrogen and in particular the Cyanophyceae blue-green algae so easily utilizable in inundated rice plantations.

With regard to applications, moreover, a much more extensive utilization of methods of inoculating the seeds of various species and varieties of leguminous plants with active and suitable stocks of *Rhizobium* could make it possible even now to improve very appreciably the productivity of soils on a large scale.

CHANGES IN THE FERTILITY OF SOILS IN THE EVENT OF LARGE-SCALE DEVELOPMENT

In the course of the agricultural improvement of a zone, the change in the fertility of its soils depends on the type of development achieved in each of its aspects. It is possible, however, to consider them as a whole.

Forest

One of the advantages of forest is that it makes possible the use of certain soil areas that are not very fertile or are too sandy or too acid, and could not economically support crops or even grasslands. In this case, the advantage of the forest is that it provides for its own conservation by inducing the cycle of chemical substances it requires. In most cases, these can only be protective forests laid down once and for all, which supply directly only very few utilizable products. Indirectly, however, this type of vegetation is very 'productive' because it prevents or restricts erosion by which the barren debris washed away by water from thin or skeletal soils would probably cover the soils at the foot of the slopes, hindering their use for agriculture (rice fields in many tropical countries) or jeopardizing the functioning of works situated downstream. The root system of forest vegetation can often penetrate the weathered rocks of thin soils, activating their decomposition and deepening the soil itself.

Mention must also be made of the frequently important role of forests from the aesthetic standpoint or as a refuge for animals. This is particularly true in many national parks of reserves for flora and fauna.

Forest used for production must cover deeper and sufficiently drained soils, with the exception of certain areas which can support forests despite bad drainage (mangroves, for instance). Though chemically poor, they may be suitable if they are sufficiently deep and penetrable. Owing to the protection against erosion which such a forest provides for itself by the undergrowth which it allows to grow, and owing to the importance of the upward biotic cycle of the mineral substances, to which it gives rise especially in hot and moist countries, it often brings about the gradual establishment of a fairly stable balance between itself and the soil. Precautions are necessary during its exploitation, especially if this is done 'to the limit', to avoid the appearance of the disastrous hydromorphic condition, a chemical impoverishment of the soil and sometimes a violent erosion which may well hinder its subsequent re-establishment. During its development, any 'undergrowth clearance' operation must be avoided, for this leads to the removal of the cover of forest litter from the soil, the forest mulch playing an important part in maintaining the fertility of the underlying soil.

During the evolution of the forest soil, there is a danger that its fertility may be diminished as a result of excessive leaching and acidification of the upper horizons and subsequent degradation of the minerals and clays which it contains (podzolization), under the influence of the acid organic substances from the coarse humus due to the too slow decomposition of the litter. This effect is particularly frequent in countries with a northern or moist temperate climate on acid rock or in equatorial countries on fairly coarse quartz sand or gravel. This loss of fertility may be very rapid and very accentuated under coniferous vegetation or under trees with a debris very rich in lignin and tannin. A forest of mixed composition—leafy foliage, coniferous—is therefore often to be looked for when possible, despite the generally slightly lower immediate economic return.

In the case of nut-bearing forests (chestnut trees, walnut trees, hazel bushes, etc.), it is also necessary to give attention to the chemical impoverishment resulting from the removal of elements which should be compensated.

In a moist tropical country, the dense forest allows some erosion to appear as a result of the flow of water which is slow but still active between the plant litter and the soil itself. It does not prevent the loss of fertility due to the ferralitization phenomenon, which is slow. The forest constitutes in these regions the utilization of the soil which best preserves the fertility characteristics and gives rise to the least imbalance in development.

Finally, mention must be made of the development of tree plantations, on agricultural land, usually in rows or curtains and combined with food-producing or industrial crops. The trees benefit by fertilizers, ploughing and irrigation of crops, and give protection to the latter, thus ensuring larger harvests. Proper spacing must nevertheless be ensured.

Grassland

Grassland, like forest, ensures effective utilization of soil which is not very deep and often sloping, provided that the climate is sufficiently moist. It can, therefore, give excellent results on a deep and fertile soil. The same applies to the steppe in a continental climate ranging from semi-arid to sub-moist. It is not very productive in an arid climate.

Grassland also, and perhaps uniquely, makes possible an effective utilization of over-moist soils offering fairly intensive reducing conditions.

When well developed, and under appropriate climatic conditions, grasslands constitute the best protection of the soil against erosion, except against sapping and mass movements (soil creep in lumps or flakes) and, in some cases, pronounced gully erosion. When well maintained, on a soil whose pH is not too low (usually pH larger than 5-5.5) and a complex containing not too much soda (Na/T less than 12-15 per cent), they permit a very appreciable improvement of the structure of degraded soils within two to four years. They may also, depending upon their richness in species of the leguminous family, enrich the soil in nitrogen.

However, in hot and very moist climates (over 3,000 mm rainfull annually as in many regions of tropical America) when not established on particular fertile soil (alluvions, volcanic soils), grasslands are usually incapable of resisting invasion by shrubberies. It becomes costly, if not impossible, to re-establish them, especially if periodical fires, which are moreover difficult to control rationally, cannot be resorted to.

The effect of grasslands on the biotic rise of basic elements is rather limited because the root system is usually insufficiently deep. The use of 'compensation' or 'maintenance' mineral dressings is all the more essential.

Agricultural development

The influence of cultivation on the soil depends very largely on the development method adopted.

The perennial cultivation of trees such as *Hevea* spp., cacao trees and palm trees or fruit trees can be very compatible with sound soil conservation practices. Except when establishing a cacao plantation in dense forest by the layer or strip method, it requires effective protection of the soil against erosion, at least during the early years; covering plants and continuous leguminous crops, for example (including the plantain banana tree in tropical countries), are the most frequently used. It is necessary, however, that the soil should be fairly rich chemically and that the water supply should be suitably ensured either by an abundant and not too irregular rainfall, or by irrigation.

The rotation system is another method of agricultural development which enables a certain balance to be reached fairly safely. Properly organized cultivation of plants in rotation permits a rational utilization of the soil, chemically more complete and more diversified and reaching to a greater depth. It makes it possible to ensure a semi-homogenization of the soil by cultivation work at various depths, a certain biotic rise of the nutritive mineral elements and the maintenance—sometimes even improvement—of the physico-chemical conditions for oxidization-reduction and reaction. This balanced utilization of the soil can only be obtained by means of large applications of fertilizer and, sometimes, of small quantities of additives. The rotation should be organized in such a way as to permit the integration of the necessary cultivation processes in order to preserve the soil against the action of erosion.

In tropical areas, a method often used is that of mixed crops, traditionally preferred to a sequence of single crops in rotation. It can provide a balanced utilization of the soil in a fairly extensive way and is used chiefly in countries with an irregular rainfall. Since the various crops have different water requirements, it enables at least a minimum harvest to be obtained each year. In areas of high rainfall, it ensures a better control of the leaching of mineral elements by the regular utilization, every year, of a greater depth of soil. For purely agro-technical reasons, this method is not applicable to intensive cultivation which requires a certain measure of mechanization, protection of the crops against their enemies, insects, fungi, etc., and the use of fertilizer suitable to each species cultivated.

The situation of commercial crops, not grown in rotation (fibres, fruit, leguminous plants, etc.), is quite different. In certain cases, sisal for instance, they occupy the soil for fairly long periods—eight years and more—but, in spite of this, they do not always protect the soil against erosion; cultivation methods such as broad-based terraces, which do not prevent the passage of agricultural machinery, are then necessary. This type of semi-permanent crop is well suited to these. As a rule, such crops are only possible on a very intensive system and are only profitable if the whole system of cultivation permits an improvement of the physical and physico-chemical properties of the soil—or at least the maintenance of their quality. Chemically, they often leave the soil somewhat unbalanced. Studies made of this subject often take account only of the nutritive needs of the plant and, with some noteworthy exceptions, do not give sufficient attention to the cultivated plant-soil combinations. Here it is more essential than elsewhere to have regard also to the dynamism of the oligo-elements, removed or applied by pesticide or herbicide treatments. Research should also be actively pursued into the future of the complex organic products spread over the soil by these same treatments.

A last case is that of irrigated cultivation. Here the evolution of the fertility characteristics of the soil is first of all submitted to the same conditions as those of crops grown under high rainfall conditions, mentioned above. It is complicated, however, according to the method of irrigation used (total supply of water or merely additional supply, sprinkling or gravity, and their variations), and the characteristics of irrigation water with regard to elements carried in suspension or in solution, as well as the volume of water used and the rate of its use. This additional water, in relation to the natural conditions of the area, has varying effects according to circumstances, on the porosity and permeability of the soil, on its richness in soluble salts—carried in the water or produced when the irrigation water enters the soil—on its content in nutritive mineral elements and in organic matter.

EXPRESSION OF THE CHARACTERISTICS OF FERTILITY OF SOILS

The characteristics of fertility of soils, such as have been discussed above, can be known and assessed more or less precisely by the usual methods of observation and measurement in the field, and then of analysis of samples of the various horizons of soils or of plants growing in them.

They can be indicated and interpreted practically in the publications accompanying pedological charts. It is essential that they should then be explained in terms of the various series or, at the very least, of the different families of soils defined by type and degree of development (often a complex type due to the combined effects of two or three simultaneous or successive processes) as well as by the petrographic characteristics of the original materials. They can be indicated also in the accounts of regional studies according to other methods, more or less fully integrated, founded upon the knowledge of the 'land unities' or 'landscape unities' used by various ecologists in Australia, Pakistan, etc., or by the FAO experts in countries with particularly complex terrains such as Lebanon.

Valuable experiments have often been made to attempt to calculate the degree of fertility of soils by means of indices bringing in the various characteristics which constitute the bases of fertility. Among the most used is that by Storey in Australia, and that developed by FAO which is more complex but perhaps comes nearer to reality. The latter uses eight edaphic factors. In the evaluation of each factor within a single multiplication formula, this takes account of the influence which a factor may have on the fertility and productivity of the soil in terms of the principal categories of ecological conditions and of broad groups of types of crops. The relationships between soils, climates and crops are still not very clearly defined, and are, in any case, very complicated. Such indices cannot take account of this complexity if they remain too simple, but if developed, they may become difficult to use. Moreover, whatever may be the method of calculation retained, they may allow numerical compensations which, in effect, do not correspond to reality and may give a false idea of the fertility of a type of soil.

It often seems useful to transfer geographically, on to a map, the results of these studies. The maps of families of or series of soils, and those of 'systems of terrains or landscapes' are already, as indicated above, a preliminary representation. It is also possible to map the values obtained by the calculation of these indices. Whatever may have been said or written, such representations have scarcely any value on a small scale, such as 1: 200,000 or below. They take on a real significance mainly at 1: 20,000 and above. With a reasonably detailed map of soil utilization, it is also possible to define 'classes of fertility', such as those used by the Department of Agriculture in the United States. In Africa, maps showing the 'optimum utilization' of soils, on a fairly large scale, have been drawn up in many regions, showing the distribution of the various classes of fertility of soils and their subdivisions in terms of the work to be carried out to maintain or improve this fertility; types of soils according to their method and degree of development, of their original material, and of their depth; of their type of plant covering and of their slope and present degree of erosion.

From the varied information thus shown on these maps it is easy to deduce, taking account of climatic conditions, the optimal capabilities of each region for cultivation.

It is also possible to produce directly, starting from the pedological maps themselves, cultivation capability charts of the sectors explored with a view to cultivation using rain or irrigation water, the two types of capabilities differing very widely. Irrigation requires above all very good physical properties, permitting an easy but generally not too rapid circulation of water (except where saline water is used). Sometimes the term 'chart of agricultural—or cultivation—employment of soils' is used. This is inaccurate, because the possibilities of using soils depend very largely on the progress made in the knowledge of soils and in technology. Thus some sandy, or sandy-clayey, often podzolic soils, have long been regarded as unusable, except for a coniferous forest—and not even that always—in France, in the United Kingdom, in Australia, in New Zealand. This view is no longer held, since the discoveries were made of the effect of lack of phosphoric acid and trace elements: copper, molybdenum, zinc, etc. Since then, it has been possible to provide remedies and to change completely the agricultural utilization of soils. This is done fairly frequently but, nevertheless, such deficiences are always expensive and often difficult to correct, and the agricultural capabilities or limitations of each soil are indeed referable to its individual characteristics. Therefore the most practically useful and most reliable maps show the distribution of the zones of aptitudes and limitations for specified crops.

CONCLUSION: THE CHOICE BETWEEN THE VARIOUS POSSIBLE TYPES OF EXPLOITATION

Every 'authority' seeking to use every parcel of land so as to ensure the best possible development for the population dependent upon it, while retaining the possibility of similar utilization in the future, should prepare an alternative as to the type of development to be carried out.

The remarkable facilities for communication nowadays permit active and regular trade between one country and another and give to each the possibility to not produce the food, plants or animals, of which it has need directly for itself, but to procure them from other regions. Nonetheless, it appears that a minimum of food should be produced within the national territory or within the framework of the national activity, whereas according to possibilities, products intended for export should be provided, directly or indirectly, by the development of the soil of another part of the country. In any case, it is most desirable from the aspect of economic development and of national economic independence.

The choices made should preserve certain areas or certain sectors in the most natural state possible, to maintain the original habitats of species and varieties of the different existing animals and plants, or the most typical representatives of the various plants and animal groups, ecological complexes or particular ecosystems. The more numerous the areas which could be thus preserved, the less will be the fear of seeing the accidental disappearance of the wild plants and animals which are of such importance to humanity.

The whole of such reserves, integrated or otherwise, may represent in total a not negligible proportion of land. Even increased by all the areas which, owing to the insufficient fertility of soils, cannot be utilized for agricultural purposes and, for various reasons, are not used for urban or industrial activities, they still represent, in most cases, areas of natural vegetation insufficient to ensure the agricultural-sylvan-pastoral balance necessary for each country, and the balanced covering of plants for each drainage basin. More extensive zones must be reserved for forest or savannah, starting, usually, with the least fertile soils. In many cases, the surfaces thus maintained under natural vegetation, with the exception of the integrated reserves which cannot be used for similar purposes, are sufficient to satisfy the touristic, aesthetic and cultural needs of populations. They are particularly important in mountainous or very rainy regions, where moreover they perform the function of regulating the flow of water. Sometimes, certain areas should be given over to reserves, consideration being given to their appearance or of events which have taken place there, or by reason of their proximity to large built-up areas.

Types of utilization intended to produce crops for national consumption or for export require soils which are sufficiently fertile or easy to render productive, and whose degree of fertility can be maintained or improved in the course of development. They are therefore usually a matter for priority choice. Underlying this choice, there is of course a political decision which involves economic and social considerations. The economic considerations include more particularly the balance of payments and the need for foreign currencies necessary for the import of capital goods. The social considerations include the employment and food requirements of populations in the over-populated or not very accessible areas.

Other decisive factors must be the real cost of each operation and its impact on the other sectors of activity in the country—small or medium-sized manufacturing industries, for instance—as well as the reasonably straight-forward or workable adjustment of the populations of the regions to each type of development.

It must not be forgotten, however, that in many cases the very nature of the soils and their fertility characteristics will generally guide the choice towards one agricultural utilization or another. Thus, in a moist tropical or subequatorial region, the existence of sandy, very desaturated ferralitic or very acid, sandy-clayey soils will lead to the development of a protective forest in broken country, or of a production forest, or to large plantations of palm-oil trees and *Hevea* species, or the establishment of certain fruit crops for export (pineapple) rather than to the development of food crops in rotation or even of cacao or coffee plantations.

It is rare to find in any given country that all the utilizable areas can be developed at the same time. The choice between zones brings in the same basic factors as the choice of types of development for each sector. One more factor, however, must be considered. It is necessary to avoid regional distortion, with its politico-social consequences, and to maintain a relative balance in the development of each region—with the exception, however, of any regions which are excessively under-populated.

It is also quite certain that every government is obliged to take into account the cost of the development of each area compared with the value of the long-term results to be expected; it must also consider the relative facility of obtaining the necessary funds from the international financing organizations, for example, for the preliminary studies and then for implementation and development.

The other types of development which do not require such quality of soil correspond sometimes to compulsory plantations: protective sectors, sectors under natural vegetation (for example, forests or savannah) for protection, or hydrological balance sectors for drainage basins. The same thing sometimes applies during the placing in reserves of nurseries or original species, or a given group of plants, if the degradation of the natural vegetation is already very advanced in the region. A parallel case would be that of the use of land for towns or industries or for 'green belts' which should accompany them. As a general rule, however, the priority nature of these types of utilization is less strict than in the earlier cases or only applies to much more limited areas.

Finally, despite all the difficulties presented, at a given time, by the choice between the various possible utilizations of the soils of a sector or an area, this choice cannot but change with time, as a result of change in the market for the products which may be obtained from them, as a result of change in the needs of the populations concerned, or as a result finally of changes which may arise in the methods of agricultural utilization of soils, of maintaining their fertility and of increasing their productivity by means of changes and progress in pedological and agronomical techniques.

Water resources problems: present and future requirements for life

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Water is essential to all forms of animal and plant life, as it is to most human activities. At the same time it is highly sensitive to the modifications of the environment resulting from these activities, a fact that inevitably gives rise to acute and perpetual problems for mankind.

These problems ensue both from the constant increase in mankind's water requirements and from the repercussions on the water cycle—and hence on the biosphere itself—of multifarious human activities. This subtle and fluctuating interrelation between water, man and the biosphere, which has existed since the origins of mankind, is today having crucial consequences, for man now possesses the knowledge and means that enable him to intervene to great effect in the cycle followed by water as it circulates in the biosphere.

Experience has shown, however, that such interventions may be either harmful or beneficial. It is increasingly important in the present-day world situation to intervene correctly and to avoid mistakes, the long-term consequences of which may be catastrophic.

THE HYDROLOGICAL CYCLE

Vast quantities of water circulate continually above, on and below the surface of the globe. Due to solar radiation, water evaporates off oceans and continents and is transpired by plants and living creatures. The atmosphere is laden with moisture. Its differential heating gives rise to the great motions that redistribute the masses of moist air above the globe. Due to condensation, water returns to the globe as dew or is precipitated as rain, hail or snow.

It is estimated that two-thirds to three-quarters of this water returns directly to the oceans. The rest falls over the 146,000,000 km² of the earth's surface, where it may either evaporate, infiltrate or stream away.

Part of the water evaporates directly off the ground and vegetation after its fall. Another part soaks into the soil and may either be stored, thus becoming available to plants, to be absorbed or transpired by them, or it may penetrate more deeply and join with ground-water flows and ultimately with the surface flows to the oceans. A third part flows over the surface of the ground when its rate of penetration is below that of precipitation. It then feeds the surface waters.

Not all the water in the biosphere plays a part in the dynamics outlined above. A certain amount is stored for more or less lengthy periods in plant and animal tissue, in the form of ice in the polar regions, in the form of permanent snow on the mountain tops, or else remains chemically or physically linked to the constituent elements of the soil.

This cycle can be very approximately described by an inventory. One such attempt has yielded the values shown in Table 1.

TABLE 1.

	Volume (cubic miles)	Percentage of sum total
Surface waters:		
Fresh-water lakes	30 000	0.009
Salt-water lakes and inland seas	25 000	0.008
Watercourse beds	300	0.0001
Ground water:		
Humidity of the soil and vadose water	16 000	0.005
Ground water to a depth of half a mile	1 000 000	0.31
Deep ground water	1 000 000	0.31
Glaciers and ice-caps	7 000 000	2.15
Atmosphere	3 100	0.001
Oceans	317 000 000	97.2
TOTAL (in round numbers)	326 000 000	100

WATER AND THE BIOSPHERE

During its cycle in the biosphere, water performs a series of fundamental actions, its primary action being at the very origin of the soil from which man wins the greater part of his means of sustenance.

The chemical decomposition and mechanical disintegration of rocks is in fact governed by water precipitation and by the temperature of the environment: the phenomena of hydrolysis, dissolution and hydration are main processes in the weathering of rocks, in the formation of soil and in the subsequent stages of pedological evolution.

When the soil has been formed, its physical properties enable it to become a reservoir for precipitation water, which is then available for plant life.

Thus before the appearance of modern man upon the earth with his interventions, the earth was covered with natural vegetation. During the greater part of the geological eras this vegetation was dense and luxuriant, as the climate of the globe was for long periods warmer and moister than it is at present: cold climates were exceptional. Such vegetation led to rapid weathering of the rocks and afforded protection against too rapid erosion. After the last ice age, when the climate again became generally warmer, forest vegetation, thanks to the great humidity, overran the lands that had become free, and the tropical forest covered vast areas.

MAN'S INTERVENTION

When man appeared on earth he began to change the original equilibria. Till the recent past, however, the hydrological cycle has been affected only in regions that, like the Mediterranean areas, the Middle East, India and China, have long been inhabited by man. It is often recalled that under Philip Augustus the waters of the Seine were drawn for drinking and that in London in the eighteenth century salmon was fished under the windows of Parliament.

It was only with the continuance of man's occupation, the rise in the population and the advent of advanced industrialization that pressure on the resources of the environment appreciably increased in order to cope with the ever-increasing demands, above all from industry and agriculture. As a result, the hydrological cycle was more radically affected, all the more so when the climate was unfavourable.

Massive deforestation reduces the regulation of river flow and leads to greater and more frequent floods. The irrigation of alluvial plains without draining may give rise to waterlogging and salination of the soil, which were the likely causes of the ruin of Babylon.

Improper working of the vegetal cover sets off the process of soil erosion, as a consequence of the prevalence of flow over infiltration. Control by dams is a costly remedy. Both dams and vegetation lose water by evaporation.

These few examples show how complex a problem is raised by the tapping of the resources of the environment. The irrational use of water can entail the loss of soil and plant resources, just as the irrational use of these can cause water-losses.

When attempting to solve certain hydraulic difficulties, for example those connected with navigation, electricity generation or even irrigation, the engineer intervenes in the water cycle but he must ever bear in mind the most far-reaching consequences of his actions for the biological and hydrological equilibrium alike. In other words, every intervention by man in the hydrological cycle must be examined bearing all these consequences in mind and utilization must be effected in every case as an integral act.

THE NEEDS OF MANKIND

Water is required in major quantities for domestic and industrial consumption; for the removal of waste products; for agriculture, including irrigation; for navigation; for hydroelectrical generation; and for both recreative and aesthetical purposes. Human biological requirements and animal needs are reckoned at 10 tons of water per ton of living tissue; 250 tons of water are needed to produce 1 ton of paper, 600 tons to manufacture 1 ton of nitrate fertilizers and 1,000 tons, evaporated and transpired, to irrigate crops yielding 1 ton of sugar or maize. The major use of fresh water in advanced countries is for the dilution and transport of wastes.

To make the best use of the water available at present, two classes of problems arise, one of quantity and the other of quality.

QUANTITY OF WATER

Man cannot hope to influence the major terms of the equation of the water balance. He can make only a minimum impact on the volume of precipitations falling on the surface of continents: 90 per cent of the precipitation is of maritime origin and only about 10 per cent is derived from vegetation and from fresh-water surfaces.

Manipulation of the vegetation cover can therefore achieve negligible increase in the total precipitation, in spite of optimistic earlier forecasts in support of afforestation. Penman (1963) has discussed this evidence convincingly.

Local initiation of precipitation by cloud seeding has achieved limited success, but is restricted to a rather narrow range of favourable conditions. This principle offers no prospect of a general increase in the annual water supplies of arid or semi-arid areas. A recent review by the Director-General of the United Kingdom Meteorological Office (Mason, 1967) concludes: 'We shall have to ... develop much better operational and evaluation techniques to prove that weather modification is feasible even on a modest scale. Talk of weather control is still very much in the realm of science fiction.'

Man therefore cannot yet control weather and climate, but he can intervene effectively at the moment when the earth surface receives precipitations and above all in the distribution of rainfall.

Here, by manipulation of vegetation, by shaping and tillage of the soil surface, by drainage, by reservoir storage and by irrigation, by exhaustive pumping or by deliberate recharge of underground aquifers, man can exert major influence amounting in some areas to strict control of the precipitation received. Within this sector the question under serious study in many countries of the world is how to assess and to provide for the needs of the growing population, both in the immediate and long-term future.

QUALITY OF THE WATER

The use of water frequently entails the modification of its physical, chemical and biological characteristics. This may in turn be attended by a diminishing of its quality, that is, of its former potential. It must then be treated so that it can once more serve a given purpose. Man can thus both mar the quality of water and restore it.

MEASURES FOR THE RATIONAL USE AND CONSERVATION OF WORLD WATER RESOURCES

NECESSITY OF PLANNING

When man is faced with the problem of utilizing water resources he must plan his action in terms of an over-all strategy to make the most of the water available in order to satisfy the short, medium and long-term requirements.

Such planning presupposes firstly an estimate of needs and resources, followed by a comparison thereof in the light of future prospects. It implies, secondly, the settling of priorities and the co-ordinating of the different uses to be made of the water. Lastly, it calls for the selection of planning units, the most appropriate unit generally being the catchment area, for it is in this area that its multifarious advantages can most easily be turned to account, that conflicts arising over its utilization can be settled and the best co-ordination of efforts be established.

It also presupposes an economic analysis of the problems involved and their possible solutions.

Lastly, the twofold aspect—qualitative and quantitative—of these problems must not be overlooked. In many cases, in fact, countries have a shortage, not of water, but of water having the qualities needed to satisfy given needs, particularly vital needs. Great attention must therefore be given to changes in the quality of waters during the hydrological cycle: it is well known that a single drop of water can be used many times over before it reaches the sea or evaporates.

DATA COLLECTION, RESEARCH AND STAFF TRAINING

The first requirement for any form of development of water resources is hydrological records. Data on the distribution, amount and intensity of precipitation, on the amount and quality of flow and of storage in streams, rivers, lakes and reservoirs, on the amount, quality and recharge régimes of ground water, on evaporation and transpiration rates on the river basin characteristics (topography, soils, geology, vegetation) are necessary to the progress of all communities, at all stages of development. The collection and the interpretation of such records needs teams of specialists not only in hydrology but also in agriculture, fishery and environmental health and other disciplines directly involved in the problems. All of the subjects discussed in this section share the same basic requirements of staff training, data collection and research.

LAND-USE PLANNING

The economic basis of development of ecological resources into arable, pasture, range or forest must remain subject to the requirements of water reception and control. The most difficult aspect of the planning of water resource development is the highly variable nature of the supply, both within seasons and from year to year. This requires provision of drainage channels and water control structures with capacity to take the highest flows expected and thus to avoid destructive floods. Provision of storage has to be increased beyond the average needs of the community to provide for the most severe droughts expected. All such investment clearly depends for efficiency of design on the adequacy of the hydrological records collected by the community for many years in advance of its use. Unfortunately, the semi-arid areas having the widest fluctuations have also the least amount of data. As Langbein (1962) said in reviewing the surface hydrology of the arid zone, 'Water facts are where water is.' In the countries where the water engineer's design problems are most exacting he usually has the least data. Establishment and maintenance of hydrological networks to obtain measurements must be accepted as high priorities in developing countries.

In the more developed countries, with large and increasing water demands, the variability of water supplies must be met by even larger and more expensive provision for storage or re-use. In semi-arid countries, where annual spates are characteristic of all rivers, good agricultural returns from low capital investments are obtained from simple diversions and water-spreading ridges. Floodflows laden with suspended solids are thus distributed over areas of alluvium, recharging both soil moisture and ground water. Crops are then grown on the stored soil moisture, frequently supplemented by irrigation from bore-holes. Excellent examples are in operation on the Red Sea littoral in the Eritrea province of Ethiopia, where only two days of work with a single bulldozer re-creates annually the diversion ridges to recharge areas of 60 hectares or more for highly productive cropping. The Gash Delta in the Sudan and many schemes along the littoral of the southern Mediterranean are successful examples of this flexible method of harnessing the most variable water supplies.

MANIPULATION OF VEGETATION AND WATER SUPPLIES

The natural vegetation covering most high-rainfall stream-source areas is some form of forest or scrub. In many semi-arid areas growth of populations subsisting by primitive agriculture or pastoralism has led to the stripping of the protective vegetation through fire and excessive grazing. The first direct effect is soil erosion, with very high loads of suspended solids in spate flows of the rivers. The drier the climate the more fragile is the vegetative cover, and although the total water available to erode soil is less, the rainfall intensities are characteristically higher. Langbein and Schumm (1958) found a maximum solids load to be generated by country having about 375 mm (15 in.) of annual rainfall. The role of vegetation in maintaining infiltration into the soil surface and in the regulation of streamflow by the delaying of run-off and also the price paid in evapotranspiration are now understood in principle (Penman, 1963). Complexities of geology and of climate, however, render uncertain any quantitative forecasting of the hydrological effects of land-use changes in stream source areas. Pilot schemes are therefore necessary to establish the details of such changes in the water régime. In temperate climates such studies have been concerned mainly with the felling or planting of forests.

These watershed studies have been based on annual records and have required from ten to twenty years to provide an answer.

In the tropics, more rapid methods are sometimes possible. In Kenya, detailed catchment-area studies are measuring the effects of the planting of pines to replace montane bamboo forest in the watershed which supplies the city of Nairobi: the replacement of high rain forest by tea plantations is also under study. By using a combination of a water-budget and an energy budget by Penman's methods, valuable early information was won in five years (Pereira, McCulloch, Dagg *et al.*, 1962). The pine plantations, clear-felled after a short rotation, gave an increased yield of water of unchanged high quality. Well-planned tea plantation, using the most modern soil conservation practices, caused a fourfold increase in peak streamflow but without loss of soil. In many developing countries there is as yet still time and space to carry out such direct studies of the hydrological effects of proposed land-use changes. Major decisions which will affect the prosperity of whole communities for generations to come may then be based on facts rather than on opinions.

SURFACE STORAGE DEVELOPMENT

Man has stored water for irrigation purposes from the beginnings of civilisation. Indeed, many of the most enduring traces of earlier civilizations are the remains of their dams and irrigation channels. With the development of hydroelectric power and of large-scale irrigation schemes, the storage works have attracted capital on an ever-increasing scale and the artificial lakes grow larger. The Boulder Dam in the U.S.A., the Kariba Dam in Central Africa, the Volta Dam in Ghana and the High Dam at Aswan on the Nile show a continuous increase in the capacity for water storage and power generation. Each major reservoir achieves partial control over seasonal fluctuations in river flow and renders easier the construction and operation of further dams downstream. The Tennessee Valley Authority in the U.S.A. and the Snowy Mountains Scheme in Australia have demonstrated the efficiency of reservoirs in series. Operation in response to conflicting time-tables for power, flood control and irrigation supply involves complex calculations in which the electronic computer now plays an important role.

All reservoirs, from the shallow stock-pond which traps a little water from the flash flow of an ephemeral stream to the dam which creates a major artificial lake, can be judged by three essential criteria. The first is the efficiency of storage, i.e., the ratio of water usefully stored to that lost by evaporation and seepage. The second is the cost per unit of water thus effectively stored, in relation to its value for power development, irrigation or other uses. The third is the effective life of the reservoir, since sedimentation steadily reduces capacity and it is rarely economical to clean by dredging. In some circumstances a fourth criterion, the hydrological effects on flood control and on the maintenance of a minimum dry-weather flow, may be of major importance. Many small dams in the headwaters of major river systems are built mainly for flood control in order to delay the peak flows in separate tributaries and thus to prevent their coincidence in the main river.

There has been much controversy over the alternatives of storing and using water for agriculture high in the catchment basin, in necessarily small reservoirs, or of trapping run-off in larger and more efficient structures lower in the valley. In countries with high population densities, the shortage of storage sites and their high social costs render new solutions necessary. Attention has therefore been directed to storage in river estuaries by the construction of barrages. Apart from the costs of distribution of water from the lowest point in the catchment area, this solution can raise difficult problems of siltation, of navigation rights, of land drainage and of sewage disposal. If fish migration is important this must also be provided for. Estuary storage is, however, a possible solution which must be studied seriously in several countries.

In the contrasting conditions of semi-arid ranch-land there is widespread use of shallow ponds for domestic and live-stock supplies. These are usually of less than 10,000 m^3 capacity. In many cases they permit the grazing of valuable ranch-land, but they incur serious evaporation losses. Langbein (1962) quotes evaporation losses as high as 20 per cent of the total flow in the dry Cheyenne River basin, where stock ponds already trap half of the total flow.

Reduction of evaporation by floating a monomolecular film of a heavy alcohol, hexadecanol, on the surfaces of reservoirs has received major research attention over the past decade, but with limited success. The film reduces water loss from evaporation pans by about 50 per cent, from small reservoirs up to about 50 hectares by 30 per cent on larger lakes by about 10 per cent if a film can be maintained against wind and wave. The very elaborate studies on Lake Hefner in the U.S.A. in 1956-58 saved nearly 10 per cent. Hopes for success in this field are now directed mainly to the chemistry of a stronger film. A practical development which has shown more promise in Australia and in Southern Africa is the use of floating tablets, about 1 m^2 in area and 2-3 cm thick, cast from an expanded polysterene material in which the cells are sealed so that water is not absorbed. The method is at present expensive but appears worthy of more experimentation.

Sedimentation of reservoirs and maintenance of their capacities are acute problems in semi-arid countries and can be prevented only by the maintenance of protective vegetation on hill slopes. The toll taken by the transpiration is such, however, that with completely effective conservation measures a rainfall of 500 mm which penetrates where it falls may be completely absorbed by the soil within the root range and lost by transpiration (Pereira, Hosegood and Dagg, 1967). In developing countries reservoirs built to take the run-off from misused semi-arid country can remain unfilled as the soil conservation services progress in their tasks. One possible solution to this dilemma is to seal the soil surface of special catchment basins with silicone resins or with sprayed emulsions of asphalt and thus to harvest almost all of the rainfall (Myers, 1964). Several years of field tests by the United States Water Conservation Laboratory have developed techniques of high promise. Various plastic sheets, protected by gravel or bonded to asphalt and aluminium sheeting bonded to a sprayed asphalt surface are under test. In Hawaii, catchments up to 7 hectares in area have been covered by artificial rubber sheeting. Practical costs for such techniques have been estimated at U.S. $0.20 per square metre (Myers, 1967). In southern Africa, promising tests have been made by spreading crushed rock over small complete catchment basins and controlling vegetation growth with herbicides. Since high rainfall and high ground often coincide, well selected sites permit gravity conveyance to storage reservoirs. Water harvesting from sealed surfaces is one of the practical solutions to the problems of semi-arid country which has not yet been given adequate resources for research and of which the aesthetical and biological consequences have not been fully ascertained.

GROUND-WATER STORAGE

Man has dug wells from a very early stage in his history but quantitative knowledge of the geology and hydrology of underground water is still very incomplete even in highly developed countries. In much of the tropics, especially in the slightly populated arid and semi-arid regions, underground aquifers are as yet unexplored. This is because methods of study have in the past been costly and laborious. Geological mapping, supplemented by resistivity measurements from the surface, selects areas for closer study. Bore-holes are then drilled in groups in order to map the contours of the phreatic surfaces and to deduce direction and rate of flow. Yield and recharge estimates have depended on pumping tests. Fortunately, much useful information accrues from oil exploration surveys. Now powerful new tools for ground-water study, based on measurements of nuclear radiation, have been developed into field techniques within the past five years. For instance, radioactive solutions are released into sections of bore-holes isolated by inflatable rubber seals. Measurements both of the rate of attenuation and the direction of drift of the radioactivity makes possible the measurement both of direction and of rate of flow across a single bore-hole. Valuable practical field results have already been achieved in southern Africa with this equipment (Wurzel and Ward, 1967).

Another major problem of the exploration of ground water has been that of distinguishing 'fossil' bodies of water which have been trapped from long past periods of abundance from water which is renewed by infiltration of fresh supplies. The latter can be exploited within the limits imposed by recharge; the former leads to extinction of available supplies after a period of use. The known rates of decay of radioactive carbon and of tritium (radioactive hydrogen) have made it possible to 'date' water discovered by drilling. 'Fallout' of tritium from atomic explosions in the atmosphere has provided peak concentrations at known dates, which is of further help. The chemical preparation of the samples in the laboratory is slow and elaborate but the information is extremely valuable.

Artificial recharge of ground-water aquifers depleted by excessive pumping has been undertaken on a substantial scale in the U.S.A., France, Germany, Sweden, etc. The difficulty of accomplishing this operation is caused by the suspended load of the watercourses which may give rise to choking. It disappears when the water is relatively free of solid particles.

Where geological and hydrological exploration has defined the aquifer and given reasonable assurance of freedom from contamination, clean water may be pumped or channelled to infiltration areas and the aquifer thus recharged. The water is stored without evaporation loss and is withdrawn from bore-holes as required. This method has been in active use for a decade by the California Water Board.

The main problem of ground-water storage is the salinity of many rock strata, by which water reaching them becomes unfit for use. This is a critically important problem in arid areas such as Kuwait, and in semi-arid areas such as Israel. Rainwater percolating into the hills around the Sea of Galilee passes through saline strata and emerges as strongly saline springs along the coast of Capernaum and in the bottom of the lake. Contamination by industrial wastes can also be serious when these are too concentrated to be run into rivers and are therefore run into bore-holes. Thomas and Leopold (1964) report that a factory pond at Denver, Colorado, over the years 1943-1961, was found to have contaminated 13 km^2 of ground water aquifer. A major danger of contamination occurs when important bodies of fresh ground water overlie saline waters or are in close proximity to them, as at sea coasts. Excessive pumping can then cause intrusion of the salt water into the fresh-water aquifer. This has occurred on the coasts both of southern California and of Israel as a result of excessive pumping of ground water for irrigation.

MAINTENANCE OF WATER QUALITY

Cumulative evidence of man's misuse of his environment may be measured in dry climates by soil erosion and in wet climates by water pollution. The former abundance of land and of water respectively has encouraged their wasteful usage. Pouring of sewage into rivers for dilution to harmless concentrations and for transport to the sea was indeed acceptable when populations were small. Pollution by industrial effluents is less easily justified, but public awareness of the severity of the problems thus created has grown very slowly. Major rivers flowing through large cities have already been reduced to the status of open sewers. This has only recently been recognized as a social and economic problem on a national scale in the U.S.A. and Europe.

While municipal waters present a problem for disposal, they also offer a major potential source of water if processed for re-use. In the U.S.A., 80 per cent of the total fresh water supplies are at present used to dilute and transport wastes. Cities are now forced to develop distant water supplies, e.g., New York draws water from 140 miles upstream and Los Angeles pumps water both from sources 200 miles north and 250 miles east of the city. Peters and Rose (1967) claim as a result of pilot-plant studies in New York State that water of potable grade can be reclaimed from municipal waste water at costs 'competitive with the development of new supplies and their conveyance from distant sources'.

Substantial experiments in Israel (Amramy, 1967) and in California (Stoyer, 1967) are based on use of sewage water, after treatment by successive anaerobic and aerobic storage, to recharge ground-water aquifers. By pumping from points distant from the recharge area, dilution of the treated water results and a long underground storage interval between recharge and re-use further decreases populations of bacteria. By combining the later stages of aerobic lagoon treatment with storage in artificial lakes, recreational facilities for boating, fishing and swimming have been created at Santee, California, thus adding amenity values to the water recovery process (Stoyer, 1967).

More direct re-use for limited purposes, by irrigation of pastures, forest plantations or of industrial crops such as cotton, reduces the cost of treatment. Many industrial uses, such as for cooling or for the washing, grading and transport of minerals, require even less rigorous purification, although the use of different qualities of water may involve costly duplication of distribution systems. Israel is reported to have more than 150 sewage utilization projects in operation at present.

Although the re-use of waste waters imposes special health problems (they are often better utilized for agricultural and industrial purposes), the water drawn directly from streams in good condition may also carry dangerous pathogens but the problem is not the same. For domestic water supplies the standard treatments of precipitation, filtration and chlorination serve well enough when closely supervised. In many of the developing tropical and subtropical countries, irrigation systems infested with bilharzia present a serious and increasing health hazard. The disease is very difficult to control since the host snail can spread from the streams into the irrigation channels and is infected via human urine and faeces from irrigation workers with primitive health habits. Indeed, with the current rapid increase in irrigation areas, the disease is spreading and is not yet effectively contained. The World Health Organization assists several national services and research centres in the study of this problem, but at present the spread to new areas overshadows the local success of control schemes.

The major problems of salinity, or water pollution with soluble inorganic materials, are discussed in the next section.

A new pollution hazard of the past two decades has been the organochlorine residues of insecticides. The present agricultural controls of insect pests, which are essential for the feeding of the world's growing population, incur the accumulation of toxic residues. The use of aldrin and dieldrin have been banned in the British Isles since 1964, but predator species of wild birds on the rivers, lakes and seashores all showed bodily accumulation of organochlorine residues when surveyed in 1966, although their populations have shown no signs of decline (Moore, 1967). This is a form of pollution of aquatic ecosystems which all nations should observe and control.

IMPROVEMENT OF WATER QUALITY

The most striking example of improvement is the desalination of brackish and saline water. Water is classified usually as 'brackish' if it carries total dissolved solids exceeding 1,000 parts per million but less than 10,000 ppm. It is saline at values above 10,000 ppm (sea-water contains about 35,000 ppm). As desalination techniques improve, areas near to the coast have the advantage of access to unlimited sea-water while many inland areas contain vast underground resources of brackish or saline water. Thomas and Leopold (1964) estimate that there are probably more than 70 million gallons of ground water per head of human population which lie within reach of the surface and in aquifers from which they could be pumped. A high but undetermined proportion of this water is, however, either brackish or saline and much of the flat alluvial areas which can be commanded by irrigation have saline subsoils. These need adequate drainage and enough irrigation water to secure downward movement of salts. Where drainage is neglected, water tables rise, and where irrigation is sparse, salts accumulate. The ancient history of the Indus Valley and of the Euphrates and Tigris rivers shows that major areas of irrigation were abandoned as a result of rising saline ground-water. The problem is still acute today in these river systems.

Desalting techniques, to render saline water supplies usable, have been used for more than a decade for domestic supply but have been too expensive for agricultural use. The United Nations Survey of Water Desalination in Developing Countries (1964) financed by the Ford Foundation, listed nine major distillation plants with capacities of more than 1,000 m^3/day. All of them used the flash distillation system developed in Britain. Two interesting alternative processes, both in units producing 900 m^3/day, were a plant in Kuwait using electrodialysis and an Israeli plant using a vacuum-freezing technique. Since seasonal fluctuations in demand are characteristic, such plants need either storage or excess capacity. Some brackish water is usually mixed with the pure product of distillation both for economy and to improve potability. By 1962 (the operative date of the United Nations Survey) conversion costs for saline water were down to U.S.$0.25-$0.34 per cubic metre for very large plants producing more than 4,000 m^3/day. It is most important that such costs be compared not with those of existing water undertakings but with the costs of developing alternative sources for an increase in water supply. By 1967 the Metropolitan

Water Board of Southern California were estimating costs from a nuclear power plant as U.S.$0.05 per cubic metre.

With the discovery of nuclear energy, new desalting possibilities have emerged, despite the discharge of greater quantities of pollutants by nuclear power plants than by thermic power plants. Ramey (1967) states that nuclear power alone is already economically attractive in the U.S.A. By 1966, decisions to build twenty-seven nuclear power plants with a combined capacity of 22 million kilowatts were announced. The Metropolitan Water District of California has undertaken a dual-purpose nuclear energy project to produce 150 million gallons per day of desalted sea-water. The United States Government is undertaking joint projects with both Mexico and Israel on similar lines.

At present, large-scale design is essential and in the developing countries the main limitation will usually be scarcity of investment capital.

It is, however, the geographical proximity of the oceans to irrigable deserts which could afford man's greatest opportunity to harness nuclear energy to food production (Meig, 1966), but only when desalination becomes economic for irrigation, which does not seem probable in the near future.

However, man's scientific and technical horizons are expanding ever faster. Recent successes with the breeder-reactor offer exciting prospects of effectively unlimited energy supplies, which through desalination would yield unlimited water supplies. This progress increases the challenge to use this knowledge for the improvement of our environment rather than for its destruction.

It is probable that desalination will become the accepted solution for major conurbations, and possibly for specially developed areas of highly productive irrigation, but in spite of these new sources, local water resources must remain man's major supply for the foreseeable future.

ACTIONS TO BE UNDERTAKEN FOR SUPPORT OF EXTENSION TRAINING, RESEARCH AND DEVELOPMENT IN WATER AFFAIRS

It is to be regretted that a population's interest in water problems is awakened only by exceptional floods or droughts, which may prove disastrous.

The solutions applied in emergency are far from satisfactory. Populations and governments must therefore be made aware of water problems.

Research in water resource sciences is best focused on practical problems and conducted by co-operation between the several specialist agencies usually concerned. The Lake Hefner project, a multidisciplinary, multi-agency study of the reduction of evaporation by spreading a monomolecular film on a 1,000 hectare lake is an excellent example. Four major technical agencies in three United States Government ministries worked in close co-operation with scientists and administrators of Oklahoma State and Oklahoma City. The United Nations technical agencies, supported by the United Nations Special Fund, have initiated and are supporting many such studies, including the Unesco research projects in the Chad Basin (four countries), in the Upper Paraguay Basin (four countries), hydrological studies in the Mekong Delta and saline water irrigation research in Tunisia. It is essential that river basin studies should not be left entirely to engineers and meteorologists. Although it is necessary to establish hydrological and meteorological networks to measure the present performance of river basins, land-use is so critical an aspect of river performance that agriculturalists, foresters and administrators must assess the future possibilities. Where these involve major land-use changes, pilot-scale studies on experimental watersheds should be initiated without delay to obtain quantitative evidence.

These considerations reveal to what extent the rational use of water calls for an integrated approach to the problems and for multidisciplinary action. All such major research projects need finance, administration and political support in the legislatures. On a general plane, the rational use of water demands multilateral intervention, as the economic, social and political aspects should not be dissociated from the technical aspects. They thus depend, quite directly, on public education to awareness of the water needs of the community.

The multidisciplinary nature of water-resources research and development raises special difficulties because of the current world shortage of trained scientists. Geologists, hydrologists, structural, mechanical and electrical engineers, agricultural physicists, chemists, soil scientists, surveyors, economists, biometricians and demographers, medical specialists in public health, botanists, zoologists and microbiologists are all involved at some stage. In most of these special fields the middle-grade technician is both critically important and in short supply. Public support for training facilities is essential to maintenance of present installations in many developing countries, as well as necessary for future progress. The shortage stems partly from the difficulties, in all countries, in securing enough good teachers of mathematics and partly from public examination systems which tend to favour the admission to universities of candidates offering subjects easier to learn (or more difficult to assess) than mathematics and science.

The public in countries at all stages of development need forceful presentation of their water problems of the next two decades. A necessary change, discussed by Batisse, is the unifying of all branches of hydrology into a university degree subject and its recognition for professional purposes by the civil engineering profession.

INTERNATIONAL ASPECTS OF WATER RESOURCES DEVELOPMENT

The large government technical staffs of developed countries often need to call on commercial groups of specialist consultants in water development and the smaller staffs of the developing countries rely heavily on the United Nations technical agencies for such help, and on IBRD, IDA and the United Nations Special Fund for financial support. Often two or more of the agencies, Unesco, FAO, WMO, WHO, ECA, etc., are involved in co-operative projects. The regional activities of United Nations Economic Commissions have an increasing role in the rational utilization of the water resources.

Training of local staff is probably the most widespread and, in the long term, the most important form of help, and short technical courses of a few months' duration are conducted on a regional basis in the developing countries, and are designed to supplement and not to replace national training facilities.

The largest scale of action yet attempted in order to achieve a scientific basis of rational use of the water resources is the International Hydrological

Decade, which was launched by Unesco in 1965. National Committees have now been established in almost a hundred countries. These report to a Co-ordinating Council of twenty-one countries, elected every two years at the Unesco General Conference and where the United Nations, FAO, WHO, WMO, IAEA and ICSU participate. The creation of the National IHD Committees has, in some countries, achieved for the first time a forum in which all the main participants in water affairs can meet. In more developed countries such co-ordination is already established by councils or commissions, but their participation in the international programme has encouraged bilateral aid and the spreading of technical knowledge. Even the listing on a world scale of the work in progress and its location is of major help in the location of gaps in the world networks of hydrological observations and the co-ordination of methods. This is particularly the case with experimental basins in which land-use changes are under study. The techniques are still evolving, the experiments are costly, and prompt exchange of information of methods and findings can lead to great savings in time and effort. Hydrological basins—usually river basins but also sometimes groundwater basins—constitute a fundamental unit for water resources development. Many such basins are international and the people living on the same watershed are indeed interdependent. There is considerable advantage for all if their common resource is conserved and managed in full co-operation, taking full account of the long-term needs of all those living on the basin, upstream or downstream. The creation of international commissions, or inter-State committees has developed rapidly, often with the assistance of United Nations agencies, and provides the proper framework for rational management of international basins. It is essential that full consideration of all environmental problems, including biological ones, be taken by such technical and political bodies. The condition of mankind after only two or three decades of the present population increase will depend heavily with respect to water resources on the success of national and international programmes of research development, staff training and public education such as those which are achieved in the field of hydrology in the framework of the present Hydrological Decade.

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Scientific basis for the conservation of non-oceanic living aquatic resources

This paper was prepared on the basis of a draft submitted by the Department of Fisheries of FAO (Dr. William A. Dill and Dr. T. V. R. Pillay) with comments by Prof. A. E. Bonetto (Argentina), K. Kuronuma (Japan), J. Lemasson (France), H. Sioli (Federal Republic of Germany), R. H. Stroud (U.S.A.), G. Svärdson (Sweden) and E. B. Worthington (United Kingdom) and the Secretariats of FAO, WHO and Unesco.

INTRODUCTION

Even that fearless lexicographer, Dr. Samuel Johnson, has warned us that 'Definitions are hazardous'. This is especially true for terms which, employed variously in different contexts and in different countries, have come to be used loosely. Thus, for the term 'conservation', one finds in most dictionaries emphasis on the concepts of 'protection', 'preservation', 'prevention of exploitation', and 'keeping in a safe or entire state'. Among modern biologists, however, a commonly accepted definition of the word is: 'wise management and utilization of natural resources for the greatest good to the greatest number'. We shall endeavour to follow this definition in this discussion. With respect then to living aquatic resources, 'conservation' will include fishery management, i.e., the application of knowledge and experience to improve the production of fish for man's use; it will also with respect to these resources be concerned with their maintenance as species for their intrinsic, biological, and educational values. Living aquatic resources include, of course, various useful plants, invertebrates, and vertebrate animals other than fish; emphasis in this paper will, however, be on those fin fishes and shellfishes primarily utilized by man for food or sport.

For the purposes of this paper, non-oceanic aquatic resources are defined as the living resources of inland waters—water areas situated within land limits—that are used directly or indirectly by man. These waters may be fresh, brackish, or saline, depending on the nature of the substratum, catchment area, or connexion with the open sea. Their biota may be also affected by the influence of the sea; euryhaline species may live part of their life in the sea and part in inland waters. It is, therefore, not easy to separate production in the two different types of environments, especially when considering resources of diadromous species.

The history of man's use of non-oceanic aquatic resources is as old as man himself. Early man's exploitation was probably seldom at such level as to cause permanent damage to aquatic resources and was sometimes characterized by extremely wise regard, verging on veneration, for the bounties of nature and anxiety to perpetuate them. Many ancient practices are even today considered sound management procedures. Fish were propagated artificially in China as early as 2,000 B.C. The regulation of fishing for carps on their spawning grounds during new- and fullmoon periods, which were observed to be periods of peaks of spawning, was enjoined by tradition in India as early as 246 B.C. The fishing restrictions voluntarily observed by tribal communities even today in the Naga and Khasi Hill areas of India compare favourably with measures imposed by the fishery agencies of modern communities. In Scotland, the capture of salmon during the closed season was punishable by death in A.D. 1411, and other fishing restrictions (generally with less severe penalties!) were in practice in many countries by the sixteenth century. Irrespective, however, of their appropriateness in some cases, most of these restrictions meant to conserve the resource were not based on sound knowledge of the biological factors that govern its maintenance. A scientific approach to the problem of aquatic resource conservation appears to have originated only in the late nineteenth century.

Efforts to study and manage the resource have followed more or less the same pattern in most countries. With the establishment of agencies responsible for management or conservation of inland fisheries, it came to be well recognized that the resources of inland waters were not inexhaustible and required as much attention from man as he devotes to the development and management of terrestrial resources. In spite of such recognition, there were still, unfortunately, few scientific data at hand to provide the essential guidelines for conservation, and however interesting they were to scientists, most faunistic or natural history studies were of limited use, by themselves, for resource management. Most agencies resorted therefore to the trial and error method—mostly error as Stroud (1963) points out—using so-called 'self-evident facts'.

This approach, as can be imagined, led to two major types of conservation activities: restrictions on fishing and fish-stocking operations. Fishing restrictions, often enacted without prior establishment of necessity and largely arbitrary in nature, failed in most cases to improve fishing. Furthermore, implementation of the restrictions was seldom easy, more so when convincing evidence could not be produced to show the public their usefulness. The more popular stocking operations came about as a result of the mistaken idea that the ill-effects of unwise use and management of the resource can be effectively countered simply by stocking artificially propagated young of indigenous species (or by the introduction of exotic species). They were often used simply as 'political stocking' to promote goodwill. Again, such measures usually failed to improve fishing.

Today, we are in happier circumstances. Fishery biology and management have been formulated as a multi-disciplinary science and the need for detailed research and experimentation to evolve sound techniques of management has been recognized. Considerable advance has been made in this field: certain concepts and methods once considered sound are being discarded, some have been modified, and some completely new ones have been evolved. Answers to many problems of aquatic resource conservation are still lacking, but substantial progress can be achieved through application of those measures which *are* proved.

During the last decade a number of commendable attempts have been made to discuss the scientific basis and the status of knowledge of aquatic resource conservation through conferences or symposia. Among those worthy of special mention are the following: the IUCN/FAO Symposium on The Influence of Soil and Water Conservation on Natural Aquatic Resources at Athens, Greece (1958), the Conference on Estuaries at Jekyll Island, Georgia, U.S.A. (1964), the Symposium on Estuarine Fisheries at Atlantic City, U.S.A. (1964), the Symposium on Man-made Lakes held in London, United Kingdom (1965), the Reservoir Fishery Resources Symposium at Athens, Georgia, U.S.A. (1967), the FAO World Symposium on Warm-water Pond Fish Culture in Rome, Italy (1966), and the International Biological Programme Symposia on Primary Production in Aquatic Environments in Pallanza, Italy (1965), and the Biological Basis of Freshwater Fish Production in Reading, United Kingdom (1966). The papers presented at these symposia cover most of the principles relevant to the subject under discussion.

PRODUCTION PROCESSES IN AQUATIC ENVIRONMENTS

The harvest of fish or any other aquatic organism by man is the culmination of a complex series of activities of the plants and animals dwelling in the aquatic environment. It is therefore obvious that rational harvesting of an aquatic resource must be based on considerations that include an understanding of the biological processes and interdependence of these biota in the environment.

Production processes in aquatic environments are generally divided into three stages, namely, primary production, secondary or intermediate production, and tertiary or terminal production. Primary production is for all practical purposes equivalent to photosynthesis—a synthesis by green plants of complex organic matter from simple constituents. And, again, for practical purposes, we may consider that the plants involved in primary production in an aquatic environment are algae. The next stage, termed secondary production, is the production of organisms that feed on green plants, but since it is difficult to separate these organisms from others that feed on detritus and bacteria, the more general term 'intermediate production' is used (Ricker, 1968) to denote production of invertebrates, especially the smaller ones. The final stage is tertiary production which results in the production of fish or other animals that generally subsist on secondary or intermediate production. It has, however, to be emphasized that many fishes (or other animals included as constituents of tertiary production) may feed solely or partly on primary production. Many workers, therefore, prefer to use more specific terms like 'fish production' denoting only a particular category of animals. 'Terminal production' may be a more inclusive concept, defined as the production of organisms directly used by man (for example, in addition to fish, animals such as crayfish, frogs, turtles, crocodiles, and waterfowl).

A very significant feature of the production processes is that considerable decrease in total bulk occurs through successive stages, accompanied by increase in the size of the individual components. And from man's practical standpoint, aquatic food chains (or webs) are often too complex and inefficient. The efficiency of conversion of primary into secondary and terminal productions is frequently very low, and much of the food produced at one level may never pass on to the next but returns as detritus to the bottom of the food pyramid. Experience in pond fish culture has clearly demonstrated that the largest yields (harvest) can be obtained from herbivorous species. Carnivores are the most inefficient utilizers of organic production and therefore the least biologically suitable form of crop. In certain areas, however, for economic or sociological reasons, their production may be highly desirable.

To maximize terminal production it may be necessary to manipulate the food chains or webs and maintain them in a desired pattern. A good knowledge of the influence of environmental conditions and methods of controlling them is essential for such a process. The latter involves control of both 'natural' and 'artificial' environments and will be discussed in later sections.

UTILIZATION OF AQUATIC RESOURCES

Uses of water. Of all our natural resources, water probably has the largest variety of uses, ranging from domestic consumption, the production of fish, agriculture, industrial use including hydroelectric power production, navigation, and the transport of unwanted wastes, to the use for sport, recreation, and amenity. Fish production which is one of the most important of these uses is also among those least consumptive of water. Furthermore, experience gained in a number of countries has shown that it is possible to combine successfully the production of fish with many others forms of water use.

Harvest from inland waters. Wholly reliable statistics of the total harvest from inland fish production are not available, but according to figures reported to FAO, which largely represent marketable surplus from natural waters and exclude the very appreciable catches of subsistence and recreational fishermen, it is about 7 million metric tons annually. To this should be added the estimated production of 1 million tons from fishponds (excluding mainland China where the production by aquiculture is thought to be about 2.4 million tons). This is a substantial contribution to the world's supply of protein food, especially as most of it is eaten directly by man and much of it has high economic value.

Yet, despite the importance of the inland fisheries, the high level of interest in their development, and a noteworthy rise in production in some areas, no marked increase in the total world production of inland fish comparable to that for marine fish appears to have taken place during the last decade. This might lead one to believe that most natural inland fishery resources are being fairly well exploited; nevertheless, large areas still remain under-utilized, especially in some developing countries. And, although inland waters may appear to be more easily fished out, there are comparatively fewer instances of large inland fish stocks having been decimated solely by over-fishing than in marine waters. In most cases, the major factor contributing to lack of rapid expansion and, at worst, decreased yield, appears to be deterioration of the environment. And most such deterioration results from importunate or non-compromising demands upon the total aquatic resource and environment by conflicting uses of man.

If, as already stated, an understanding of the biological processes is the basis for the assessment of permissible catches, it has also to be pointed out that better methods of harvesting, processing and preservation will greatly contribute to the world's supply of protein food.

Effects of changes in patterns of water-use. In early days, the utilization of aquatic resources—both living and non-living—was a relatively simple process. There was usually ample water for all uses and conflicts between varying uses were generally minor or of only local significance. But with the rise of industrial technology, urbanization, and population pressures, patterns of water use have changed appreciably and it has come to be realized that the resources of inland waters are not inexhaustible and that exploitation of one type of resource can have very deleterious effects on others.[1] In industrially advanced countries, competing demands on water resources, reclamation of wetlands and water pollution have had far-reaching effects upon the aquatic environment, its consequent production and ultimately, therefore, upon utilization of this production. The same processes are now occurring in the developing countries, especially where the growth of agriculture and industry is being hastened by river basin development.

The construction of dams or barrages is usually a dominant feature of river basin development. Such structures and their operations may have the following effects on living aquatic resources. Dams often constitute barriers or deterrents to fish migration. They alter the magnitude, chronology and quality of streamflows below them and, therefore, may affect aquatic stocks, by reducing or increasing available space, and the size and quality of spawning, nursery and food-producing zones, and changing water velocity, temperature, chemistry, turbidity, and the river's ability for self purification. Diversions or conduits leading from dams often result in loss of fish which enter them and, in some cases, may result in the introduction of aquatic organisms into drainage basins to which they are not native.

The 'flood fisheries'—fisheries in overflow areas of rivers during seasons of flood—contribute very appreciably to inland fish production in tropical countries, but as a result of flood control and irrigation projects such fisheries are fast disappearing. They have already almost disappeared in the industrialized temperate countries.

Pollution and reclamation also affect inland aquatic resources. Wide-spread use of insecticides and other pesticides as part of public health, agricultural and forestry practices is of special danger to aquatic life. For example, fish culture in rice fields is an age-old practice in many South-east Asian countries, which contributes substantially to much-needed protein production. But with the growing use of pesticides in rice fields, this form of aquatic production is fast becoming extinct. Large-scale reclamation of estuaries, lagoons and marshes for industry, agriculture, or real estate development has also destroyed valuable breeding and nursery grounds of fish and other aquatic animals.

Although many forms of land and water development have adversely affected fish production, others have created new and enlarged water areas for potential use in increasing fish production. Four of the major dams built in Africa alone

1. The review by Dill and Kesteven (1960) has been used extensively in preparing this paper.

in recent years have created artificial lakes of a total area of about 19,000 km^2 (7,340 square miles). The Tennessee Valley Project (TVA) in the U.S.A. increased the water area of the Tennessee River system from about 45,600 hectares (114,000 acres) to almost 240,000 hectares (600,000 acres) and brought about a much greater production of fish than existed in the original rivers. Many more such reservoirs will be formed in the future and if properly managed, can yield considerable quantities of fish.

SCIENTIFIC BASIS FOR CONSERVATION

Conservation, being the wise use of resources, has necessarily to be based on scientific knowledge and experience. As the living aquatic resource, mainly fish, is biological in character, there is a natural tendency to consider only the biological basis for its conservation or management. Undoubtedly, an intimate knowledge of resource biology and the environment should form the basis of a conservation policy. However, realistic and practicable policies must also be based on judicious methods of harvesting, processing and preservation and on sound economics and suited sociological needs. For example, in the United States of America—where about 25 per cent of the population already participates in fishing for recreation, spends almost $3,000 million annually for equipment and services for this fishing, and where the number of anglers is expected to increase 50 per cent by 1975 and 150 per cent by the year 2,000—the adoption of conservation measures to preserve and increase the sport fish stocks (even while reducing certain competing 'coarse fish' which are only of food value) has been judged to be the most appropriate policy for most inland waters.

Affluent societies—or at least certain segments thereof—exposed to comparatively less population pressures and having greater opportunities for leisure and recreation may like to preserve nature in its pristine purity for aesthetic reasons and scientific study; whereas an economically backward country faced with the problems of rapidly increasing population and inadequate food production will naturally have to design its conservation policy to meet the needs of improving food production, employment and well-being of its people. Undoubtedly the immediate needs should not be the sole basis of resource management and the long-term effects should be carefully considered and man's ethical responsibility to nature of which he is a part, be recognized. It is clear, therefore, that a uniform policy of conservation based on accepted biological principles and technological considerations alone cannot be recommended for adoption in all areas. An integrated scientific approach, based on all the disciplines involved, is essential for the rational utilization and management of aquatic resources.

ECOLOGICAL AND BIOLOGICAL BASIS

The biological basis of conservation is a sound knowledge of the biology and ecology of the resource.

As already stated, the 'resource' or terminal production, mainly fish production, originates generally as a result of: (a) primary plant production; (b) conversion of the organic matter produced by the plants into suitable food for fish, usually by a 'food chain' of animals; and (c) the feeding of fish and the conversion of the food into flesh. The fish produced is then harvested by man and the stock is replenished through reproduction (see Le Cren, 1958). Scientific management for optimum yield should be aimed at the control of all these stages as well as of the environmental conditions that affect them. Primary production should be maintained at the optimum level. The loss of organic matter involved in the conversion of food to fish should be reduced to the minimum. It should be ensured that mortality of fish due to natural causes and fishing is compensated by adequate reproduction and recruitment. Finally, as much of the production of fish as would permit the highest rate of sustainable yield should be harvested. Most of these phases of fish production are susceptible to human control in varying degrees. The control may be directed primarily at the environment, or it may be directed at the stocks themselves.

First, with respect to the physical environment, it is desirable that it be preserved in such condition that it can offer the following: (a) water in quantities adequate to provide sufficient *Lebensraum* and of suitable temperature and velocity; (b) water of ample dissolved oxygen content and suitable chemical quality (including adequate quantities of nutrient salts and freedom from toxic or otherwise harmful substances); (c) suitable substratum (for attachment, cover or shelter, spawning and hatching); (d) freedom for movement and migration, etc. Given all such factors in the ideal environment, there may still not be a full development of the resource in the manner that man desires it. Such development is also dependent upon the composition and relative densities of the biota and again man has an opportunity to control these. Finally, man's own predation (we call it fishing) upon the aquatic stocks is a factor of high importance.

It follows, therefore, that any discussion of the preservation or alteration of the non-oceanic environment and the conservation of its resources must consider man as a major component in an ecosystem which—either through design or inadvertence—he has already altered decidedly. To be quite realistic, in this shrinking world there are an ever-diminishing number of inland waters which one can call 'natural' and many of these will soon lose their original character. Can one call the regulated Columbia or the Danube or the great reservoirs on the Zambezi, the Volta and the Nile, or the polluted Rhine or the eutrophicated lake of Geneva or Lake Erie, or even small highland becks or alpine lakes whose trout, like the carps of the Ganges plain, contain measurable amounts of pesticides—can one call any of these 'natural' today?

Thus, we come now to the main theme of our discussion: (a) how can we best conserve inland waters for aquatic resource production; and (b) given such production, best manage it on a rational basis for the use of mankind. We may briefly outline below the major methods of preservation and management of these resources considered primarily from the biological basis.

Control of the physico-chemical features of the environment

Adequate water supply. Of primary importance is the provision of sufficient water in lakes, streams and reservoirs throughout the year. In completely natural lakes or streams, the supply of water is largely dependent upon the natural hydrological cycle, but obviously this cycle can be modified (as through reforestation) to bring about increased or improved water supply.

In artificial waters or those affected by dams or other engineering works, the regulation of such dams, the inlets and outlets of reservoirs and the control of water levels are important elements of such water provision. Such regulation provides not only living space, but has profound effect upon food supply, movement and the success of spawning.

Water temperature. A major factor influencing all phases of production is water temperature. Even though this is part of the natural hydrological or seasonal cycle, man can modify it. The temperature of streams or lakes can be altered by provision or curtailment of shade or the deepening of pools. Selective release of water from surface or lower levels of reservoirs above dams can result in a supply of water of required temperature range in the downstream area. Use of the vast quantities of heated water from the cooling towers of thermal and power stations promises in some localities to be an effective means of raising temperature in otherwise temperate aquatic environments, resulting in higher biological production (but see also the next section). Destratification of lakes and reservoirs by mechanical means may also result in higher production under certain conditions.

Water quality and pollution. Provision of water of good chemical quality is paramount in maintaining optimum production at all levels. Definition of such quality is, however, dependent upon the particular resource considered. Thus, salmonoid fishes require water of high oxygen content; this is of lesser importance to most tropical fishes. In any event, among the criteria of greatest concern one must consider provision of water of adequate dissolved oxygen content, suitable range of pH and alkalinity, and freedom from excessive quantities of suspended solids, toxic substances, pathogenic organisms and contaminants producing objectionable tastes and odours. Obviously, control of water pollution is essential in attaining such ends and one of the first steps towards these ends is the establishment of water quality criteria for the production of fish and other aquatic organisms. Within the developed countries, numerous committees or commissions, provincial and national governments and several intergovernmental bodies are now actively engaged in studying and recommending specific water quality requirements for all classes of water use, including that for fish and aquatic life. This type of work—fundamental for aquatic resource management—should be extended throughout the world, preferably in advance of development.

Water pollution, which affects production in aquatic environment in all phases, may be caused by domestic and industrial wastes, pesticides and herbicides, radioactive substances, oil, and other substances purposely discharged or inadvertently (e.g., through air transit or land drainage) finding their way into lakes and streams. Of particular attention today to the aquatic biologist is the effect of the seemingly ubiquitous pesticides, eutrophication (or early ageing) of waters caused by the introduction of excess nutrients, and the newest addition to the list of pollutants, heated (cooling) water discharged mainly from power-generating steam plants, which can affect some cold-water species adversely.

With respect to aquatic stocks, the most serious effect of pollution is the slow degradation of the physical and biological environment, which usually goes undetected until well advanced, unlike mass mortality of fish and other aquatic organisms which is readily observed and thus attracts the most attention. When conservation agencies are able to work in close co-operation with industrial and city administrations, suitable methods of pollution control such as pretreatment of effluents and regulation of effluent discharge, land disposal of pollutants and redesigning of processes to alter quality and quantity of effluents are possible.

Fertilization. Water must be 'fertile', that is, contain nutrients, to produce an aquatic crop. There is, today, a considerable emphasis on wishing to decrease the fertility of certain natural waters—especially where excess nutrient supply has led to eutrophication, made them less attractive visually, and changed the composition of a fish stock from, say, a valuable coregonid population to a lesser one of cyprinids.

On the other hand, with many natural waters one may wish to increase fertility to obtain greater production. At present, efforts towards such fertilization seem best, that is, most economical, when directed towards small or controlled artificial ponds—those used for fish culture. However, the extent of control or influence possible is increasing with gains in scientific knowledge. Some experiments have demonstrated significant increase in photosynthetic rates following the addition of trace elements. It seems possible that through use of such methods, economical means of fertilization for large water bodies can be evolved.

Mention might also be made of the great store of nutrients in the hypolimnion of tropical lakes; there may be opportunity for bringing these back into circulation and thus increasing productivity.

Habitat protection and improvement. Many other management practices, generally termed habitat improvement, contribute to optimum production at all of its stages. Land treatment and water control measures, such as reforestation, cover cropping, terracing, contouring and drainage, prevent erosion and stabilize the soil. Excess turbidity that retards photosynthesis and thereby primary production is thus prevented, as also silting of stream riffles that result in smothering of plant beds and insects, and injuring spawning gravels. Careful preservation and improvement of watersheds is of vital importance in the conservation of inland aquatic resources, but often this type of management is beyond the means available to aquatic resource agencies and depends upon the general application of appropriate soil and forest conservation practices. Public education and co-ordination with other concerned agencies are essential to implement such measures.

In addition to such general practices, certain stream and lake 'improvement devices' have been used for many years, on British trout waters, for example, and in North America where for a time they were heralded as the primary answer to providing good sport fish production. Some of these devices or methods (e.g., the use of deflectors to utilize the digging force of a stream to scour away silt from needed gravel, speed current and produce pools) have appeared to be useful. However, in many cases they have only short-term value and may be unsound economically. On the other hand, small flow maintenance dams on natural lakes have provided unusual benefits through increased flow to provide sustained habitat in outlet streams—otherwise with no or meagre flow during the dry season.

Brush shelters in lakes are another means of 'improvement'. Many of these have been installed ostensibly as shelter for young fish and to provide substrata for periphytic food organisms. Their role in increasing tertiary (fish) production has not been well established, and in some cases they might better be called 'attractors' in that they concentrate adult fish for easier capture. This may, of course, be advantageous in facilitating the over-all utilization of the resource. They have traditional use for this purpose in the commercial and subsistence fisheries of some East European, Asian and West African waters, and are employed in recreational fisheries in the U.S.A. for certain centrarchids.

Provision of free and safe movement for fish. A highly specific form of stream improvement is provision of passage across or through obstructions. In some instances it may be advantageous to extend the range of a stock by the removal of natural barriers (such as waterfalls) or obstacles such as log jams on streams subjected to lumbering. In most cases, however, the problems lie in facilitating the passage upstream and downstream of migratory fishes such as the Pacific salmons *(Oncorhynchus)*, Atlantic salmon *(Salmo salar)* or the Indian shad *(Hilsa)* across man-made dams or weirs. The means adopted to ensure upstream passage are many: simple or complex fishways, fish lifts, fish locks, transport by trucks, etc. The selection of the method depends upon the nature of the dam and its operation, the biology of the species, and—because such devices are often very expensive—economic implications. As with the other problems of fish movement discussed below, ensurance of fish passage at dams is a very complex matter which requires close co-operation between fishery biologists and fishery engineers. Its cursory treatment here must not blind the reader to this complexity.

The passage of downstream migrants over dams has received adequate attention only in recent years. Although this may not be a very difficult problem at low dams with ample overflow, formidable difficulties are encountered in ensuring this at high dams forming large impoundments. As most young fishes migrate near the surface, their passage over a dam may be possible if suitable spillways with regulated water flow and appropriate basal pools are provided. Other means of passage such as diversion tunnels or by-passes and even fishways may be used effectively for this purpose. A variety of methods, including artificial currents, lights, curtains of chain, walls of air bubbles, chemicals, vibrations, and electric shocking devices, have been employed to direct fish to use safe exits or reach collecting areas from where they can be removed by mechanical means. None of these measures has so far proved to be entirely satisfactory. Furthermore, no suitable methods appear to have been designed so far to ensure downstream movement of young or adult fish through large lacustrine areas of impounded waters.[1] As more rivers become only a series of impoundments, the situation with respect to riverine migratory species becomes more serious, and demands intense study.

Heavy losses of fish, especially migratory species, may also occur when they enter diversions (canals, penstocks, etc.) from streams or reservoirs. Different basic types of fish screens such as stationary panel screens, parallel bar screens rotary drum screens, belt-type travelling screens, perforated plate screens and

1. A paper by R. F. Raleig and W. J. Ebel (in Lane, ed., in press) describes a method for ensuring downstream movement of young Pacific salmon through a large deep impoundment through timed drawdown.

louvre systems, have been devised to prevent fish from entering such diversions. Electrical screens or deflectors which repel fish from entering diversions have also been used. They have the great advantage that they do not get clogged with debris as do mechanical screens. In any case, success of screens depends not only on correct design and placement, but on proper maintenance, and each installation demands individual study. Furthermore (and this has often been neglected) it has to be ensured that screens on diversions situated at some distance from the headworks are provided with by-passes so that fish can return to the streams.

Control of the biological features of the environment

Introduction of food organisms and forage fish. Many of the management techniques described above relate to the phases of production, including secondary or intermediate production. Introduction of food organisms or forage fish is adopted in waters where intermediate production is found to be inadequate. As many plankton-feeding fishes seem to feed by capturing individual plankton animals rather than by a straining process, the size of zooplankters and the density of their populations are of considerable significance. It is therefore possible that the introduction of larger planktonic crustaceans like phyllopods and mysids would contribute to greater fish production. In many waters the major food resources of fish are benthic invertebrates such as oligochaete worms, chironomid (midge) larvae and small molluscs. Where the occurrence or densities of populations of these organisms have been found to be limiting factors, their introduction and facilitation of growth may be most desirable. The systematic planting of mysids and polychaete worms in revervoirs in the U.S.S.R. is reported to have resulted in spectacular increases in fish production. The introduction of pelagic forage fishes to occupy otherwise unused central or offshore water masses of reservoirs has also been accomplished with notable success, especially in certain waters where the carnivore population constitutes the desired harvest. Of course, such introduction should be made only when there is previous experience or after thorough ecological studies and consultations.

Control of aquatic vegetation. Although certain invertebrates and fishes make use of higher or vascular aquatic plants, plant growth is often harmful to aquatic resource production and harvest, and in some areas its excessive development is a major concern. Classic examples include the rapid spread of the introduced (from South America, originally) water hyacinth, *Eichhornia*, in the waters of several continents, and the introduction of *Salvinia*, an aquatic fern, to the newly impounded Lake Kariba. The standpoint crop of water hyacinth in East Pakistan alone, which has recently been estimated at over 25 million tons, goes largely unutilized and is positively harmful to fish production and other uses of water. Among the detrimental qualities of aquatic vegetation may be listed their storage of nutrients otherwise available for primary production by algae, creation of shade which reduces photosynthesis, increased water loss by transpiration, and interference with fishing.

Control of such plants is usually accomplished mechanically and chemically. Biological methods of control (the use of fish, snails and insects, for example) have also been tried, but harvest and use of the plants, rather than destruction may, in the long run, prove to be the soundest method of all.

Control of predation and competition; population manipulation. Attempts by man to control animals which prey on fish have been made for many years. Thus kingfishers have been trapped and pike gigged on trout preserves, mergansers have been shot on salmon streams, cormorants and crocodiles killed in African lakes and swamps. The results of studies of predation are not always conclusive and the subject is somewhat controversial. Local situations and desired ends determine whether it should or can be practised successfully. For example, control of otherwise unutilized predators may undoubtedly be valuable in areas of intensive aquiculture or where their control leads to higher survival of fishes whose food supply and consequent growth is assured. On the other hand, there is evidence to show that excessive destruction of predators may result in over-population with consequent stunting of the prey species. Introduction of predators may even serve as an effective means of controlling dense populations of economically unimportant species.

It is, however, not the control of comparatively few predators, but large-scale control or complete elimination by chemicals of competitive populations of fish which has been perhaps the major advance in inland fishery management by which man can influence tertiary production. The first chemical to be used with marked success was rotenone, which had three great advantages: it killed fish easily, did not destroy their food supply, and its toxic effects wore off in a short time so that the waters could be restocked with desirable fish species. Rotenone and now a large number of newer chemicals or formulations have been widely used for 'reclaiming' lakes, especially in the United States to improve sport fishing, for over twenty-five years. Originally used in already established lakes and reservoirs, the use of chemicals has been extended in attempts to eradicate entire fish populations from the headwaters of a stream system downstream to the site of a new reservoir. Such elimination enables the new reservoir and its upstream drainage to be stocked from the start with only those species considered desirable. (This practice, when it has eliminated species native to a drainage basin, has in some instances brought strong criticism from those with large interest in the preservation of native stocks or natural communities.)

Aside from the use of chemicals to improve sport fishing, it has been conclusively demonstrated that in certain small water bodies, production of fish for food can be increased many-fold by completely eliminating existing stocks of un-economic species by chemical and other means, fertilizing and restocking with economic ones. In somes lakes treated in this manner in the U.S.S.R., the standing crop of fish food organisms is reported to have increased 500 to 700 times and fish production 6 to 10 times.

The control of fish by chemicals occupies much attention today. Selective chemicals—those which will affect but one species—enable a high degree of population selection. Their development as well as those of partial control to regulate rather than totally eliminate populations are among the most promising tools of fishery management.

Artificial stocking

Many successful aquatic resource management measures relate mainly to the terminal stage of fish production. As emphasized earlier, scientific management of a fishery resource should be based on adequate knowledge of the populations involved, their biology and their environment. The replenishment of the populations should balance their reduction in density due to natural causes and fishing. It has to be ensured that a minimum number of spawners are available in the stock and that adequate number of young are recruited to the stock. As observed in many other animal populations, in fish also there appears to be some density-dependent factor that tends to regulate their number. Although there is only scanty data available to show the nature of relationship between the size of spawning populations and their progeny, it is clear that adequate recruitment for efficient growth and optimum production can be provided by a moderate number of spawners.

In view of the above and the favourable environmental conditions for subsistence and survival that are likely to prevail in well-managed waters, the addition or continuous stocking for maintenance of artificially propagated fish is generally wasteful. It has, however, to be pointed out that there are a good many special cases where the practice is useful. Stocking may be necessary, for example, to maintain a high fish production in waters adversely affected by environmental changes, such as those where the spawning grounds have been lost. With respect to anadromous salmonids, stocking of hatchery-raised fish, especially at the migrant stage, has yielded good economic results. Other examples of useful stocking are: replenishment of fish in waters where the stock has been destroyed (by pollution, for example), in reclaimed waters, in new reservoirs, and where the introduction of a different species or species combination is desired. The dangers of indiscriminate introduction of exotic species is, of course, well recognized. The stocking of 'catchable' fish for sport fishermen, i.e., liberation of fish of such size that they can be removed immediately by angling does not fall within any of these categories. Its success is dictated primarily by economic considerations and can flourish only under affluent conditions.

Fishing regulations

Proper regulation of fishing may be necessary to conserve stocks in large bodies of water and, as mentioned earlier, is one of the first techniques used for this purpose. Using appropriate techniques for estimating population abundance, its rate of change and growth, mortality and recruitment rates, it is possible to determine the relationship between catch from a stock to the amount of fishing and to the sizes of fish at first capture. Proper management of a natural fishery has to be based on such information. Regulatory measures should be established only when the need for them has been determined and the effect of such measures estimated and found practicable. Regulation aimed at changing the proportion of stock caught or the sizes of the fish caught can be achieved mainly by restricting: (a) the sizes or conditions of fish that may be landed; (b) fishing areas and fishing seasons; (c) fishing methods; (d) total catch and effort.

The suitability of these regulatory measures will have undoubtedly to be judged against economic and sociological considerations. Where it is practicable to return captured undersized fish to the water alive and selective fishing for size groups is possible, size limitations can be very effective. The closure of areas to fishing and establishment of closed seasons can effectively reduce fishing mortality and also help to control the sizes of fish caught when there are areas and/or seasons of concentration of size groups (e.g., spawning and nursery grounds during and after breeding seasons). Restrictions on fishing methods generally take the form of prohibition of or limits on the use of damaging methods, gear and implements, or prescription of constructional details such as mesh size. Such restrictions are particularly warranted when increased fishing effort will affect recruitment but should not be made at the loss of efficiency and increased costs of operation. Destructive methods of fishing, such as the use of poisons and explosives may be—in fact, generally are—prohibited. Regulation of mesh size has been very widely used with success, especially in marine fisheries and one of its major advantages is that it does not generally affect the cost of fishing. However, where the fishery bears on multispecies resources, there can be considerable difficulty in designing appropriate mesh regulations that will ensure adequate catch of smaller as well as larger species. Effective fishery management in most cases will have to include control of fishing mortality (the amount of fishing) by limitation of total catch and fishing effort. The allocation of catch and effort quotas for each stock presents many problems, especially in large river systems and lakes where the fishing rights are owned by more than one country. Even in the same country, quotas should be allocated on an over-all basis or on the basis of individual fishing units, taking into account the organizational, economic and political situations.

ECONOMIC AND SOCIOLOGICAL BASIS

In the discussion above of the methods for management of aquatic resources, largely based on biological knowledge, it has been indicated that economic considerations should be taken into full account to decide the ones to be adopted under a particular set of circumstances. Normally, any administration will take into account the cost-benefit ratio before implementing any conservation measure. Many of the management techniques mentioned require considerable sums of money and trained personnel for their implementation. It is, therefore, most important that appropriate economic evaluations are made before conservation measures are recommended.

Many expensive management measures could probably be avoided if water- and land-use projects which are potentially harmful to living aquatic resources were not carried out. However, such projects may be urgently required and implemented in an area for economic or sociological reasons, unless it can be shown that the value of the aquatic resource greatly exceeds the values to be promoted by the project. For aesthetic reasons and for scientific study, it may be highly desirable to preserve an area in its natural or close-to-natural state, but in the face of economic and sociological needs it is not possible to retain all areas in that state. The most realistic, and therefore scientific, approach will be to take stock of the situation in its entirety and give adequate consideration to all aspects before formulating a policy of wise management to derive the maximum benefit for man.

The nature of use of a resource, as for example whether the fish produced is to be used for sport or for food, may make considerable difference in the evaluation of relative values. The value of a commercial fishery for food production is to be judged largely on the basis of the commercial soundness of the operations involved and possibly of the contribution it makes to the nutrition of the people for whom alternative sources of protein are not available; the criteria to be used for evaluating a sport fishery may also have to include its recreational, touristic and in some cases public relations value. Many measures that are uneconomical in a commercial fishery may, therefore, be justified in a sport fishery.

Large-scale reclamation of estuarine and marsh areas now being undertaken in many parts of the world has caused much controversy and conflict of interests. Here again the most appropriate decision may have to be based also on proper economical evaluation and assessment of sociological needs. The costs of reclamation for agriculture and aquiculture are relatively easy to compare. But if an area is to be used (naturally) as nursery and feeding grounds of fish, the actual loss due to their destruction may not be easy to assess, even though it may be large. If reclamation is for human settlement in highly populated areas with no alternative possibilities, the only possible solution may be to work out ways and means of minimizing the deleterious effects on aquatic stocks by provision of at least minimum nursery grounds or by the adoption of aquiculture to compensate the loss of production.

PROBLEMS AND PROSPECTS OF SCIENTIFIC CONSERVATION

Considerable knowledge has accumulated to serve as a basis for action in aquatic resource management. Nevertheless, many management techniques once considered effective have not stood the test of field application through the years and have failed to demonstrate their technical or economic efficiency. Ideally, basic knowledge is obtained from research. On the basis of this research, experimental management projects may be undertaken and the results of these pilot studies should provide the guide for scientific conservation. Considering the long and intensive work required to achieve this, it has to be admitted that we are still in the very early stages of building a scientific basis for conservation. It is said that not even the broadest outlines of life history information are known for more than 0.5 per cent of the world's known 25,000-odd species of fishes! Probably even less is known of their environmental needs. The fishery biologist is sometimes taken to task for his slowness in advancing this knowledge. However, fishery science is young and only a comparatively small number of 'fishery biologists' are really doing fishery research. The time of many of them is occupied almost wholly in management or quasi-management, trouble-shooting, administration and other duties. It is clear that, although such activities are useful and necessary, much of the expenditure for these services is at the expense of acquisition of basic knowledge or principles having wide application to pressing problems.

It is also very clear that problems which are already complex are getting more so with increasing agricultural, industrial and urban development. Fishery or conservation agencies are not always able to produce the basic data required to adapt land- and water-development programmes to the needs of aquatic resource management. The biologist cannot be blamed for this. Most commonly it happens that there is extremely limited time available to conduct the studies necessary for intelligent recommendations. Before the effects of a project on resources can be determined, it is necessary to know in relatively complete detail the design and operation of the project, and therefore the resource agency can often begin its study of probable effects and formulate methods of resource protection only after the engineering studies are well advanced.

Investigations such as pre-impoundment surveys, which involve inventories of resources and their composition, soil types and the extent of their distribution in the basin, especially in relation to the spawning grounds of fish, characteristics of the water area, including silt load, areas and rates of siltation, extent and volume of water available, water-level régime and flushing rate, nutrient status, thermal and chemical stratification and history of fish production, are obviously time-consuming. To add to this are the major gaps in our knowledge of resource biology previously emphasized.

Even in those cases where enough basic knowledge is at hand to predict the effect of land and water development on the resource, and where the tools of management or alleviation of ill-effect of the development is known, it is imperative that the fishery biologist be associated with the project at a very early stage. For example, where construction of a dam may decidedly modify downstream flow, planning during the initial survey and design stages may result in provision of appropriate patterns of water release and operating schedules that are not detrimental to aquatic production in downstream areas. Similarly, the harmful effect of fluctuations in lake level above the dam can be minimized by integrated planning at the drawing board stage of the project. Fishways where found necessary can be incorporated into the design of a dam at an early stage; later on this becomes difficult, more expensive and often impossible. A major problem with respect to reservoir exploitation today—manifested especially in Africa where some of the new impoundments are virtually great inland seas with high potentiality for fish production—is clearance of the site of trees and brush, either wholly or partially, before filling to make areas for fish capture available. Early biological and economic evaluation of net benefit in individual cases must precede such clearing programmes to decide on the extent and type of clearance justified.

Such examples could be multiplied, but is has already been emphasized in previous sections that the basic requirement for solutions to problems of water resource management is an integrated approach. It must be admitted that such an approach and adequately co-ordinated action of various agencies concerned is rare. There is a tendency for many aquatic biologists and conservationists to view irrigation, drainage or hydroelectric engineers with antagonism and suspicion, and vice versa. This is not entirely due to the incompatibility of their callings or their respectively desired end points, but more because of their lack of understanding of all the problems involved, probably born out of incomplete education on both sides. It is therefore extremely heartening to see, at least in some countries of the world, biologists with training in engineering and engineers with a knowledge of ecology. Aquatic resource management can benefit immensely by having more of such people in the field. The greater degree of co-ordination and compromise that is urgently required in water resource planning and management can then be expected to become feasible. The need for the association of economists and social scientists—also with an appreciation of ecology—in planning of programmes can also not be overemphasized.

The discussion of knowledge of conservation workers of related subjects brings us to the consideration of one of the fundamental problems of resource management, namely, the lack of and need for an adequate number of trained personnel at all levels. Although the situation in this respect has improved in the last two or three decades in some of the advanced countries, it remains a major problem in most developing and many developed countries. Research scientists with broad-based training and well-qualified management personnel are essential to design and implement effective resource conservation policies.

The many and complex problems of conservation can be solved only by integrated planning based on a sound and progressive scientific policy adopted by governments and intergovernmental agencies. Such an approach results only from a clear-cut mandate for multiple-use planning, and governmental policies should be oriented towards this. There is a great need to build public recognition of the importance of conserving aquatic resources and ensure its reflection in guiding policies and legislation safeguarding the protection, use and enhancement of aquatic resources as an integral part of water development.

Regional and intergovernmental bodies have played important roles in the development of other types of natural resources but, unfortunately, there are very few such bodies primarily concerned with non-oceanic aquatic resources. Regional and international co-operative action can do much to promote resource research as well as management of similar and especially of internationally-owned resources. The formation of bodies dedicated to such action is desirable.

The foregoing discussion of the problems of aquatic resource conservation has endeavoured to draw particular attention to the need for: (a) better knowledge of resource biology; (b) the importance of good harvesting and processing methods; (c) the participation of aquatic biologists from the very early stages of planning and execution of land- and water-development projects; (d) a greater co-operation of agencies, as well as scientists and technicians concerned with resource management based on broader understanding of the problems, and (e) an adequate number of qualified personnel with wider education, involving all the major disciplines concerned. Only if given these as a base, and with the adoption of positive policies and guidelines at national, regional and international levels, will it be possible to have appreciable and sustained advances in the conservation of the living resources of the inland waters of the biosphere.

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Natural vegetation and its management for rational land use

This paper was prepared on the basis of a draft submitted by Professors H. Ellenberg (Federal Republic of Germany) and J. Lebrun (Belgium), with comments and additions by the Secretariats of FAO and Unesco.

INTRODUCTION: NATURAL PLANT LANDSCAPES

THE DIVERSITY OF PLANT LANDSCAPES

The astonishing diversity of natural plant cover is due in the first place to the fact that it faithfully reflects varieties of climates and substrata. It is shown primarily in the physiognomy of the vegetation stand, which is governed by the laws of zonation and homologous environments. Floristic differences on the other hand are due mainly to the historico-genetic evolution of living beings and communities. But the contrasts between vegetations, which in addition bring about contrasts between biotic populations as a whole, are also caused by the dynamic nature of phytocoenoses. Phytocoenoses change, adapt themselves, develop and decay depending on sudden or gradual changes in environmental factors.

This evolution proceeds by stages which are in fact clearly visible milestones in a continuous process which alternates between the very slow and the very rapid. The vegetation stand tends, by successive stages, to reach a state of equilibrium corresponding to the potential of the biotope.

In a particular climate other environmental factors may lower the level of the apparent stability of the plant cover, for example numerous physico-chemical properties of the substratum which ultimately determine its fertility, or even various physiographical or biotic conditions. Plant growth is inhibited and appears to have reached its point of equilibrium, and the living community acquires a permanent nature, since these adverse factors exert an unbroken or regular influence. In the humid inter-tropical zone, a region obviously destined to be covered by forests, the spread of grass savannahs is most frequently the result of fire, which prevents the growth of timber. This is usually the sole cause of the persistence of large areas of heathland in Western Europe. A plant community also includes a number of animals, they too adopt a dynamic equilibrium among themselves, predatory animals with herbivorous ones, and the latter with the vegetation which provides their food.

To sum up, variations in natural landscapes reflect zonation and the diversity of climates and soils, the particular dynamism of vegetation stands, which is often set in motion by exogenous upheavals or internal processes, and the temporary or permanent arrest of these successive changes, under the influence of restrictive factors, at various stages of physiognomy. These basic causes also react upon one another and contribute many minor variations to the mosaic of plant cover.

BIOTIC SIGNIFICANCE OF PLANT TYPES

Phytocoenosis represents only one aspect of biotic population, although admittedly the most essential and basic aspect. All heterotrophs depend on phytocoenosis and its photosynthetic productivity, but they in their turn have an effect both on the mass of autotrophs and on their specific diversity.

The energy and matter stored by green plants are partially taken up in a series of trophic chains which increase in complexity with the progressive development of succeeding phytocoenoses.

Each stage of consumption and transformation is however marked by a growing volume of waste products; and the output of energy decreases.

To this group of heterotrophs, secondary producers, should be added another, animals and plants, which progressively reduce organic waste to a mineral state.

This entire biotic circuit depends primarily on the resources of energy and metabolic matter of the habitat. The habitat in turn is determined by the biocenotic activity itself, which governs and distributes the effects of exogenous factors, and conditions the rapidity and level of the geochemical cycles.

As will be seen, vegetation in the current meaning of the word is the driving element in a dynamic system influenced by all the elements of both the biocoenosis and the biotope.

Any type of vegetation stand, whether natural, wild, man-managed or purely artificial, is the sign of an ecosystem of this kind. Where the plant cover appears to be stabilized, it is because it has reached a state of dynamic equilibrium which is undoubtedly far from stable, sometimes subject to wide fluctuations, and indicative of a system of energy and matter where entropy is at a minimum.

THE IMPACT OF MAN ON PLANT LANDSCAPES

It is now recognized that the biotic population of our planet began over a thousand million years ago. Man himself, who is a newcomer, appeared on the scene only a million years ago.

The human race was originally only one living element among others. As fruit-gatherer, hunter, or fisherman, man fitted in without difficulty into the trophic chain of the biotic communities in which, with other elements, he was a commensal.

The action of mankind begins really only with the Neolithic era, not much more than ten thousand years ago. Much ground has, however, been covered since that period, which marks the true starting point of the stupendous advance of humanity whose effects we are now analysing and whose future consequences we are calculating.

The achievement of man has been primarily the conquest of nature, the taming of its resources by fire and sword, by the bulldozer, and soon it will be by atomic energy.

As we are dealing here with plant and land management, several outstanding stages should be recognized in this progressive and ever-widening extension of man's power over nature.

The very marked spatial inequality of this evolution is due not only to ethnic or demographic differences but also to considerable variations in habitats. As between one continent and another, and one area and another, there is sometimes a very important difference in time-scales and productivity. Most of the methods and levels of man's conquest of land still survive today; they can even exist side by side in the same region.

NOMADISM AND SEMI-NOMADISM

The various early forms of protoculture give way to different localized types of agricultural or pastoral nomadism, reflecting the more or less complete and successful domestication of animal and plant species, the appearance of favourable cultigens, and man's increasing mastery over natural landscapes and soils.

The increasingly sedentary existence of growing populations does not necessarily exclude seasonal movements of flocks or nomadic agriculture. Both are still current over wide areas, and their effect on the plant landscape is considerable.

In widely differing forms, with countless local or traditional variations, nomadic agriculture reflects an undeniable sum total of pragmatic knowledge and a true philosophical approach to the facts of nature. Basically it consists in the rapid transformation of potential energy and of the biogenic matter which has been slowly stocked by wild ecosystems into food and even economic production. A sufficient area of new land is brought under cultivation to obtain the crops desired; much of the biomass which has been cleared is reduced to minerals by burning. The loosened earth is sown or planted; often it is well divided up into breaks, with a short but adequate crop rotation. After the harvest the land which has been sown is abandoned, and is taken over by a secondary but progressive plant growth which finally results, often after a very long time, in the reconstitution of the original biosystem. But even during the crop rotation, new land is brought under cultivation and the cycle continues.

This system of cultivation—for it is indeed a system—is primarily based on the principle of the conservation and sparing use of natural resources. This is however only true provided that one respects 'the rules of the game', and that the same break is not used again until the potential biocoenosis has been restored and has resumed its normal ecological productivity. Further, none of the elements of the ecosystem, whether biocoenosis or ecotope, must have undergone a degradation definitively impairing its potential. This is what inevitably happens when the biotic participants in the sequence of reconstitution are eliminated, or if access to the area becomes too hazardous for them; it also happens when soil which has been uncovered excessively falls a prey to irreversibly or irremediably detrimental processes.

To sum up, it is essential not to prolong the crop cycle beyond the inherent soil possibilities, and to leave the land alone until its cover is completely restored: to put it succintly, cultivation periods should be brief, fallow periods long.

The more complex the nature of the ecosystem originally ploughed up and the higher its ecological productivity, the greater will be the size of the crop which can be sustained over a suitably chosen period of rotation. It is moreover for this reason that nomadic cultivation is primarily a silvi-agricultural method.

It has, however, great drawbacks and dangers. The perimeter of the territory to be covered is considerable, sometimes even enormous, when it includes land which cannot be cultivated. It the number of cultivators increases, and the mouths to feed augment, there is soon a scarcity of available land. The new clearings are no longer made in terminal communities at their highest potential but at stages of plant life which have not reached the term of their progressive evolution. This is all the more tempting since such cover is less dense and easier to clear over large areas. The lengthening of the period of cultivation is another mistake typical of agricultural populations whose aim is to supplement the production of food crops by economic crops which are more profitable. In both cases the results are the same, and possibly even cumulative: a disequilibrium has been created; the actual potential of the environment, as well as that of the biocoenoses, is diminished; the final stage of the progression, if reached, represents no more than a biosystem with a reduced productive capacity. If the process continues in defiance of ecological laws the decline also continues and is often auto-catalytic. In tropical regions this is a prelude to the spread of the savannah over large areas, a phenomenon accelerated by running fires which prevent the regrowth of the forest.

In pastoral communities the grazing of flocks in woodland encourages the growth of pasture; grass which is not cropped or scythed is protected by fire from the reappearance of ligneous plants. The productive potential of ecosystems is lessened, but a larger proportion of plant matter is nevertheless consumed by herbivores. If, however, the number of herbivores increases, regrowth is slower and of poorer quality, and the area subject to deforestation increases progressively. Moreover, vegetation rejected by herbivores increases if not destroyed by man, and finally makes pasture land completely worthless.

In savannah lands, over-population in cattle and the consequent heavy trampling underfoot, prepare the way for the steppe, and the steppe for the semi-desert. Everywhere, however, grazing has inpinged on the forest.

Nomadic agriculture or praticulture, and sometimes both, bring about profound changes in plant landscapes. Contained within limits which respect renewable resources, exploiting only the interest on capital, or alternatively forced into a damaging over-exploitation which eats into capital, these forms of cultivation lead to an astonishing mosaic of plant types, even where a certain degree of unity of physiognomy dissimulates, but barely, a real ecological diversification. Vast areas of the surface of the globe bear the traces of such exploitation, past or present.

THE ORGANIZATION OF SOILS

Population growth, the introduction of political systems, and a certain degree of division of labour, have resulted gradually in the organization of rural communities on the basis of the distribution and stabilization of land in use.

One form of use much practised in western Europe and the Mediterranean world—but which has its equivalent in many other regions—is far from having been completely abandoned, and has left obvious traces in the manner of using and dressing the soil. It consists of dividing the land belonging to the community (often very appropriately in relation to the natural fertility of the soils in question) into three separate sectors: woodland, to provide timber and firewood *(sylva)*; pasture land for cattle *(saltus)*; and cultivated fields *(ager)*, generally the only land which is the property of an individual family.

From the ecological point of view, this is basically a system of assisted transfer—as naturally occurs between adjacent ecosystems. Household ashes return to the *ager*, which also receives manure from the *saltus*. Live-stock grazes additionally on the fallow land of allotments. Finally, the fertility of arable soil is maintained thanks to the indirect contribution from the other elements of the land which has been distributed.

If this system is not pushed beyond the productive potential which can be exported without sowing the seeds of disequilibrium, this method of exploitation is rational and conserves resources. It can lead to a real improvement in agricultural soils, when they are in addition developed by terracing, the construction of enclosures or wind-breaks, the clearing of stones and sometimes irrigation.

But the growing number of mouths to feed, the higher proportion of agricultural produce marketed elsewhere, and also political factors, all constitute incentives for an intensification of the system which is invariably dangerous and sometimes catastrophic.

The *saltus* invades the forest. On the siliceous soils of the European Atlantic seaboard, heathland takes over from pasture and the devastated *sylva*. In some cases not only does the forest provide domestic firewood; in addition, the clearing of undergrowth is introduced for the direct benefit of the *ager*. Pasture land itself is exploited for the same purpose: mowing and clearing provide litter and manure, or else a superficial deposit of organic matter covers the cultivable soils, which are more and more sought after. Ridges and slopes, ill protected, are eroded and gullied; the flow of surface water becomes intermittent. The countryside is soon devastated, even if the *ager* remains in good condition.

The distribution of soils by use does not necessarily go with a final abandonment of nomadic cultivation. It may also include, either as a complementary or as a primary activity, the clearing of the forest simultaneously with the rotation of underwood or high wood. The burning of wood refuse and litter makes possible the growing of one or more crops in forest land. Little damage is done if the rotation is long and the cultivation cycle short, and if broom or furze help to restore the fertility of the soil rapidly and encourage the return of forest cover. Here again however, a too intensive working of the system inevitably brings about degeneration of the over-exploited vegetation, and completely spoils whole regions.

The clearing of coppices, often accompanied by burning over, is also widespread in tropical regions largely covered by sparse deciduous forests where rainfall is relatively high but there is a long dry period. It is frequently carried out in Africa, on the banks of the River Zambesi, with the particularity that the mass of wood burned comes not only from the cultivated breaks themselves but also from the deforestation of a wide peripheral band. This method of working considerably impoverishes the forests and accelerates both their decline and their replacement by savannah.

THE INDUSTRIAL REVOLUTION AND 'MODERN' AGRICULTURE

With the nineteenth century and its industrial revolution, the impact of man on plant landscapes is more marked, and extends progressively to most of the regions of the globe. The tide of human population rises, and with the new tools available to him man takes over land in ever more sophisticated ways. Communications and contacts between peoples increase; land, both old and new, is more and more sought after. Not only do food requirements soar but the requirements in the matter of raw materials for industry are felt more and more acutely. All plant forms are increasingly called on to meet these needs. Nature becomes more and more domesticated or replaced by artificial systems.

In the agricultural field, the industrial revolution takes the form of an irreversible demand for large and diversified crops, together with the acquisition of scientific knowledge and powerful technological resources. The resulting scientific and technological system of agriculture is overthrowing or changing traditional customs; spreading out from more advanced centres, it is extending even to regions where primitive systems still survive. This gives rise to the appearance on all sides of extremely acute problems of mutation, not merely ecological or agricultural, but also economic and social.

Where conditions favour its expansion, modern agriculture has had a considerable effect on both the rural scene and its plant environment. Various aspects of this agricultural change will de discussed here.

1. The first aspect relates to the agricultural ecosystem, and comprises several elements. Firstly, there is the discovery and use of fertilizers, employed as necessary in conjunction with organic ameliorators. This has led to a marked diversification in the crops sown and an increase in harvest from poor soils, as well as a significant increase in the fertility and productive potential of rich soils. It has put an end to the system of leaving land fallow.

The second element concerns the species cultivated or domesticated. It is true that ever since the age of proto-culture, stock breeders and cultivators have selected the most favourable races or varieties, which have been thrown up by mutagenic pressure or have appeared as part of the hybridogenic pattern of the agricultural environment. The development of communications and exchanges have, however, made possible extraordinarily diverse experiments, and recourse to a much wider range of useful species. There are well-known examples of the introduction of new species which have changed the diet of so many peoples. But, with contemporary agriculture, it is the use of selection on a genetic basis which is the origin of the most striking results in this respect.

A third element is the tendency to set aside solely for crop species all the benefit gained from the improvement in the environment. War is declared on rodents, predators and parasites, and biotic competition is increasingly eliminated by the destruction of adventitious species.

Thus, the two constituent parts of the agricultural ecosystem have been simultaneously affected and improved. The use of fertilizers, together with many other practices beneficial to the environment, increases the growth of the primary producers, plants. The use of better adapted varieties more favourable for agricultural purposes, with a higher output, increases crop production or, in the case of secondary producers, the transforming capacity. At the same time the quantity of the biomass which is rejected and which continues to grow or returns to the same soil, is also increased. In both these domains—and one acts upon the other—progress is enormous, the energy circuit and the geochemical cycle alike being intensified.

2. A second aspect has equally significant effects, both on the profitability of agriculture and on the physiognomy of plant landscapes. It concerns the relationship between different agricultural ecosystems and the use of soils.

The concentration of crops and the use of fertilizers, with other techniques to improve soil, on the most suitable parts of the *saltus*—for example, permanent semi-natural grasslands—has freed vast surfaces formerly devoted to pasture, and has lightened the toll on the forests. Coppice woods have been transformed and reafforestation of the devastated perimeters has often taken place.

Thanks to new methods of soil dressing, a large part of the former *saltus* has been incorporated into arable land, the areas which have declined the most being improved by stocking with hardy tree species.

The foddering of a growing number of live-stock, improved in quality but with correspondingly greater requirements, has necessitated the inclusion of a new kind of crop among those cultivated by the community: fodder plants having a high nutritive value, to be eaten cold, dried or as ensilage. Thus the role of the former *saltus* is taken over by the agricultural breaks. Alternatively—and this is certainly the most modern trend—the two forms of experimental farming are entirely separated, specialized and independent.

3. A third aspect is currently being developed: the intensive cultivation of arborescent plants. While agricultural systems have traditionally included seasonal or short-lived plants, the role played by long-lived plantations is now continually growing, due both to the abandonment of marginal agricultural land in certain regions and to the development of new techniques and the availability of suitable genetic matter. This extension reflects to a great extent the concern for taking the maximum advantage of the species of an environment and for meeting a variety of food or industrial requirements.

It has already been seen that the redevelopment of uncultivated land or former communal land has been achieved to a great extent through the planting of trees. Agricultural landscapes have been extraordinarily changed by non-forest plantation, whose many-sided protective role should be emphasized. Other dense stands have also been introduced: these are mainly from selected shoots with a rapid growth rate and a high technological value, such as the various types of poplars.

Above all, there is a great increase in the cultivation of fruit trees, for which techniques continue to evolve. These agricultural ecosystems, often mixed, have a high productive potential and a very effective stabilizing influence on the environment. Orchards are now cultivated not in villages but on an industrial scale.

It is chiefly in intertropical regions that a form of modern agriculture which is sometimes very intensive comes into contact with, and progressively displaces, traditional systems: the cultivation of trees which provide food, economic or industrial products in large quantities. In very sunny climates, where the energy circuit is well supplied from the outset, and there is no shortage of water, the percolation of light makes possible genuine agricultural communities which sometimes have several strata. The productivity of each level fertilizes an enriched circuit, and each storey directly or indirectly contributes to crop production.

CONCLUSIONS

The impact of man today on plant landscapes is by no means limited to his agricultural, zootechnical or even silvicultural activities, whose methods have been barely touched on. The 'anthropization' of nature is also due to urbanization, industrialization, and the development of communications, processes which may be either unco-ordinated or else provided for in development plans prepared in advance.

Thus, man creates 'wildernesses of concrete' which encroach haphazardly on highly fertile land, and sadly reduce his agricultural heritage.

Originally an unimportant new element arriving among the biotic population of the world, the human race has, through its proliferation and its genius, won for itself the role of the primary element in the environment—the most active, the most determining, and the most powerful. Whether we wish it or not, whether we consider it deplorable or desirable, the landscapes of the earth which already bear such deep traces of man's action, cannot escape domestication or transformation under his increasingly energetic sway.

Going even further, man has already outstripped the position of the leading agent in nature; it is his ambition to model nature to his convenience and to adapt it to his immense and insatiable needs.

THE USE AND MANAGEMENT OF NATURAL VEGETATION

INTRODUCTORY REMARKS

To the ecologist, there is no fundamental difference between natural, wild or modified, semi-natural or developed, domesticated or purely artificial vegetations. The laws governing these ecosystems are identical.

The golden rule for their use is to take out nothing but the income. Improvements therefore increase the productive potential but also and above all increase the part of this production which can be taken out—the harvest—without devaluing the capital. The yield can apply to one part—sometimes very large—of the primary production in the case of plants, or of a transformation experiment in the case of animal production. There is in reality no break in the sequence of the forms of exploitation of plant covers which range from the least developed to the most intensive and perfected agricultural systems, calling upon all the resources of technical knowledge, from heavy machinery to the use of synthetic hormones. All these methods are still employed, although some of them are only encountered locally or sporadically. That is in fact one of the paradoxes of modern times: in a single territory, violently contrasted development methods, some very perfected, the others purely traditional, sometimes compete.

It can sometimes be useful to consider two extreme types of the use of land, the first in which only a simple exchange takes place in the natural or semi-natural biocoenosis, the second in which there is a drastic alteration of the ecosystems. The differences between these two extreme types of land use are all the more marked when the ecological conditions are more severe and techniques more developed. The essential rules however remain, *mutatis mutandis*, basically the same.

We should first of all examine, or better still roughly describe, the processes which cause a lack of balance which is often self-catalytic and which culminate in a more or less evident manner in the lowering of the productive potential of the sites exploited. The phenomena here are so numerous and complicated that we can only choose some examples.

The practices which have already proved their value and the governing ideas which are likely to point out new ways of obtaining an increased yield or a better expression of biotic potentials will be referred to in later stages of this paper.

CAUSES OF DISEQUILIBRIUM

Any action likely to increase entropy in a stable ecosystem which has attained the normal operation stage or in a temporary ecosystem or a sequence of ecosystems on the same land must be considered a cause of disequilibrium.

These breaks in equilibrium, whether tenuous or sudden, slight or violent, can be caused equally well by biocoenosis as by ecotopic conditions. The closeness of the interactions between the two facets of the biosystem are, moreover, well known. Any deterioration of one, however slight, affects the other. And very often the deterioration impulse is amplified as it passes through the energy of nerve circuits.

Soil degeneration

Of the different forms of soil degeneration, the best known and the only one which will be considered here is erosion.

Erosion is first of all a geomorphological phenomenon and, as such, affects all physiographic surfaces.

But it is the rhizosphere, the superficial layer of the lithosphere, which forms the biodynamically active part of the substratum. It is at that level that in the ecosystems, the last stages of the recycling of many biogenetic or metabolic mineral elements take place. It is there also that they accumulate, representing one of the essential factors of fertility. Again it is from this soil that the true nutrition and hydrous feeding of phytocoenosis normally derives its real intake of minerals and water.

Now, in this respect, the properties of the substratum are dependent at the same time on the parental material and biocoenosis. A state of balance is slow to become established and is disturbed, more or less brutally, by any form of erosion.

Certain plants are known for their power to hold the earth in place and especially for their prevention of soil drift. They are widely used for this purpose.

The efficiency of the plant screen's protection against water erosion lies in its action on two parameters of the phenomenon. The first of these is that of the impact of raindrops on the soil, leading to degeneration of the structure and the destruction of aggregates by heavy rainstorms. The denser and better stratified the plant cover, the more rain is intercepted, the more the impact of the drops, which are slowed down and scattered, is deadened and the less is their force when they meet the ground. The sparser the cover, the greater the degeneration. It can be seen that this first form of erosion is independent of the slope of the land.

The other aspect is that of lateral erosion, whether it be linear or zonal. In this case, there can be interplay of different characteristics of the plant cover. Among these may be mentioned root stratification and the presence of spreading plants which act as a sponge, the presence of obstacles which prevent the water running down or which retain the earth.

This analysis shows that the total efficacity of the vegetation lies in the combination of its screening function and its power to keep the soil in place. This distinction explains many misapprehensions and apparent aberrations.

Because it deprives the soil of its capacity to retain water and minerals, making the substratum dangerously thin, thus causing transfers which are sometimes catastrophic, insidious or accelerated erosion is obviously one of the most important causes of disequilibrium which affects cultivated ecosystems, especially when climatic or pedological conditions are favourable to it. The 'dry farming' once so much in vogue, produced ill effects from which certain regions are slow to recover. The existing remedies are well known; but here, as in pathology, prevention is better than cure.

Deterioration of the geochemical cycles

Anything which acts on the decomposing communities, temporarily increasing their action of modifying their living conditions, changes the rhythm of mineral recycling. Here initial and maintenance methods of culture which react on the soil climate will be considered.

The edaphic factors which decrease the ionic exchanges between soil and roots create a bottleneck in the circuit of biogenetic elements: there is a decrease in fertility even when analysis shows no loss. The smallest downward deviation in the total humification process rapidly effects the whole ecosystem.

Indirectly, mobility and consequently mineral absorption are also slowed down if other factors of the metabolism, such as water and air content, become deficient.

What we are merely referring to here is in fact an important aspect of pedology and the relations between soil and vegetation (edaphology).

Management of the water balance

The external parameters of evapotranspiration are obviously very much influenced by the energy balance of the ecosystem. This is reflected in the thermal curves of the air and the soil. The edaphic water potential, as also the range of usable water, are complex properties based on the adjustment and interactions of a whole series of elementary functions.

The group of pedological characteristics which finally intervene in water retention and availability of the substratum are among those which might be considered the most delicate, in the sense that any modification of the plant cover or of the soil itself, any deviation of the microclimate and the soil climate react on the water balance. The development of a natural vegetation, its transformation from one type to another which is considered more productive, should first of all take into account its effects on the water of the soil in general. That is the essential source of hydrous nourishment for the plant, the importance of which in its constitution, physiology and even photosynthetic production is well known. The tolerance range of plants in this respect is often small and the slightest indisposition affects the whole biosystem.

Salinization

Among other sources of disequilibrium, we should not fail to mention the effect of salinization on the substratum due to the rise of ground water and the salt pan. It is precisely in the regions where it is most essential to compensate for the lack of water by irrigation or watering, that is to say in the arid or semi-arid regions, that the danger is the greatest.

The effects of salinization on the biocoenoses and on particularly sensitive cultivated plants with edaphic halomorphism is well known.

Change of biotic relations

When there is a change in one of the levels of the trophic network, the resulting deterioration can cause a disequilibrium which ultimately affects the whole biocoenosis and finally the ecotope itself. The fact is evident when the condition affects primary producers. Excessive thinning out of the cover, the replacement of one species by a less healthy one, the thoughtless removal of vegetable matter appreciably reduces the amount available to the decomposers and the edaphic fertility decreases if it is not compensated by sufficient contributions from outside. The same occurs when green plants are subject to epiphytic disease or to attacks by predators. If the field is over-grazed, fresh growth becomes difficult and the quantity produced decreases. The quality of the grass is also reduced and rejections increase. In fact, the load capacity of the area decreases and the cattle derive less benefit from it.

In a biocoenosis, whether natural or artificial, as in the soil, a relationship between the strength of the commensals is necessarily established. An ill-judged addition, the destruction of one of the links in the chain upset the balance. Literature relates many examples of such occurrences which often have dramatic consequences.

Similar processes are in fact set in motion, though without such spectacular consequences, when strains or varieties, which may be well known but are ill-adapted to the conditions of the site, are introduced in the crop rotation. Their unsuitability may even disrupt a whole cultivation plan.

The elimination of parasites, and especially insects, increases the yield. It is an agricultural necessity. But their general elimination is not without drawbacks. To quote one example, many horticulturists are obliged to hire beehives during blossom-time to obtain sufficient pollination in their orchards. There are certain fruit-producing regions in Europe where harmless bees are brought a very long way to carry out their temporary task of compensating for local biotic deficiencies.

IMPROVEMENT OF THE PRODUCTIVE POTENTIAL

The crop is therefore that part of the productivity which can be taken away —we might say the 'potentiality'—according to a rhythm suitable for each biosystem exploited, without decreasing the potential of the environment. It is clear that the size of the crop depends on the amount of the 'restitution' and complementary external contribution, in the form of fertilizers for instance.

Soil improvement

Manures or ameliorators of every kind therefore constitute a first—and very effective—method of stimulating the geochemical cycle. It is clear, however—is it even necessary to recall the fact?—that the saturation curve of the response should be interpreted not only from the physiological but also from the economic point of view. The increase in the crop as a result of the adequate—from the point of view of quantity, quality and timing—provision of manure conforms to a law of diminishing returns which reveals the restrictive action of progressively limiting factors. The rational use of mineral fertilizers at all stages of the valorization of the phytocoenoses necessarily leads to over-all improvement in productivity factors.

In this connexion, other methods of land improvement will be referred to, with special reference to ways of acting on the biotic behaviour itself.

Biotic transformation capacity

Zootechnical or hydrobiological studies have clearly shown the diversity of the transformation capacity of each species belonging to the same trophic level. The same thing is true of strains as of individuals.

In the circuit of secondary producers, it might be useful to look for the types which are the best transformers. It is possible to do so even in biosystems which are not purely artificial and at each stage of the transformation cycle. It is basically an initial method of improving the energy flow.

The adjustment of the trophic chains to produce an equilibrium adapted to the yield is a practice which has already proved its value in fish-breeding, starting from chlorophyllaceous hydrophytes as primary producers. But the principle itself is valid in a more general sense.

Improvement of primary production

It was useful to refer to methods of improving transformation. But here we are mainly concerned with plants and should therefore confine our attention to the initial energy transfer, the action of passing from the mineral to the organic.

The photosynthetic yield depends essentially on two ethological parameters: the specific net efficiency coefficient and the leaf surface developed per surface unit.

Encouraging results have already been obtained in the improvement of the photosynthetic efficiency of species. Types, strains and individual plants show very different figures for the same incoming radiation.

The adequate adjustment of the leaf surface can be obtained by a morphological organization of the mosaic to obtain the optimum chlorophyll production conditions. Such interventions raise the question of the auto-ecological and syn-ecological aspects of the agronomical notion of 'plantation density' and 'selective thinning'.

Chlorophyll content, to a lesser extent perhaps, like the relation between chlorophylls *a* and *b* (or better still between the pigmentary systems in the photophosphorylations) might constitute other parameters of photosynthetic efficiency.

There is, however, another procedure which might be followed in the organization of substitute vegetations or even in the exploitation of almost natural phytocoenoses: the adjustment of the limiting factors of the phytosynthetic production.

Although, in general, it is luminous energy which is usually the minimum factor, other environmental factors can locally or temporarily define the maximum rate of photosynthesis. We shall quote only one example.

The photosynthetic action is known to be closely connected with the circulation of water in the plant. The very high transpiration coefficient value is ample proof. It is often lack of water which prevents chlorophyll assimilation when all other conditions are favourable. The improvement of the water balance is one of the methods to be tried in this case; its prospects of success are excellent. This is evident in arid or semi-arid regions or habitats. But it would be wrong to believe that even in well-watered territories, a deficient water balance cannot, temporarily or occasionally during the plant cycle, cause an appreciable decrease in the yield. In many cases, the provision of additional water is obviously required.

Here we shall not only refer to the various forms of irrigation techniques, which are generally only applicable to high yield, artificial or semi-natural ecosystems but also to simpler practices likely to have a similar favourable effect. We shall mention devices to reduce potential evapotranspiration, such as windbreaks, hedges, shelter-belts and their associated cultivation methods.

Phytocoenosis management

This is certainly a particularly promising technique. Man in fact has only a small number of domesticated plant species at his disposal, but the resources of the plant world have by no means been sufficiently investigated. We have still little knowledge of the useful species. It is urgent that this investigation should be completed.

We can first consider the exchange or transposition in an ecosystem of species, varieties or ecotypes in terms of their greater adaptability or better photosynthetic efficiency. A change of this kind is possible, in order to improve primary productivity, without noticeably modifying the biocoenotic balance or the ecological pyramids. Is it not already done by the forestry experts who try to encourage by selection or to introduce tall, long-living strains or to develop plantations of quick-growing species? It is not only the quantitative aspect which should be considered. There are also qualitative properties such as the characteristics which increase the proportion of yield to the total biomass.

In such cases, we must obviously have recourse to genetics. Selection has already led to such progress that it would be inconceivable to believe that its possibilities are exhausted in the ecophysiological plane we are discussing here. The research to be carried out in this direction should associate the selection garden with the laboratory as well as with the phytotron.

Finally, it is not only the photosynthetic efficiency as such which must be considered but also the adjustment of the ecotypes to the conditions under which it is proposed to exploit them. We already know how different can be the behaviour of strains with different photoperiodisms or thermoperiodisms.

RATIONAL MODIFICATION OF PLANT STANDS

To modify natural vegetation is not only to damage or improve them, to transform them or to replace them by others, it is also to allot them a definite place in space and time, by the introduction of economic and social considerations.

Crop rotation, shifting and cultivation complexes

We have seen that the natural groups themselves, when they form stable communities, can produce a succession of different species on the same site. These successions correspond to different waves of specific groups which replace each other. Numerous dependent, antagonistic or competitive relations between plants, even auto-intoxication or edaphic auto-sterilization phenomena enter into these rules of the communal life of living beings.

Rotation, properly so-called in the agricultural sense, corresponds to a succession of ecosystems on the same ground, each of which leaves part of its productivity or capital for the benefit of the next. The progressive dynamism of the vegetation corresponds precisely to a sequence of this kind in which there is enrichment at each stage, culminating in the final balance.

In many cases however, it is precisely the stages of secondary succession which are generally more useful to man than the final balance. Man then takes a calculated risk in interrupting the succession, but he is obliged to do so when the climax forest does not produce or no longer produces the quality and quantity of products required by the economy. A better evaluation of pioneer species, better adapted to rapid growth, more capable of reacting favourably to treatment and more resistant to variations of soil and microclimate than species nearer to their climax, is an important addition to the knowledge of modern forestry.

In the extended systems of the use of plant-stands, rotation corresponds essentially to the alternation of a cultivation cycle—in some cases a single cultivation—and a fallow period, the length of which depends on the native fertility of the substratum, which has the task of reconstituting the environmental potential. The more the agricultural systems are improved by fertilization, the greater will be the reduction in the importance and duration of the fallow land, the use of which is disappearing. Rotation will then become refined within the cultivation cycle itself.

Shifting is the spatial reflection of rotation imposed by the rhythm of crops and what we might call the revolution in forestry.

We shall confine ourselves to a reference to a method of arranging cultivations and modified vegetations to produce cultural complexes. These may be anything from the large, primitive hedge of wooded regions or of the tree belts—often pruned or pollarded—which mark the boundaries of fields and are merely the remains of the original forest, to non-forest plantations, groups planted to hold up terraces, slopes and *ha-has*, alternating strips and associated or stratified cultivation. These arrangements are very often characteristic of an area dedicated to a certain plant potential and give a clear indication of the type of land.

Management

The idea of management is inseparable from its technical substructure even though, in reality, it varies appreciably with particular circumstances. Its aim is to associate with increased productivity the economic and social prosperity, the greater well-being of the inhabitants of a district, territory or country. Its object is the development of man and the maintenance or restoration of harmony between natural resources and economic progress.

Old countries or new nations, industrialized territories and purely rural districts, regions with a high population density and those with a scattered population, all can profit from management if it is adapted to the circumstances and if its technical implements correspond to local economic dimensions and means.

Management can be conceived and carried out either at the level of individual enterprises, sector by sector, or for a territory as a whole, to fit in with national, provincial and local requirements.

1. At the level of each agricultural, forestry or pastoral enterprise, the production of goods and services should be organized so as to achieve the aims fixed by the owner, whether it be the State, collectivities or private individuals, taking into account technical possibilities and limitations. A better knowledge of long-term production and consumption prospects at the national level makes it possible to organize the production of goods and services in each enterprise for a given period, within the framework of a longer-term policy. This organization of the production of goods and services is at present facilitated by the development of management techniques. It also requires as precise a knowledge as possible of the effects on productivity of different processes (fertilizers, working of the soil, irrigation, etc.).

Management which consists in development control comes up against economic problems depending on the scale of the operation and on co-ordination with national and regional plans. The search for viable units is more complicated today, for it is no longer possible to be satisfied with looking for the type of production with the greatest economic utility. We must try to find a method of exploitation which produces the greatest possible difference between costs and profits. The co-ordination of local development plans with national programmes calls for an intermediate stage which is often found in regional planning.

Much is said at present about multiple-aim management. It may be called silvi-pastoral, silvi-touristic, silvi-agricultural management, etc., and its aim is to turn to account the different uses of the land. Theoretically, such management is certainly beneficial, but its practical control on the site is difficult. That is why the development is often based on a priority use of land while certain secondary uses are still accepted. For instance, a forest which is developed for production can serve as pasturage for cattle in particularly dry summers or be open to tourists under certain conditions.

2. Land-development concerns not only the countryside and natural landscapes but also towns or villages or even factory districts. It consists in an effort to integrate the different programmes and to reach some coherence between the various sectors. Even in industrial areas, the developer must allow for the 'green belts' indispensable to health and sanity.

The management of vegetation should always be one of the aims of any general or special, national or local development plan. But the question has special priority in the case of the development of country areas, which still possess an extensive plant cover.

The management and agricultural, silvicultural or pastoral development of such areas corresponds, from the ecological point of view, to a spatial redistribution of the natural, developed or completely artificial ecosystems with a view to obtaining maximum productivity and the best crops compatible with economic and social necessities and in harmony with the laws of the plant cover. It therefore includes the correction of imbalances, the restoration of damaged land, the drainage of ground for housing, the harmonization of the country as well as its valorization and the increase of returns on the investment made in it. It is in fact the means of domesticating nature without any deterioration.

Its success demands preliminary studies and a good knowledge of the environment as well as of the agricultural techniques to be used. Those engaged in the work of management should also be provided with adequate material: plants and animals, with whose characteristics they are familiar and whose possibilities in the local environment have been tested in advance. Any management, like any agricultural development plan, even specialized, must necessarily be based on the results of experiments as well as on knowledge of the vegetation, soil and all the factors of the environment. The best way of representing these elements and the most appropriate to local needs is cartography.

Nothing is more instructive than to analyse management plans and discover to what extent they have succeeded or failed. The analysis of the misuses provides useful lessons. A post-mortem of the most obvious failures always throws light on a fault, an insufficiency of preparatory studies. Also, it often appears that favourable results could have been obtained with completely different methods. The fault lay in a misinterpretation of nature's message. Plants can express themselves clearly to those who understand them.

Once it has been decided on a clear, well-defined basis to develop a territory which is considered interesting, it is necessary to allot the zones which are most favourable for the various types of cultivation it is intended to engage in, the plantation of orchards or young trees, the establishment of natural, improved or artificial pasturage, forest reserves, control or enrichment, or for the siting of villages, commercial, social or cultural centres or even of conversion industries. The best use must be made of soil and vegetation. It would be absurd to clear a forest if its economic potential is higher than that of the grassland which would replace it and if it were necessary to provide for afforestation further on to supply the wood necessary for the activities of the inhabitants. Unfortunately, this is what happens in many regions, especially in the tropical zones where the inhabitants are driven to it either to remain alive or through ignorance of the economically valid solutions or the lack of machinery to carry them out.

The planning should also take the water resources into consideration; the plant structure is a very reliable guide in this respect. It would be little use to suggest that a certain hill should be covered with pasturage if there was no source of water for the cattle, nor to plan for irrigation without checking the existence of water reserves satisfactory both in quality and quantity.

Nor is any allocation valid without a concerted soil protection and conservation plan. Even in wholly cultivated land, the knowledge of natural local vegetation guides the choice of the most suitable species and communities for any form of 'cover', support or shelter.

Agricultural management often implies a redistribution of land. Regrouping of land is not a problem peculiar to a country which has been cultivated for a long time or to old land. The intensification of the rural economy in many developing regions also often calls for a more judicious and equitable sharing out of community lands.

Finally, the planning should take into account the aesthetic aspects of the countryside, the importance of providing for accessible green zones for essential recreation and of ensuring the preservation of protective covers against water and air pollution. The planning should go so far as to provide for rows of trees near major lines of communication and industrial centres to deaden the noise, because it is important for the country to keep or regain the calm which should be its essential characteristic.

In conclusion, it can be said that land management is the result of team work in which all disciplines should be represented, to arrive at a solution of synthesis.

Preservation of samples of natural vegetation

The inventory and study of various terrestrial ecosystems which may sooner or later be threatened is a scientific task which should be actively encouraged, if only for its utilitarian consequences.

Many excellent advocates have defended with verve and pertinence the social and touristic importance and even the economic value of national parks, natural reserves and protected sites.

Allowance must be made even, and especially in the developed districts, for the preservation of sufficiently large strips of land on which the different forms of local vegetation are represented. These samples will comprise so many experimental fields, so many living laboratories for the study of the biocoenoses, the true nature and key character value of which have been fully stressed in connexion with many aspects of land valorization.

But there is yet more: it is in these reserves that the living species which may later be of use, will be kept alive. Biotic investigation is by no means at an end. There still remains a considerable potential which has not yet revealed all its resources. So these samples of natural vegetation will be conservatories of genes in the widest sense, veritable stores of promising hereditary characteristics into which future biologists will be able to dip.

CONCLUSIONS

The surprising diversity of the physiognomical and ecological forms of terrestrial vegetation is due to environmental factors as well as the historic-genetic conditions peculiar to the different major natural territories. It also reflects the dynamic laws inherent in plant stands as well as in the biocoenoses themselves. The appearance of the cover, however, is largely dependent on human influence. From time immemorial, with different tools which become more and more effective and methods which have greatly evolved but which still exist at all stages of development, man has tried to derive benefit from plants, and to exploit the land which they cover and protect and the fertility of which they often ensure. The human impact can today be considered the most active mesological factor. Future prospects indicate that the domestication of natural renewable resources will continue to grow.

Whether it is a question of stands which have remained completely or almost natural, developed covers or purely artificial, temporary or long-living cultivation communities, the plants within the biocoenoses and ecosystems in every case follow parallel laws.

The rational modification and exploitation of these plants and the land which bears them are obliged to take these laws into account.

Man is by no means powerless with regard to the possibilities of restoring and increasing their productivity and harvests, while still maintaining and enriching the capital which provides his food and so many raw materials for his industries.

The possible improvements can be made in the elements which constitute each ecosystem or in the collection of ecosystems represented or implanted in a specified territory. For these landscape units are not in fact independent. The harmony and effectiveness of their combination and distribution, even in relation to fixed or allotted aims, are precisely the objects of the management of rural areas and of the local or special agricultural development plans which aim at ensuring increased production at the same time as the welfare of the inhabitants.

Rational management is therefore a prospect which gives great hope of new progress in agriculture and the other methods of exploiting plant cover and land. To be effective, the method should be based not only on a good local knowledge of the useful species and their exploitation techniques but also on a thorough study of the plants and environments. The most certain way of obtaining the best results is therefore an interdisciplinary approach to the problems raised by planning. To provide useful economic and social results, these developments should be completely integrated in the general plans of which they constitute one of the factors.

Finally, at each of the stages of the study of vegetations and soils and of the analysis of their modifications or uses, the value and reliability of the ecological disciplines can be seen. This emphasizes the role of ecologists in the management of rural areas.

Animal ecology, animal husbandry and effective wildlife management

This paper was prepared on the basis of a draft submitted by Professor Derek Tribe (Australia), with comments and additions by Dr. K. Curry-Lindahl (Sweden), Dr. J. Pagot (France), Dr. V. Sokolov (U.S.S.R.), Dr. F. Smith (U.S.A.) and the Secretariats of FAO, WHO and Unesco.

INTRODUCTION

Many reasons make it imperative that, in the interests of both national prosperity and human progress, the problems of animal ecology, husbandry and wildlife management deserve to be accorded high levels of priority in terms of scientific and economic planning. The nutritional need alone provides sufficient justification for renewed national and international efforts to improve the efficiency of world live-stock production and wildlife management for meat production. Yet, to this reason can be added others, also urgent and compelling, such as the production of milk, fat, wool, skin, leather, fur, honey and silk. The potential importance of animals as reservoirs or transmitters of disease, as predators or pests, as pollinators and as participants of soil-forming processes must also be included in the consideration of any particular ecosystem.

Animals also contribute to man's enjoyment and pleasure, and they play an important role in a variety of scientific, aesthetic, cultural and recreational activities.

The economic value of tourism and hunting for sport is becoming extremely important in many regions of the world and, as standards of living continue to improve, the importance of wildlife management and the husbandry of 'sporting-type' animals is certain to increase.

The mismanagement of animal populations, wild and domesticated, leads to the serious degradation of soil, water and plant resources, changes in local climatic patterns, and even the eventual creation and spread of deserts. Ultimately, therefore, animal populations need to be studied so that they may be managed, conserved and used in ways which will maintain in the long-term an ecological balance favourable to human existence.

While recognizing the vital importance of animals in a variety of economic, ecological and recreational situations, the present paper emphasizes particularly the role of improved animal husbandry and effective wildlife management in satisfying the widespread and urgent demands for animal protein. Moreover, the scope of this paper has been mainly restricted to the larger herbivores and no attempt has been made to deal at length with the broad field of animal ecology.

The need to use efficiently the animal protein resources of the biosphere for the benefit of mankind has never been more urgent than it is today. More than half of the world's present population is inadequately nourished and this proportion is increasing. In many developing nations of Africa, Asia and Latin America, protein insufficiency is the most important single cause of child mortality. Because of the generally superior biological value of proteins derived from animals over those derived from plants, the shortage of animal proteins, one of the most serious of all world shortages, is of particular nutritional significance. Moreover, live-stock resources are often most limited in areas in which there is the most rapid increase in population growth.

In many countries, plans for developing secondary industries usually depend to a considerable extent upon the generation of surplus investment capital and foreign exchange by primary industries. Compared with the future economic outlook for many primary products (e.g., cotton, pyrethrum, sisal), the long-term prospects for meat are generally sound and it is for this reason that many developing countries are increasing their efforts to improve their live-stock industries.

In addition to these nutritional and economic arguments, there are also powerful and sociological reasons for live-stock and wildlife development in many areas of the world. Animals play a dominant part in the lives of many unsophisticated rural communities. The herds and flocks of nomadic pastoralists, for example, frequently occupy an extremely important cultural, or even religious, niche in the life of the community as well as vital, or even exclusive, nutritional and economic positions. To be successful, efforts to improve the standards of living of such communities must often find a basis in the cultural and husbandry practices which form their traditional way of life. Improvements in techniques of animal husbandry may constitute an essential first step to improvements in child care, public health, and educational and economic advancement.

The need to ensure that the animal resources of the world are at once conserved and used with greater efficiency can thus be justified on several grounds.

The biological efficiency of animal production is inevitably less than that of plant production. Good-quality proteins can be produced from fungi, yeasts, bacteria and algae using such substrates as crude petroleum, coal products or a combination of inorganic nitrogen with starches and sugars. Proteins suitable for human nutrition can also be extracted from green leaves. As these various types of production, together with the supplementation of plant proteins with synthetic amino-acids, become commercially possible on a large scale, the nutritional case for developing live-stock production will grow less cogent. Nevertheless, the nutritional case is likely to remain of extreme importance in many localities for a long time. The strong conservatism in food habits shown by most communities, even by those who may be inadequately fed at present, makes it unlikely that new food products will find rapid and widespread acceptance. Moreover, many people in the world, and most of those who are undernourished, exist on a subsistence type of agriculture in which it is possible to increase their own supplies of food from animals and crops but impossible to purchase the products of a technically more efficient food technology industry operating, almost certainly, in a foreign country.

However, the development and acceptance of new protein foods will not remove the need to extend the rational use of the animal resources of the world. In most environments animals form an essential part of any ecosystem that may constitute an efficient form of land use. Any policy for conserving other natural resources, such as soil, water and vegetation, must normally involve a rational system for managing the associated wildlife and live-stock resources.

ANIMAL HUSBANDRY AND LAND DEVELOPMENT

The problem of allocating land for a specific use is a complex one. Although economic and social considerations are extremely important, long-term ecological factors can often be critical. Environmental factors such as climate, soils and topography are the best guides to the long-term use of land and, of those, a combination of rainfall and temperature often constitutes the main factors which determine whether a region is or is not to be used for live-stock production and, if so, what type of live-stock production is to be practised.

In many parts of the world, population pressures and/or the increasing needs for cash and food crops have led to the development of extensive live-stock industries in those areas which are least attractive to human settlement and least suited to crop production because, for example, they may be too hot and dry (e.g., the arid rangelands) or too cold and wet (e.g., mountainous regions).

Where live-stock industries occur in areas of dense human population and high agricultural potential they are usually of an intensive type (e.g., feed-lotted or housed ruminants, intensive pig and poultry production). It is paradoxical that although such environments are commonly more stable and better suited for most animals than those in which live-stock are managed extensively, it is in these situations that animals (and birds) are frequently housed, trough fed and otherwise protected, at least to some extent, from natural environmental changes. Indeed, the most highly controlled environments (e.g., buildings with temperature, humidity and day-length regulation) are now used for species such as poultry which have inherent physiological and behavioural mechanisms which enable them to adapt successfully to a wide range of environmental conditions. It is conceivable that where man himself controls the environment within narrow limits it would be more efficient to substitute non-traditional species (e.g., reptilian poikilotherms) for such species as birds and pigs.

DOMESTIC ANIMAL ECOLOGY

Of the many biological, economic and sociological factors which at present combine to determine the low efficiency of animal production, an important ecological factor is the suitability of domesticated animal species for the environments in which they are at present used.

In some specialized cases, such as the use of reindeer in the boreal tundras and forest lands of northern Scandinavia, yaks in Tibet and the Himalayas or alpacas and llamas in the mountainous regions of the Andes, man has domesticated and used indigenous species that are extremely well adapted to their environments. However, many of the species that occur most widely throughout the world's live-stock industries are used for reasons other than their ecological suitability. Despite the occurrence of more than 5,000 mammalian species in the world, only some sixteen have been domesticated and are of substantial economic importance. These have originated from the ancient civilizations of Asia, Europe, South America and North Africa. The aboriginals of North America, Australasia and Central and South Africa, whose agriculture never developed beyond primitive and shifting cultivations and whose food and clothing were largely furnished by the hunting of wild animals, have failed to produce any domesticated animal species of importance.

As the more highly developed civilizations became involved in exploration, immigration and colonization, they took with them into their new environments, the domesticated live-stock and cultural techniques of their homelands. Only rarely were attempts made to domestic species indigenous to the new lands and, as in the case of the Australian marsupials, these attempts usually failed.

Thus the main factors which determined the spread of, for example, sheep and cattle from Europe (mainly Spain and Great Britain), throughout the world included a knowledge of the necessary and basic techniques of husbandry on the part of the explorers and colonizers and a demand for familiar products (wool, beef and mutton) on the part of those who purchased their products. Attempts to establish alpaca and llama industries in Australia more than a century ago failed mainly because there was no ready market for their products; on the other hand, the sheep industry prospered because Europe wanted wool.

The pressing need to improve the efficiency of the world's live-stock industry is now resulting in a wide and detailed re-examination and comparison of the domestic stock in common use. In numerous countries in tropical and subtropical regions the intrinsic characteristics of indigenous and exotic *Bos taurus* and *Bos indicus* cattle are being compared. In view of the tremendous economic importance of the water buffalo in many countries of the Middle East and Asia, some studies are also measuring the performance of *Bos bubalis*, and many more such studies are urgently required.

In this work it is important to measure the performance of species in relation to both their ecological adaptability and their economic suitability. For example, despite the general ecological efficiency of water buffalo in several Asian countries, a trend towards mechanization (particularly of rice cultivation) would largely remove the need to consider the use of buffaloes as draft animals, and as meat or milk producers they may not be the most efficient species available.

In areas of intensive cropping, where farm size is small and farmers are mainly operating at or near to subsistence levels, the need may be for a small, inexpensive type of herbivore that can utilize most efficiently the by-products of cash and food crop production. Under these circumstances such an animal as a cow or even a sheep may represent too large a capital investment and risk while a pig or bird may be too inefficient in its use of available feed. In many such parts of the world a greater use of small herbivorous species (e.g., guinea pigs, goats or rabbits) may result in a much improved availability of animal protein for the local populations.

The increasing amount of work now being done in this field by national and international organizations, and the stimulus such studies are receiving from the herbivore section of the International Biological Programme, will result in a much greater knowledge of problems which now are but poorly understood. This in turn will lead to sounder ecological policies and practices which will considerably improve the efficiencies with which we utilize the live-stock resources of the world.

ANIMAL HUSBANDRY

The outstanding characteristic of the live-stock industries of the world is their extreme diversity. Clearly no single pattern can be applied to so great a range of conditions in which climates, soils, vegetation, population densities, land tenure systems, levels of knowledge and wealth and social customs all vary widely. The pattern of husbandry best suited to any particular locality must take into account the peculiarities of the physical and social environments, as well as the degree of development already reached. Nevertheless, although the improvements required in existing animal production methods may be technical (e.g., disease control), social (e.g., new systems of land tenure) or economic (e.g., credit facilities or improved marketing organization), they must occur in an appropriate order in relation to one another if progress is to be continuous and resources are to be used efficiently.

Although, ideally, the improvement of animal production is a continuous process, it is convenient to talk of 'stages' of development. These are not water-tight compartments into which different processes and considerations can be snugly fitted and completely segregated from one another. On the contrary, they serve only to illustrate the principles of live-stock improvement which must be followed in ordered sequence if available resources are to be used efficiently.

These principles are summarized in Annex I which serves to illustrate the general framework of development. This does not exclude that in a given country all or some of the so-called 'stages' can be combined for their mutual benefit. Furthermore, research programmes are necessary at all stages but special research institutions are mainly needed for the more elaborate stages.

In the early stages not much specifically technical progress can be made in live-stock production. The first essential is that the general educational standards of the rural communities must be raised so that not only will they gradually become dissatisfied with their traditional lot but also they will begin to understand the ways of improving it.

For example, efforts to raise the imaginative horizons of pastoral communities must concentrate upon loosening their traditional regard for live-stock. In the past a great deal of effort has been made to try to induce pastoralists to sell their animals and to recognize a different form of currency. Only when he has to pay cash for school fees, taxes or his limited range of consumer goods, e.g., beads, tea, sugar, beer and an occasional blanket, does the pastoralist need to sell an animal and to obtain a cash currency. If his appetite for goods valued in money could be cultivated, his willingness to sell cattle, buffalo, sheep, camels or goats, would be correspondingly increased.

When he begins to regard live-stock in terms of their monetary equivalent, the pastoralist must at once begin to appreciate quality in live-stock, at least in so far as quality is assessed by differential price values. Only when this change in attitude has been achieved is he likely to co-operate in improvement schemes involving destocking or a rational use of water and grazing resources.

Given a basic standard of education, ambition, an acceptance of a monetary economy and co-operation the next requirement for live-stock development is a scheme for land tenure reform based on either an individual or group basis. Experience in many parts of the world has repeatedly demonstrated that attempts to improve live-stock productivity have only been rewarded when traditional systems of communal land tenure have been replaced by recognized holdings, the legal titles or sole rights of use being held by individuals, family groups, co-operatives, companies or corporations. Not only does an established right of occupancy provide the owner(s) or tenant(s) with the long-term security that is the prerequisite for the investment of private savings and personal effort, but also it is the security that must be produced before long-term loans can be obtained from banks and other credit organizations. Moreover, land privately held by a producer or group of producers, from which the live-stock of other producers can be excluded, can be developed with grazing schemes, diseases can be controlled, and breeding can be regulated.

In areas of arid or semi-arid land, covered with dry bush or steppe, people are often pastoralists from necessity and it may be undesirable to alter substantially indigenous systems of land use based on nomadism. In conditions of erratic and scanty rainfall, a nomadic habit can make the most efficient use of water and the ephemeral green vegetation where and when it is available. Conversely, to turn the nomad into a settled rancher (particularly on a small scale) by providing additional water supplies, so that instead of ranging over a wide area he is confined with his herd to a limited locality, is likely to lead to widespread land deterioration. It is often better to seek the solution by combining nomadism with further development in irrigated or high rainfall areas.

The desirability of regular movement of animals from one locality to another (transhumance) is not limited to arid or semi-arid environments. It can also be seen in the movement or migration of some wild, as well as domestic, species to and from mountain pastures, the steppes or savannahs, and the zones temporarily abandoned by a river or lake.

When producers are anxious to convert live-stock and their produce into a currency that is more widely negotiable, they begin to become aware of the need for a fair and adequate marketing system. At this stage, too, quality becomes important and at first, at least, quality in meat animals is synonymous with size and in dairy stock with milk yield. In order to make rapid improvements in these respects it is usually advisable to improve nutritional régimes and to introduce sires of superior genetic merit which in dairying districts at least often means a sire of an exotic breed. Because of the shortage of good sires, the high cost of their purchase and maintenance, and the danger of spreading breeding diseases, a system of artificial insemination is often needed. When quality is appreciated, an immediate improvement is required in the general standards of nutrition and management. Support is needed to identify non-disease factors limiting production and feeding and breeding practices at once become more sophisticated.

As live-stock production continues to develop, the trends intensify, new land is generally fenced, credit facilities need to be more generous (involving larger sums and longer repayment periods), marketing organizations are further refined and extension services need to be multiplied. Producers increasingly demand new information, particularly of a local nature, that may not be available and therefore the establishment of local research centres becomes essential. At about this stage, too, some producers are inclined to become interested in new forms of animal production. Where ecological conditions permit, exotic breeds of sheep and cattle, for example, may be introduced as wool and meat producers, improved types of pig may be kept for the production of quality bacon, while systems of poultry management become progressively more intensive.

Finally, the most progressive farmer or rancher needs the support of statutory agricultural boards, a barrage of government legislation dealing with a diversity of special subjects ranging from stock theft and scheduled diseases to taxation and the control of home and overseas markets, well-staffed extension and research services, and a variety of commercial services such as seed merchants, compound feedstuff and fertilizer firms, farming associations and societies and stock and station agents.

Although the detailed order of these developments changes from region to region according to differences in, for example, climate and social customs, their general order is surprisingly similar. For example, there is no point in introducing a controlled grazing scheme in an area in which live-stock owners are reluctant to sell their cattle and insist on grazing their land communally according to tradition. Similarly, the introduction of improved exotic stock to areas in which diseases have not been controlled is a move that is certain to fail. One of the most serious causes of loss in domestic live-stock is disease. Particularly during early periods of development, animal epizootic disease is commonly the most important factor which limits live-stock production. Strict veterinary measures are essential to control the important infectious epidemics that can ruin production and decimate an animal population. It is at this stage that veterinary services are particularly important, whereas other technical services involving specialists in fields such as animal husbandry, pasture production and farm economics have only a limited contribution to make. However, the veterinary service required at this stage involves only a limited number of professional specialists whose work is largely of a planning, supervisory and administrative type. These veterinarians must be supported by much larger numbers of sub-professional staff trained to carry out the extensive programmes of inoculations, vaccinations, and field recording that are involved in work of this type. These field units also need the support of the veterinary research workers who produce the vaccines and drugs and the pharmaceutical houses which manufacture them.

This structure contrasts markedly with the veterinary services needed by a more highly developed animal industry. As development proceeds, the treatment of disease on a herd basis replaces the treatment of whole animal populations, until eventually individual animal treatment becomes possible. The emphasis shifts from the prevention of epizootic diseases to the prevention of enzootic conditions (including nutritional, metabolic and parasitic diseases), and preventive veterinary medicine is of growing importance. In this situation the need is for a larger number of veterinarians, who personally diagnose and treat individual animals and advise on animal husbandry but who do not need the support of sub-professional staff in the same proportion as before. However, they do need the support of well-staffed and equipped diagnostic and investigational centres. In other words, the structure of the veterinary services differs between localities of different levels of development or, of course, with time in any one locality as its industry progresses. It is paradoxical that at an advanced stage of live-stock development, although the role of the veterinary services is no longer as overwhelmingly important as at first, and although the services of specialists in fields such as animal husbandry, pasture production and farm economics have all increased in importance, the demand for veterinary graduates is higher than before.

The curing of animal disease is not usually an end in itself. It may be important as part of a general public health campaign in which the aim is the control of major zoonoses. In most cases, however, the work of the veterinary services is directed towards improving animal production. Unless simultaneously accompanied by improvements in feeding, management and breeding the advantages of an improved health situation can be lost. There is no point in preventing animals from dying of disease if they are then to die of starvation. Given the establishment of disease control systems, other live-stock policies must be re-aligned. Organized marketing channels, to permit regular stock off-takes and their orderly evacuation to holding-grounds, slaughtering houses and consuming centres, play a critical role in the efficient use of live-stock and their products.

Among some important factors which determine the efficiency of live-stock use, the ecological habitat, the population density and the state of communication are three essential and interrelated ones. The broad effects of each of these factors can easily be seen in most parts of the world. In East Africa, for example, the pattern of rail and road systems has had a marked effect on the growth of live-stock industries in Tanzania, where several large areas in the south, west and north have remained relatively undeveloped, even though they have a high ecological potential, because of the absence of communications. In Uganda, where the ecological potential is often outstandingly good and the system of road communications is well developed, the low population pressure in many areas has resulted in a slow rate of development. In the north of Kenya large areas are comparatively undeveloped because the ecological potential is extremely low.

Other, more specific, factors which are often extremely important in determining the extent and intensity of animal production are the availability of trained manpower, live-stock, knowledge, markets, and finance. Of these, the shortage of trained manpower is of urgent and general importance. In efforts to husband the world's live-stock resources, the greatest single obstacle is the shortage of well-trained personnel at every level from the farmer or rancher to the research scientist. In addition to the need for men with a sound theoretical training, there is also a need for men with experience, particularly experience of a practical and field nature. The lack of such experience, particularly in senior officials, must lead to a wasteful use of scarce resources. This problem is made the more difficult because this type of experience can only be gained in the course of time and in the world today time is the scarcest resource of all. To some extent a country can offset a limited experience in its own nationals by seeking advice and support from experienced expatriates.

ANIMAL PRODUCTION AND LAND DEVELOPMENT

In many countries, large areas of land are still virtually uninhabited and, as population and food pressures increase, the ordered development of these regions will become of vital importance. However, unless this development is based upon sound and long-term ecological considerations, paying due attention to both the potentialities and the limitations of these areas, there is a very serious danger that the natural resources now contained in unexploited virgin areas will be rapidly frittered away and destroyed.

Much of the land now undeveloped cannot be used for animal production until its water resources have been developed. However, experience has repeatedly shown that water development without land reform, grazing control and co-operation from live-stock producers leads rapidly to the destruction of grass cover by serious overgrazing, bush encroachment and soil erosion. The damage that can be done in five or ten years may take many decades to repair. Water development programmes should be reviewed most critically and should never be operated unless the enlightened co-operation and self-discipline of live-stock producers, backed by an appropriate system of land tenure, can be guaranteed. Unfortunately, the arid and semi-arid pastoral areas in which water is most needed are those in which, generally speaking, the people are least inclined to co-operate in measures of land reform and better range management.

Enormous areas of Africa are largely uninhabited and, although many are of high ranching potential, they remain ungrazed by domestic live-stock because they are infested with tsetse flies (*Glossina* species), which carry both human and animal trypanosomiasis. For example, approximately two-thirds of Tanzania is tsetse infested. Sufficient is known of the biology of the tsetse fly to make control methods and major reclamation schemes possible and successful examples of these are to be found in several countries. These schemes depend on careful survey, planning and execution. There are a number of different methods of attack and fly eradication frequently depends on a careful moulding together of these measures. The elimination of tsetse fly must be followed by controlled maintenance of open tsetse free ranges, the upkeep of which may entail periodic operations of bush control, or the use of insecticide, which can be a heavy recurrent economic burden, particularly in areas where the ultimate land-use is comparatively unproductive. Although any general policy of tsetse control involving the indiscriminate slaughter of wildlife and the complete removal of all trees and shrubs should be strongly opposed, there are certain critical but limited localities where extreme measures need to be taken in order to prevent the spread of fly to areas which at present are fly-free and where people and live-stock are thriving. Where special barriers of this sort are needed, it is essential that an intensive settlement of the cleared areas takes place immediately.

In some countries tsetse barriers have been, and still are being, created at great expense without there being any such plan for the intensive use of the newly cleared land. Too often the regrowth is so rapid, in the absence of some form of intensive settlement, that within five to seven years the regenerated bush once again forms an ideal habitat for the flies.

Some West African breeds of cattle (e.g., N'Dama and Baoulé) are grazed successfully in tsetse-infested areas in the savannahs of the Congo (Brazzaville), the Central African Republic and the Ivory Coast. It may be profitable to extend the use of these breeds into other areas, and the physiological peculiarities which confer on these breeds a degree of tolerance or resistance to trypanosomes should certainly be investigated.

The problems of water development and tsetse-fly control illustrate a general principle of the first importance. Any plan for the development or extension of agriculture, live-stock production or wildlife management in areas which at the present time are in their virgin state should be most carefully planned and controlled. Detailed land-use surveys should always prelude such development and the results of such surveys should form the basis of subsequent development plans. At present there are, in most countries, several authorities and organizations competing with one another for land. Too often an area is committed for use as, say, a game park or a cattle ranch, without sufficiently considering the long-term ecological interests or the opportunity costs.

So important is it to ensure that all the various forms of land development which are now going forward should be co-ordinated in sound national programmes of land-use, based on long-term ecological as well as economic considerations, that all governments are urged to consider establishing their own Land-Use Authority or Commission. It is important that such a commission should have strong powers and for this reason it should give advice direct to the Central Development and Planning Committees of cabinets. It should certainly not be set up within a single ministry for it should have overriding powers in determining the land claims put forward by ministries. Without an investigation by, and the approval of, such a Land-Use Commission it should be impossible to demarcate new areas for specific purposes such as tsetse barriers, game parks or reserves, cattle ranches, cash crop plantations, forests, etc.

Plans for the development of live-stock production in virgin areas must also pay due regard to the need for: (a) a rational system of land tenure and, if appropriate, land enclosure; and (b) an economically sound demarcation of property size and an adequate system of communications and marketing. Having satisfied these conditions, the subsequent progress in increasing animal production can be comparatively rapid, since no time and effort need be spent in modifying established customs and attitudes, particularly those relating to land tenure and stock. However, it is still necessary to inculcate good management practices into new settlers. Finally, until carefully organized plans have been prepared for the settlement of new areas, the unoccupied lands must be protected from unplanned encroachment, infiltration and exploitation.

EFFECTIVE WILDLIFE MANAGEMENT

LARGE HERBIVORE MANAGEMENT

Prominent among the most valuable of the world's natural resources is its varied population of wild mammals, most of which are herbivores. Although diminishing at an alarming rate, this population is still extremely large in some areas. It has been estimated, for example, that the total weight of large mammals on the *Acacia* savannahs of East and Central Africa often varies between about 575 to 1,050 kg per hectare while in the *Acacia commiphora* bushlands there are often some 470 kg of large herbivores per hectare.

Only rarely are similar weights approached by concentrations of domestic live-stock. One of the most important of the many reasons for endeavouring to conserve such large mammal populations is that they represent vast potential revenue earners and sources of food for the local populations. At the moment this potential is being realized to a far from complete extent in terms of tourism, legal and illegal hunting, and a small amount of game cropping.

Efforts to exploit, and at the same time to conserve, the enormously valuable food source represented in wildlife are needed as urgently as the efforts which are now being made to develop further the scope and efficiency of the domestic live-stock industries. If the full potential of wildlife outside national parks and game reserves as a source of revenue and food could be realized, the most obvious and cogent reason for general animal conservation would have been established. Moreover, the need for conservation would have been demonstrated in the manner most likely to convince local politicians and the population as a whole. Until people see that the conservation of wildlife is in their own material interests, their extensive co-operation is unlikely to be forthcoming and the continued elimination of wildlife species is likely to continue.

There are three main ways in which it is possible to manage large herbivores for the production of meat and saleable by-products such as skins, horn and bone-meal.

First, there is 'game culling', which is the selective reduction of wild populations mainly in national parks but also in other wild areas. In national parks and reserves, the primary motive in culling is not meat production but the control of animal numbers in order to preserve, as far as possible, a balanced equilibrium between animals and plants of various species. If some degree of culling is not carried out, the population of a particular animal species may grow to the point at which a marked modification of the habitat occurs, or at which there is an accelerated plant-animal succession, which may be to the detriment of the particular animal species concerned. Examples of this are to be found in the culling of hippopotamus and elephant in East and Central Africa. Such schemes often produce large quantities of meat for the local population, as well as trophies which earn a considerable income. At present, however, the meat potential of culling schemes is seldom fully realized, mainly because of the technical problems associated with processing and marketing of the products.

'Game ranching' is a system of wildlife management outside the national parks in which wild animals, usually plains game, are encouraged to graze in an area operated as a commercial ranching enterprise. These areas are sometimes, but not necessarily, fenced, at least round the boundary, and are normally in localities with a mean annual rainfall of less than 25 inches characterized by bush savannah vegetation. The game animals are in no sense tame or domesticated, although they may graze in association with herds of domestic stock.

'Game farming' generally involves the domestication or semi-domestication of the species involved. In these circumstances the animals, usually the less temperamental gazelles or buck, are grazed in fenced paddocks and may even receive a limited measure of supplementary feeding. The domesticated elands in Rhodesia are herded with cattle or, if separated from cattle, are turned into a kraal at night.

All three forms of utilization are potentially important, although in most circumstances the culling and ranching techniques hold out most hope of success.

Workers in East and Central Africa have proposed several important reasons why the ranching of wild animals should be encouraged. They include the following:

1. Game animals are physiologically and ecologically better adapted to the rangelands of Africa than are domestic stock and their production of meat per acre is greater.
2. They do not damage their habitats, e.g., through erosion and bush encroachment, as quickly or as markedly as do cattle, sheep and goats, and land utilized by game is less susceptible to drought.

3. Game can safely be maintained in tsetse areas, thus opening up new tracts of land for the good of man.
4. Game ranching requires less development and operating capital than does the ranching of domestic stock.
5. Game meat is palatable and nutritious.
6. Game animals are less susceptible, or even completely resistant, to some diseases that affect cattle and, under well-managed game ranching schemes, the game-to-cattle disease transmission hazards can be minimized.
7. In marginal areas the inclusion of game utilization can convert an uneconomic cattle ranch into a profitable enterprise.
8. Game can provide sport for the landholder and a visiting clientèle.
9. The provision of game with a further important niche in the economy of the country will contribute to their preservation.

Although some evidence exists to substantiate each of these claims, much of it is circumstantial or small in quantity. That is why it often fails to convince those who are predisposed to the view that cattle, sheep and goat husbandry provide the most productive and economic forms of rangeland use.

Those who advocate the rapid extension of the live-stock industries can base their case on an extensive and factual knowledge of the problems and methods of domestic animal husbandry and rangeland management. The results of many years of intensive research are already available and well-based advice on land-use systems can be given. Moreover, a wide understanding of the problems of disease control in domestic stock is already available and techniques for the hygienic and economic marketing, slaughter, processing and retailing of meat are widely practised.

By comparison with the state of knowledge and development in the field of wildlife utilization, the domestic live-stock position is most favourable. There is now an urgent need to collect a great deal of similar information regarding the problems of wildlife management and the techniques for harvesting, processing and marketing game products. This information must be obtained before it will be possible to exploit fully and on a sustained yield basis the vast meat potential of the wildlife resource or to show whether in certain areas, this type of production and land-use is preferable to domestic live-stock husbandry.

It has been claimed that game animals are nutritionally and reproductively more efficient than cattle or sheep. In view of the limited nature of the evidence, such broad conclusions require qualification. Evidence also exists to show that under some conditions wild ungulates make less efficient use of available feed than do cattle or sheep. Similarly, claims cannot confidently be made concerning the comparative reproductive efficiencies of domestic and wild stock until studies have been carried out involving both classes of animal simultaneously under the same environmental conditions. It would be wrong, on existing evidence, to form any conclusion other than that there is a great and urgent need for further detailed and reliable information on the comparative physiological efficiencies of wild and domesticated animals. In any case, clear distinction has to be made between the various ecological zones.

While there is good evidence to show that in some situations wild animals can yield a higher biomass per unit of area than domestic stock (although the techniques for estimating biomass are notoriously uncertain and, in any case, the results should not be taken to mean the same as the sustained production of meat), it is wrong to imply that game animals can inevitably be relied upon to maintain or improve their habitats, while well-managed domestic stock inevitably destroy theirs.

There is evidence that wild animals are resistant or immune to some diseases that affect domestic live-stock. Moreover, although it is commonly alleged that wild ungulates act as reservoirs of disease which they spread when travelling over large distances, it has been suggested that these suspicions are not well founded. On the other hand, serious outbreaks of disease among wild animals, for example tuberculosis in buffalo and lechwe and rinderpest in wildebeest, are well documented. This is another field in which further critical research is an urgent necessity.

One of the few points on which all observers are unanimous is that game meat usually has much less fat than does beef or mutton, a feature which makes it particularly suited to the present requirements of the canned meat trade. Although the lack of fat is said to result in a less succulent meat than beef, when properly butchered and prepared, most game meats are palatable and tender, and they do not have a strong 'gamey' taste. Also the killing out percentage, or carcass yield, of game animals is often greater than that of cattle. At present, experimental evidence concerning the advantages and disadvantages of using wildlife for meat production and as a revenue earner for the live-stock producer is inadequate in quantity and conflicting in nature. Before a well-based decision can be reached on the long-term productivities of different forms of land-use, with and without wildlife, it is necessary to obtain much more detailed, factual information on the factors involved. The need for this information is urgent; but, at the moment, few scientists and only inadequate facilities and finance are being directed towards producing it. Unless a much larger research effort is made in the immediate future, it might come too late. That is to say, the present rapid expansion of cattle and sheep ranching (involving enclosures, game elimination, vegetation changes, etc.) may rule out for ever the possibility of game ranching in huge areas of the world, even though, at some future date, the biological and economic advantages of wildlife ranching may be shown to be irrefutable. That future work may demonstrate these advantages is indicated by the efforts that are now being made to use large herbivores as meat producers in South, East and Central Africa and Australia. Although often struggling in the face of financial stringency and a limited knowledge of the principles and techniques of wildlife management and utilization, some of these schemes have nevertheless made encouraging progress.

The utilization of wildlife in the Transvaal is a well established and growing concept and has developed along many lines. Some successful ranches use only wild species, others combine cattle ranching with utilization of one or more species of wild mammal, and one combines maize farming with the harvesting of blesbok. For the past two decades animals have been sold alive for restocking purposes and this activity is increasing. Meat is sold fresh, either on the open market or privately. Thus one lesson to be learned from the Transvaal is that there is no single way to utilize game, there are many ways that large mammals have already been utilized on a large scale and integrated with several types of land-use.

From Rhodesia it has been reported that, in 1964, the meat derived from wild animals in addition to that derived from cattle ranching, provided a weekly ration of more than 1 kg of meat for as many as 80,000 people. A total of thirty-three 'game ranches' was in operation and, on fourteen of these estates, game provided a considerable source of additional income. Although permits were issued for the harvesting of 35,776 animals, only 34 per cent of these were in fact used. This low offtake was due to a variety of reasons, including restrictions imposed by disease, but the most important factors were the technical difficulties of harvesting, processing and marketing the meat.

In Australia it is estimated that some 1.5 million marsupial animals (mostly red and grey kangaroos) are harvested annually. Although these animals are shot mainly for the value of their skins, a considerable amount of kangaroo meat is marketed as pet food within Australia and, in recent years, over 4 million kilogrammes of kangaroo meat have been exported annually. This industry is not well controlled and precise statistics do not exist. However, it is thought that the total income of the industry now exceeds $(A)1 million a year. Unlike the wildlife utilization schemes in Africa, however, the slaughter of kangaroos in Australia largely involves the indiscriminate shooting of animals irrespective of their age, sex or species. It has already led to a substantial reduction in the populations of certain species in several localities and, if continued, may result in the extermination of some species in areas where in the past they have flourished in considerable numbers. In any wildlife utilization scheme it is essential that animals should only be harvested on a strictly controlled basis so that sex and age ratios in the surviving population are preserved at a desirable level from the point of view of continued breeding. Clearly the first aim of any utilization scheme must be the continued and long-term conservation of the resource that is being used.

The early attempts to utilize wildlife for meat production have not always achieved a high degree of success because, in many cases, the absence of suitable techniques of harvesting, processing and marketing have proved considerable handicaps. For example, of the 3,000 elephants culled or killed in control operations in Tanzania each year it is probable that the meat of only 5-10 per cent is used for human consumption. Similarly, it has been calculated in Uganda that, although the meat potential from culled game greatly exceeds 2 million kilogrammes per year, only a small proportion is being used at present. The urgent need is therefore stressed for developing sound and economic harvesting, processing and marketing techniques.

The symposium organized by CCTA and IUCN in Tanzania in 1961 to discuss the 'Conservation of Nature and Natural Resources in Modern African States' concluded that: 'Experiments in East, Central and South Africa show that the harvesting of wild animals is feasible and can produce high yields of inexpensive meat. Much work is, however, required in techniques of cropping and processing, and detailed studies are needed on the economics of game utilization, on the disease aspects and on marketing facilities, before such projects can be more generally applied. Many practical difficulties are inherent in cropping, processing and marketing the products of such schemes. The management of wildlife involves a great deal of basic preliminary research.'

Since 1961 the development of wildlife utilization for the production of game meat has advanced. For example, in the Luangwa Valley of Zambia, in 1967, over 300 elephants were successfully harvested, processed and the fresh meat transported and sold with negligible loss.

The urgent need for a broad programme of research into the ecological, sociological and economic problems of wildlife management and utilization was a recurring theme at the International Conference on the Utilization of Wildlife in Developing Countries which was held at Bad Godesberg, Federal Republic of Germany, in 1964. The need was recognized in the following general recommendation which was passed at the conclusion of the conference: 'Increased knowledge of wildlife management is necessary to cope with the new problems with which we are faced. There is an increasing need for research on a broad front. Studies are urgently needed in ecology, economics, sociology, veterinary science, agriculture, forestry and public health as they each relate to wildlife management. Team approach should be encouraged.'

Because the central theme of such work should be concerned with productive management, attention needs to be paid to the habitat requirements of wildlife species, to methods of assessing changes in the plant and animal communities, and to the interactions between management and disease.

The study of disease is also important because it affects the efficiency of meat production from wildlife, the public health aspects of meat marketing, and the disease relations between domestic stock and wildlife. It is necessary to investigate in the field both the incidence of disease in wildlife populations under various systems of management and the epizootiological factors which might govern disease transmission. Complementary laboratory research is also needed into the nature and pathogenecity of specific organisms.

The study of these harvesting, processing and marketing problems must be fully integrated with the related investigations into wildlife management for meat production. The problems of harvesting and processing vary according to the types of wildlife and environment considered (e.g., the problems involved with plains game differ in important respects from those of hippopotamus or elephant). The most promising method of processing appears to be canning but investigations are also needed to examine the feasibility of producing meat extract, dehydrated minced meat and by-products such as blood and bonemeals. In the development of processing techniques it is necessary to use methods which involve low capital and operating costs, and which also involve the highest possible degree of mobility.

The successful development of an inexpensive mobile field abattoir and processing plant capable of dealing with game meat would also be of great value for processing certain domestic live-stock. In periods of drought, for example, it is often desirable to provide a temporary market for live-stock which are too old or emaciated to trek along a stock route and which are too poor in quality to find a place in normal meat markets. Such animals can only be used if a field abattoir is available.

It is equally essential that the marketing of game products and by-products should be explored and developed. It is probable that the best market potential for most products, other than trophies and skins, lies within the areas of origin; but it is important to examine the possibilities that may exist overseas for game products such as skins, ivory, meat extract and canned meat.

Many observers have suggested that it would be possible, and might be advantageous to domesticate certain species of wild animals for ranching purposes.

Although individual animals of many species have been tamed and raised as pets or might be suitable for domestication, the eland is one of the few that has been tamed and studied by the normal methods of animal husbandry and this only on a small scale. Although the evidence is limited, it does indicate that the eland grows rapidly, produces high milk yields, has a low water requirement, and is amenable to routine handling. In addition to studies carried out in Rhodesia, the possibilities of 'farming' eland are being explored in Karamoja and there are small 'tame' eland herds in Tanzania. Domesticated herds of eland have been used in the Soviet Union since the beginning of this century, where good results have also been obtained with the domestication of deer (*Cervus nippon* and *Cervus elaphus*). While eland and deer seem to be the most promising species to use in a domestication programme, the possibilities of using other herbivorous animals (such as zebra, buffalo, oryx, and some of the smaller gazelles) should also be investigated.

The possibility of using wild animals in hybridization with domestic animals to raise better strains of the latter also deserves to be explored. For example, not long ago a new race of sheep called 'arharomerinos', well adapted to conditions in the Tian-Shan mountains (U.S.S.R.) was raised as a result of the hybridization of wild mountain sheep, 'arhar', and domestic sheep, 'merinos'. Interesting experiments are being made in the highlands of Peru to breed hybrids between vicuña and alpaca for increased high-quality wool production.

In order to make further progress in domestication, large-scale experimental investigations need to be undertaken. Enthusiastic individuals working on a hand-to-mouth, temporary basis have domesticated small herds of eland and, in some cases, they have also 'tamed' individual buffalo, zebra, gazelle, etc. What is now needed are detailed investigations under ranching conditions in which the possibilities of running herds of semi-domesticated game both alone and in association with cattle or sheep can be studied.

COMMERCIAL OR SPORT HUNTING IN WILD AREAS AND HUNTING BY LOCAL POPULATIONS

The management of wild mammals either for sport hunting or as an integral part of tribal life is, to some extent, more complicated than the management of domestic or half-domestic animals. Unlimited hunting can completely exterminate some species of high commercial value, for example, the sea cow in Kamschatka waters, or decrease sharply the number of some animals (e.g., beavers and sables in the Soviet Union at the beginning of the twentieth century).

Commercial and sport hunting

Rational exploitation of wild animals must be based on the knowledge of ecological habits of the species involved; their feeding, reproduction, age and sex-ratios, dynamics and so on. Cropping must be organized under the direction of specialists who have acquired sufficient knowledge to control rational use of these resources. This implies the determination of an acceptable level of hunting. The rate should be different whenever there are different speeds of reproduction and different structures of the utilized part of the population. A short life-cycle and a high speed of reproduction imply a higher rate of withdrawal than for types with a long life-cycle, a complex age structure of populations and a low speed of reproduction.

It is also evident that the rate of acceptable withdrawal will vary from year to year, depending on the different state of the population. The management of reproduction is an important method of increasing the productivity of the population of living organisms.

Genetic studies and, in particular, studies of age genetics are very important in this respect. By systematic selection, the productivity can also be increased within the natural population. The decrease of natural mortality is an important way of increasing the productivity of a useful population. In this connexion, however, the regulation of predators should be looked at with the greatest care so that the natural interactions within the ecosystem are not unduly disturbed. For example, by liquidating the predators so as to protect a useful type of animal, it is essential not to liquidate at the same time the predators of the natural competitors of the animals to be protected, since otherwise this will result in less food supply for the population and ultimately a possible decrease in productivity.

Hunting by local population

Here the situation is much more difficult to control. For instance, in West Africa and in many parts of tropical Latin America, the various systems of game utilization are an integral part of tribal or community life.

In some countries, such as Ghana, over 80 per cent of the protein consumed was in the form of wildlife. A well developed traditional system involving hunters, meat processers, transport, etc., has developed. In fact, the traditional and widespread customs could certainly be improved and put on a management basis to ensure the survival of the stock on which the local populations depend.

In tropical America, which lacks the large variety of savannah ungulates of Africa, several forest species appear to have a high potential for commercial food production. Prominent among these are the representatives of the genera *Hydrochoerus*, *Cuniculus*, *Dasyprocta*, *Dasypus*, *Tapirus* and *Tagassu*, all of which are at present hunted for meat and are important components of the diet of local dwellers. Recently some canning enterprise began commercial activities in Eastern Columbia, using *Hydrochoerus*, a large rodent, which in a similar fashion to African game, is accused by local ranchers of competing with cattle for grass and is often killed. Their numbers have already reached low levels in many regions. It is obvious that, while hunting by the local population to supply their own needs does not necessarily affect the number of wild animals, this situation changes immediately when commercial exploitation without proper management becomes effective.

CONCLUSIONS

During the next twenty years it can be anticipated that, with modern techniques of production and marketing, domestic live-stock are going to utilize an increasing proportion of the world's rangelands. The present development plans of many countries make provision for extensive schemes of land enclosure, tsetse clearance, water development, tick control and improved stock routes and marketing systems. More and more large ranches owned by development corporations, co-operatives or individuals are being developed and more are planned for the future. All such developments are bound to have serious effects on wild animal populations, particularly the plains game, which are concentrated in these areas at present, and there is an increasingly serious risk that many wild species will be exterminated or (at best) be confined to national parks.

ANNEX I. Characteristics and requirements of stages in live-stock production

Characteristics	Main improvements and research needed in connexion with habitat, animals and economic and social framework	Institutional measures required
	STAGE A	
Nomadic or semi-nomadic pastoralists whose economy is based on live-stock. Shifting agriculturalists. Land held by communities according to tradition. Poor educational standards and low level of political understanding. Generally unco-operative with government. Although may be potentially wealthy, the present living standards are low and seldom above sub-sistence. Herds moving according to an annual cycle regulated by rainfall and river floods which influence fodder and water resources supply.	Soil conservation measures. Control of epizootic disease. Specific measures to improve efficiency of animal production (e.g., grazing schemes, de-stocking cam-paigns) unlikely to succeed. General education. Prevention of stock theft. Appreciation of monetary values and the cultivation of an appetite for consumer goods and more varied diet.	Schools and adult education facilities. Strong administration, police services, etc. Improved shops and demonstration units to publicize better nutrition, housing, child-care and animal production. Construc-tive political propagandists. Strict veter-inary control. Efficient marketing organiza-tion with adequate stock routes and quarantine grounds.
	STAGE B	
Settled communities who have a system of land tenure involving registration and legally recognized holdings on an individual or co-operative basis. An economy based on money in which live-stock are a recognized income earner. Quality in live-stock appreciated as a factor of economic importance. Disease control measures accepted.	Water facilities on each holding. Better grazing schemes to avoid erosion, reduce drought losses and increase off-take. Disease control facilities, e.g., dipping schemes. Opportunity to improve quality of stock by using superior bulls. Adequate and fair marketing system. Prevention of stock theft and illegal movement of animals. Milk distribution and treatment facilities.	Veterinary services collaborating closely with district administration. Bull camps or an artificial insemination service. Soil conservation and water development ser-vices. Farmers' training centres and extension services. Co-operative marketing system for milk, eggs, hides and skins. Credit facilities for capital improvement.

STAGE C

Individual or co-operatively-run farms or ranches which are fenced, watered and serviced by adequate communications. Disease control based on individual animals rather than on herds. A more highly developed marketing organization and co-operatives which assist with production as well as distribution and marketing. No longer entirely dependent on family labour.	Livestock improvement schemes (e.g., performance and progeny testing). Agricultural information of all types, particularly relating to improved husbandry and problems of management. Organization for processing and marketing products overseas as well as at home.	Farmers' training centres and extension services including animal husbandry and farm management. Regional research and demonstration units. Agricultural societies and clubs, shows, etc. Better credit organizations. Marketing boards.

STAGE D

Modern economic units, well mechanized and with employed labour. Good quality stock, including stud breeding. Close attention to health of individuals and production of high quality.	Advanced information on animal health, breeding and production. Security from stock theft can be critical. Long-term security to attract large-scale investment, often from private or overseas sources.	Research stations and good extension service. Agricultural colleges. Private veterinary services and diagnostic centres. Radio and magazine information on farming.

Preservation of natural areas and ecosystems; protection of rare and endangered species

This paper was prepared on the basis of a draft submitted by Professor Stanley A. Cain (U.S.A.) with comments and additions by Professors Vladimir Sokolov (U.S.S.R.), Frederick Smith (U.S.A.), Kai Curry-Lindahl (Sweden), José Candido de Melo Carvalho (Brazil), Sir O. Frankel (Australia) and Mr. P. Scott (United Kingdom), and the Secretariats of Unesco and FAO.

INTRODUCTION

This agenda item consists of two subjects that are often interrelated in nature and in human programmes. The protection of rare and endangered species usually requires the protection of ecosystems by the preservation of the habitats that the species require.

In consideration of the present subjects, the first need is a clear statement of what is being discussed: natural areas, ecosystems, rare species, endangered species.

NATURAL AREAS

To the general public a natural area is a region in which the impact of man is minimal. The development of hills and valleys, soils and streams, and flora and fauna are due entirely to the processes of nature. Such natural areas as national parks, game refuges, and wilderness tracts are usually cadastral in origin, set aside by society as preserves and hence commonly having artificial boundaries. Other natural areas persist in remote areas, remnants of regions formerly inaccessible to civilization.

To the environmental scientist, however, a natural area not only suffers minimal disturbance from man, but is self-defining on a basis of natural characteristics. That is, a natural area is defined by selected characteristic features of the living world and the physical environment, if the focus of our attention is ecological. If the focus is on the physical environment alone, it is possible to distinguish areas that are natural in terms of climate, soil, geological features, or hydrologic situation, for example. In the frame of reference of a conference on the biosphere, the ecological approach is more pertinent. In any case, we are not concerning ourselves at this point with areas whose characteristics have been formed mainly by human actions, such as cities, man-made lakes, or intensively used agricultural fields, pastures, planted forests, and fishponds.

The word 'area' in the term implies both geographic extent and boundary. And extent and boundary are not arbitrary because the area is defined in terms of naturalness. This does not preclude a natural area having some natural characteristics in common with neighbouring areas, or even some areas that may be widely separated, but a biologically natural area must have some distinguishing natural features, such as the occurrence of certain species or plant-animal communities. An area may be small or large; its actual size is not a defining characteristic. It must, however, have integrity in the sense that it is sufficiently homogeneous throughout. When it fails this, especially by the loss of defining characteristics, it attains boundary. Although the boundary between two adjacent natural areas may be so sharply defined that a man can stand with a foot in each, it is much more common for there to be a zone of transition, more or less broad, usually called an ecotone.

As a matter of fact there is no such thing as a natural area in the sense that an area is distinct in all its natural features from all other areas. Man chooses which of the natural features of an area are distinctive and can be usefully employed in locating the area on the ground, in using the concept of 'area type' for classifying areas, and in the management and use of the natural resources of the area. This selection or abstraction of certain 'diagnostic' characteristics of a natural area from among the nearly endless variety of characteristics is clearly based on human purposes. In this sense, 'naturalness' depends in large part upon what man wishes to do with an area. There is nothing unique about this approach to nature. It is a constant imperative if man is to deal with nature efficiently. It is a step in classification of complex merging phenomena, a process of simplification, that is necessary for comprehension, understanding, management, and use.

A natural area—located somewhere, having extent and boundary—is seldom unique; rather it is one of a series of similar areas which collectively compose a type of natural area, and which may be more or less widely scattered. We do not expect exact comparability among the members of a type any more than we expect perfect homogeneity throughout the area of a single example. Again, man determines the degree of homogeneity required within an area and the amount of similarity required for members of a type. This uncertainty is inescapable and is no great deterrent to the usefulness of such simplified 'pictures' of nature.

These comments reflect the interests of the ecologist and biogeographer. It is evident, in comparison with the layman's view, that many of the reserves set aside by man include several or many natural areas. On the other hand, an ill-chosen reserve may contain too little of any one natural area to preserve the rich variety of species characteristic of the area, or to permit the existence of species such as eagles or elk that require large areas. A reserve is not necessarily a natural area.

ECOSYSTEMS

An ecosystem is an arrangement of life and environment together as an interacting system, the system being the consequence of the interactions—plant with plant, animal with animal, plants and animals with each other, and all living organisms with the environment and the physical environment with them.

The most satisfactorily definable ecosystem is the global one of our world. Even this, however, is an open system with a constant exchange of energy with outer space of indispensable importance, and with some exchange of matter (incoming meteorites and, recently, outgoing space vehicles).

In the global ecosystem we recognize global subsystems: atmosphere, hydrosphere, lithosphere, and the subject of this conference, 'biosphere'. Within the latter, some of us find the concept of noosphere to be intriguing and useful to understand the pervading features of man's intellect, especially in view of the modern worldwide network of communication media.

The features of the global ecosystem that are amenable to scientific study are of interest in themselves—changes in the oxygen– carbon-dioxide percentages in the atmosphere, the nitrogen cycle, world meteorological patterns, ocean circulation, sea-air interface, features of astronomy and geological history, biological evolution, and present-day biogeographic patterns.

On a less than global basis we get closer to units that are comprehensible to the common man—differences between continents and oceans, the Indian Ocean as distinct from Arctic seas, Australia as different from Greenland, Africa from North America. We come to matters more useful for this conference when we focus on the biosphere, not forgetting its interrelations with the rest of nature.

But habitat selectivity of plants and animals is on a finer scale. Although there are some wide-ranging genera, perhaps even species, in each different biome, they are distinguished mainly by their physiognomy, that is, 'how they look'. A forest biome, for example, is subject to subdivision into biologically and environmentally more homogeneous units on such bases as: deciduous or evergreen character, height, number of layers (synusiae), abundance of species, homogeneity, dominance of one or a few species or the absence of dominance. Thus we arrive at the concept of forest type (perhaps forest association, or some other technical term), and a hierarchy of type groups.

It follows that the analytic process referred to can be stepped down to a very small scale with very precisely described parameters for certain ecosystems. It is just as sound to speak of the essentially aquatic micro-ecosystem of a pitcherplant leaf *(Sarracenia)* as of the macro-ecosystem of the biosphere.

On the other hand, whereas we can speak of the ecology of an individual organism or a species population, an ecosystem cannot be applied to an individual organism or a species. The individual is always a participant in an ecosystem and while it has an ecology, it does not have its own ecosystem independently of other living organisms. On the biological side of life and environment it is the community of organized plant-animal groups that is central to the concept of ecosystem.

Recognition of ecosystems as the most basic units of nature (molecular phenomena aside) arose from studies of natural communities—mineral cycling, the transfer of energy along food chains, behavioural phenomena, impacts of life processes on the physical environment, and the reverse. There is nothing philosophic or scientific, however, to prevent the application of the ecosystem concept to situations where man intervenes strongly, not only in agriculture, animal husbandry, forestry, fish and wildlife management, but in his most urbanized and industrialized situations. Man-centred and man-dominated ecosystems are in urgent need of study, understanding, and management if man is not to destroy the fundament upon which he depends for survival.

PRESERVATION OF NATURAL AREAS AND ECOSYSTEMS

We have come to a period of human history when there is a great need for and some recognition of what has been described by various terms, notably 'landscape planning or' 'regional planning'. What is implied is more than land planning, land-use planning, resource-use planning, city planning, park planning, etc., as usually undertaken. It is a multidisciplinary, multiagency, public-private joint planning that can stem only from a recognition of the existence and nature of natural and human ecosystems. Essentially it is 'ecological planning'.

The felt need, such as it is (and it is presently only primordial), has resulted from the failure of traditional single-purpose approaches to human needs and the ability to wrest from nature the resources to meet them. The prevailing single-purpose planning by both public and private enterprises has changed the human condition. It has given some people and some nations affluence, an affluence that all people would like to enjoy. It has produced a new hope for the poor, the disadvantaged, the downtrodden, but it has proven inadequate to meet the needs of humanity, in rich as well as poor countries, in the cities as well as the countryside. What has been called 'the revolution of rising expectations' is not being met in the populous poor countries, and in the rich countries there is being realized the great cost of restoring and then maintaining an environment of quality fit for the human state.

Although the vision may have been glimpsed, it is not a promised land that lies somewhere awaiting human enjoyment—a Utopia or Garden of Eden that could be moved into. It must be created by human effort from the rubble and confusion and inefficiencies that have accumulated from past actions—uses and abuses of the environment, uses and abuses of human powers.

Our present interest in the preservation of natural areas and ecosystems is a proper one, and it can be argued that it is a vital one, but it must be set beside other human needs which must also be met. The difficulties that confront nature preservation include the past lack of restraints that have allowed demand to exceed supply. The scientific method, which lies behind the developments that have given us the modern, technological world has not been applied effectively to man himself nor completely to the use of the land, at least in a large number of countries. There is the ironic and tragic application to medical and public health advances of science-based measures to reduce the human death rate (good in itself) while leaving the birth rate unaffected or tardily affected. There are the failures of land reform, conceived as one measure or another, such as redistribution of land ownership, without realization that to be successful (within the limits of a stabilized demand) it involves social revolution—the adoption and adaptation of land-use technology, especially agricultural, the development of public services that take suitable techniques to the individual land users, the creation of adequate capital for land-use modernization, development of credit and marketing arrangements, etc. But with all of that, land hunger will persist until both sides of the human equation are adequately balanced—demand and supply. Other difficulties lie in the inadequacy of governmental and social institutions for total, integrated planning and management of natural and human ecosystems. Behind this inadequacy lie ideological barriers to such planning.

With attention narrowed to the specific question of preservation of natural areas and ecosystems, there are present opportunities for ecological planning. Nearly every country has some wildlands, and some have vast acreages that have up to now been peripheral to the main areas of human activity, and marginal or sub-marginal in an economic sense. They have been protected by virtue of remoteness, topography or by inaccessibility, or the lack of readily exploited resources such as minerals, forests, and rich agricultural land. It is in such places, often mountainous regions, that the opportunities for national parks, wildlife refuges, and nature preserves still exist.

Other kinds of regions, too, are available. In earlier days human occupancy included regions that were economic for subsistence use, but are not presently economic for modern, industrial farming, live-stock raising, lumbering. These areas (from which people are migrating to cities in search of work) offer opportunity for public use and for nature's healing powers for the landscape. Here, too, parks and wildlife refuges can be established as well as perhaps small natural areas for the preservation of ecosystems and rare and endangered species. But not only should untouched, remote or abandoned regions be considered. In fact there is always some way of co-operating with the 'living' landscape to achieve some of the goals outlined, even in urban and suburban areas.

Although there are some who reason ethically that every species has a 'natural right' to survive, man's interest in the preservation of natural areas and ecosystems is generally egocentric. We are approaching the centenary of the national park concept which combines the idea of preservation of nature with that of human enjoyment of nature. And this idea has spread around the world and is currently more active than ever. Here is the great opportunity of present times. For its full realization, the purists must not insist on preservation alone. Neither can it be expected that the pattern established in any one country must or can be adopted by others. Each national park system, if it is to grow beyond token status, must be developed out of physical conditions of the country and be compatible with the historical and cultural characteristics of the people. The urge for and the desirability of nature preservation must be tempered by practical realities.

Having said all of that, it remains, however, that each nation in its development and use of parks and related areas must plan so as to give maximum protection to representative or unique stands of the natural ecosystems and to rare and endangered species. Taking a regional approach, with the joint planning of agencies of all levels of government, and with the participation (even the regulation) of private enterprise in and around a park, it is possible to accomplish highly desirable preservation of nature. Admittedly, it will be difficult to enforce such a policy; because of human population pressures, new resource-use developments, and higher land prices resulting from competing uses, it is becoming more difficult each year to establish new parks and related areas. This being the case, it is important that research be undertaken to reveal the values of an area, to determine appropriate boundaries, to help devise management procedures, and to enhance visitor pleasure through information services.

The natural and the social sciences, and all of the technologies derived from them, need to be brought into co-operative participation for planning, policy formulation, management and use of parks and related areas. What is newest in this is the formation of multidisciplinary, multiagency, approaches to a complex problem, and the design of social machinery (institutions) that will permit such teams to function. Tinkering with the complex ecosystems as we have in the past, without realizing that they are in fact 'systems', can no longer be warranted. We are now learning the cost of unco-ordinated actions. We need to repair the biosphere, to the extent that we can, and act in harmony with it, as, in the long run, we must.

Particularly critical is the need to learn from past mistakes when it comes to 'ecological planning' of the developing countries. Since development is intimately linked with human aspirations, the selection of development projects as to areas and scope should meet the long-term objectives involved through ecological planning.

PROTECTION OF RARE AND ENDANGERED SPECIES

Before analysing policies or techniques that would lead to protection, it is necessary to provide answers to three questions: (a) Why do plant and animal species become rare and threatened with extinction? (b) When we recognize species in this condition, what can we do about it? (c) Why bother to do anything about it?

As to the first question, we need to make certain distinctions to help clarify our thinking about the problem. Some species are 'rare' in the sense that they may occur over a wide geographic territory yet are scarce, sometimes extremely so, in any local area. There is usually no real knowledge of population numbers. Such species give a false impression of their rarity. They are probably species of narrow ecological amplitude with rigid and limited requirements of microhabitat, including microclimate and substratum. When the appropriate habitats are small and scattered, the occurrence of the species is inevitably 'rare'. Without substantiating data, there is no reason to conclude that they are 'endangered'.

Some species that have circumscribed areas of occurrence and small populations are relics of earlier widespread and large populations; others may be 'new species', not having had time to develop wide areas and large populations. In both cases survival may be unsure, irrespective of human actions.

We need also to consider the case of peripheral or disjunct populations of species that elsewhere may have large and apparently secure populations. In the present main range such species are certainly not endangered, but their small populations, separated from the main range, may be threatened with extinction. Such a situation presents two questions. Firstly, do the populations belong to the same taxon? In other words, are we talking about a species, or two subspecies, a species population and a race, or what? Does it matter? This brings us to the second question: Should we have the same concern for a small peripheral or disjunct population when there is a massive occurence elsewhere as we have for a species that in the entire world is known only from a small and endangered population? The latter question deserves further consideration.

Concern for the preservation of the small population of the Asiatic lion of the Gir forest and efforts to save it from extinction are at least as great as for the great Indian rhinoceros, although the lion has a wide and apparently safe population in Africa whereas the great Indian rhinoceros is circumscribed to Nepal and its neighbourhood. However, it may be argued that such discontinuous distribution offers a considerable interest because there may be new species or subspecies in *status nascendi* and therefore of evolutionary significance and importance. Iberian disjuncts are as zealously guarded in Great Britain as though they did not exist in relative abundance in the Eastern Mediterranean. The same is true for Cis-Atlantic species that are rare on one side of the ocean and abundant on the other. For those of us who are concerned for the preservation of rare and endangered species, this is a 'non-problem'. There is a justifiable provincialism in this position, however. What matters is that the entity is rare and endangered where we live, and we would hate to see it extirpated no matter the situation on another continent.

With these preliminaries out of the way, let us return specifically to the first question: Why do plant and animal species become rare and threatened with extinction? There are two classes of causes: the processes of nature and the actions of man.

Species extinction is an age-old phenomenon that must have started with the first forms of life. Natural geologic, climatic, and biologic processes have brought about the extinction of more species than are now extant. And given a geologic time-scale, other species will become extinct despite man's concern and efforts.

In a real sense, the separation of natural processes as geologic, climatic, pedologic, and biologic is an abstraction from nature. It is becoming clear that these are interacting subsystems of a global ecosystem, changing continuously with time. The continued existence of each species depends upon a continued balance of gains versus losses in successive generations, a balance that can be maintained only if new adaptations evolve for each new situation. When the rate of change of the environment exceeds the evolutionary capacity of the species, extinction follows. Thus, continental glaciation, mountain formation, peneplanation, and coastal elevation or subsidence are possible causes of extinction. An event as sudden as an avalanche could destroy the entire colony of a species on a cliff or talus slope, although such a species, confined to a single site, was already leading a precarious existence. Biological causes of extinction may appear when two different assemblages of organisms, formerly separated geographically, come together. New stresses from competition, predation and disease may develop rapidly, squeezing many species out of existence.

More remarkable than extinction is the fact of survival. Every organism alive today represents a line of descent that has never been broken since the dawn of life. Despite vast changes in climate and geology through half a billion years, life has survived and diversified. Thus, the amount of change is not itself a cause of extinction. Given enough time, the processes of evolution appear able to solve almost any problem. It is evident from the survival of life that, until now, enough time has always been available somewhere in the biosphere. It is also evident from the record of extinction that time is frequently lacking. Thus, the continued existence of any one species is a fragile possession.

Turning our attention to man's actions that threaten or actually bring about the extinction of species, locally or absolutely, we can note first that many of his actions accelerate or duplicate natural processes. This is easy to illustrate by reference to human modifications of hydrologic conditions. Impounding a stream, changing it from fast-flowing 'white water' to deep still water, changes one ecosystem to an entirely different one. The opposite physical change, drainage of lakes and marshes, can destroy the habitats that are necessary for critical populations. In arid and semi-arid regions the over-pumping of water from aquifers for irrigation of crops can lower the water table and affect springs and seepage areas, possibly some distance from the withdrawal area. The hydrologic régime of an area can be changed otherwise: by deforestation, overgrazing grasslands, conversion to cropland, and various constructions, dredging and filling.

Man can bring about the extinction of rare species in other ways that affect the quality of the environment for one or another species. Pollution can speed up the natural eutrophication of a lake, making it untenable for certain species that have no means of escape by migration to favourable waters. Some pollutants may act directly, as in the case of heavy dosages of pesticides, not only on the target species but on others as well because most of the pesticides go into the environment, pass into food chains and result in the death of innocent bystanders. Then there are discharges of industrial wastes such as oils, acids, phenols, toxic metals—some accidental and others as a matter of practice on the false assumption of the capacity of the environment—water, soil, and air—to absorb such materials. In general, we have no idea of the total number of species that have been exterminated by such relatively rapid changes in the environment caused by human acts, for our attention has been given largely to mammals and birds of interest to the sportsman, and to songbirds.

Many recorded extinctions, possibly a majority of them, are attributable to man-caused vegetational changes—destruction of original forests, either completely or reduction to small and isolated patches providing inadequate territory for survival, ploughing large areas of grasslands, draining swamps and marshes. Moreover man as a predator has demonstrated a greater ability to annihilate a species than any other animal—lion, tiger, bear, wolf, eagle, hawk, owl—by his use of gun, trap, and poison. Primitive man did not have this ability. In the Peruvian selva today, it is said that native fish and wildlife make up to 85 per cent of the protein in the human diet, but this threatens no species. Although sportsmen in large numbers can over-shoot game animals and when a species is already near extinction exterminate it, it seems that the principal threat is entirely otherwise. It is the commercialization of wildlife species. This can be market hunting for food, an entirely different matter from subsistence hunting. Or it can be market hunting for a valued product—feathers, hide, fur, horn and ivory, oil, and the like. When the price is right, there are men who will hunt down and kill the last member of a species. At the present time, largely because of the vagaries of fashion, alligator hides for shoes and handbags and the skins of spotted cats, 'fun furs' for the wealthy, are bringing prices that encourage hunters and poachers on parks and wildlife reserves to kill the last animals, while the demands of medical and pharmacological research threaten rare species of primates. This brings the discussion to the second question: When we recognize that species are becoming very rare and endangered, what can we do about it?

We can turn to laws and administrative regulations designed to afford protection to vanishing species. However well drawn in a legal sense, laws and regulations are no more than tools for enforcement protection. Laws can have a national basis, applying to all parts of a nation. In some countries protective wildlife legislation is the prerogative of states, provinces, or departments. And for resident species they may vary considerably from one part of a nation to another. In such cases the nation may seek effective action by controlling interstate transport and commerce. Migratory species cannot be protected unless there are comparable laws in adjoining states, or in some cases without treaty agreements between nations.

Several species threatened with extinction are native to countries without effective protective legislation or enforcement. The valuable animals or their products are commonly marketed elsewhere. When this is true, there can be recourse to export restrictions by the market countries. Effective enforcement is difficult. Shippers can route their cargoes through intermediate countries. The importing country's laws may forbid import of species that are protected in the countries of origin and be unable to act because an intermediate country is without protective laws. Another dodge is that of mislabelling the cargo, which puts a difficult problem of identification on customs officers. A large country may have several dozen ports of entry. The problem of verifying the accuracy of labelling can be reduced by limiting the ports of entry for particular products, enabling a small, competent staff to make the necessary identifications.

As in the case of poaching, when profits are great, law enforcement is difficult. Penalties need to be high and courts informed and determined. The law needs to be reinforced by public opinion that influences the customer and reduces the demand.

Laws are necessary, but by themselves they are wholly inadequate to save an endangered species. The first requisite for survival, for survival of any living organism, is an appropriate and adequate habitat. As was said earlier, environments change because of natural processes, most of which are effective only through long periods of time. Our concern must be directed to the accelerating changes that result from man's actions. Since human survival is also at stake, we cannot be against the utilization of the forest for its indispensable products, the conversion of fertile land to the crops that feed us, or the useful development of water and other natural resources. What is needed at the present time are forms of ecological planning and landscape management that take into account all of the human needs and seek to balance them. It is by this route that we can assure ourselves of parks and related areas, wildlife refuges and game ranges, swamps and free-flowing streams, and other areas free from destructive developments that will provide the necessary habitats for rare and endangered species.

Planned use of the environment has not been one of man's usual activities. Restraint in harvesting the wealth of natural resources is difficult for those of us, individuals and nations, who see a resultant profit in maximum harvesting. Neither do we tend to show restraint in the demands on nature that we produce by unlimited growth of the human population and, for the richer among us, the proclivity to consume prodigiously. Typically, we react late, when a species is already on the brink of extinction, when all but the last of the primeval landscape has been changed beyond retrieval, or when the quality of the environment has been reduced to an intolerable level, as in the case of extreme pollution.

There are cases for which species on the brink of extinction have been rescued, or so it seems now. The nene goose of Hawaii is an example. It was systematically and successfully reared on the island of Hawaii and subsequently in Britain and restocked in appropriate Hawaiian range. The whooping crane has benefited from a wintering refuge, while rearing efforts are also under way at Patuxent, an important research centre for wildlife and endangered species, operated by the United States Bureau of Sport, Fisheries and Wildlife. The Alsakan fur seal, once clearly endangered, has recovered a large and healthy population on the Pribilof Islands breeding grounds under decades of management agreed upon by treaty of concerned nations. Such are examples of extreme measures taken one minute before midnight in the life of these species.

Something needs to be said about the need for research. To begin with, there is the question as to what we mean by 'rare' and whether the rarity is real. Many species are extremely difficult to census. Even when census methods are reliable and the sampling coverage is adequate to describe a species population, we usually lack comparative data for different periods of time so that we do not know whether a population is stable or changing. Except for extremely small and circumscribed populations of easily observed species, it takes sophisticated and persistent research to determine the numbers and the life-table data for a species population.

Assuming that a species is rare and endangered, or having proven the case, it is clear that we must have detailed knowledge of the ecological requirements of the species if we are to do something effective to aid its survival. The unfortunate fact is that the world's scientists collectively usually know very little about the biology and ecology of most of the species that are recognized to be rare and endangered. But to study a species, important as it is, is not enough. It is necessary to understand how it fits into the ecosystem of which it is a part. Serious mistakes have been made because of a lack of knowledge of territorial requirements and the interplay between species. For all the vast area of McKinley National Park in Alaska, its boundaries were so drawn as to cut off the ends of caribou and wolf migrational paths, and that Garden of Eden for East African ungulates, Serengeti, has proven to be too small to accommodate the wide-ranging species it was intended to preserve.

When it is intended to establish a new park or wildlife refuge and it is already understood what the purposes are, it is important that an adequate ecological reconnaissance be made before boundaries are set so that the landscape unit will be a rational one.

The last question posed: Why bother to do anything about rare and endangered species?, seems scarcely necessary for Unesco's Biosphere Conference. We can at least recognize that arguments for preservation of nature fall into a limited number of categories. There are the economic justifications that are based largely on tourism, not just the expenditures at given sites but the widespread business activities associated with travel to parks, refuges and places where rare and interesting plants and animals can be seen. There are also other important values: protein potential for food production under a scientific cropping system may fit well into proper management systems. The lack of maintenance of habitat and ecological balance can be devastating.

The diversity of living organisms, which has developed by now in the course of long evolution, constitutes one of the most important conditions of the biospheric stability in time. In nature, living organisms are in constant interaction with each other, both within a single population and within ecosystems. The impoverishment of ecosystems both in the number of individuals and in the number of species results in the reduction of their stability in time and in the laxity of their biogeochemical activity.

Scientists have powerful reasons for preservation of nature that are related to the desire and need to understand and to improve the world about us. Many arguments support this attitude. Natural areas must be preserved because they provide the materials for breeding of better domesticated species, the search for chemicals useful against weeds and animal pests, and the search for drugs of medicinal use. The first is critical. Every now and then a new disease appears that attacks wheat, or rice, or cattle, etc. One of the best countermeasures is the breeding of a strain resistant to the new pathogen. In almost every case, this involves a return to the native or wild representatives of the species, where the natural wide spectrum of variability offers the best chance of finding appropriate adaptations. These wild strains cannot be preserved in a garden, because they will rapidly lose their variability under any form of care. They must be maintained in a natural system, complete with all of the hazards and uncertainties of a feral existence.

In order to preserve the genofund of the planet it is absolutely necessary to conserve not only the individuals of a certain species, but the population of species—the latter being of particular importance. It has been proved that the value of each gene is not only defined by its own properties, but by the community of individuals, i.e., by the population in which a free exchange of genes is realized. Because of this, international and national legislation on the conservation of species and populations of organisms, and the establishment of a network of considerably large reservations are very important prerequisites for the conservation of the genofund of populations from extinction and degeneration.

The search for chemicals and medicinal drugs among the millions of species of plants and animals has been well publicized, and does not need elaboration here. If representative ecosystems of all kinds are not preserved, who knows what substance superior to pyrethrum or penicillin will vanish, undiscovered, from the earth. It goes also without saying that all these arguments involve very effective and irreplaceable educational values.

Finally, a very important part of the public interest in conservation is motivated by aesthetic appreciation and ethical beliefs. Because man today has been endowed with this power of modifying and controlling the biosphere, it is only fair that he develops a proportional feeling for transmitting this heritage, within the limit of his possibilities through preservation of adequate samples which will foresee the economic and aesthetic demands of future generations.

Problems of deterioration of the environment

This paper was prepared on the basis of a draft entrusted to the World Health Organization and prepared by Dr. Abel Wolman (U.S.A.), with the specific contributions on air pollution by Professor L. T. Friberg (Sweden) and on soil pollution by Professor H. Shuval (Israel) and with comments and additions by the Secretariats of Unesco and FAO.

The late twentieth century marks the advent of a series of social changes quite unlike those of any previous time in history. The mass movement of people to the urban areas, the rapid evolution of industry and the accelerated rate of population growth are all characteristic of this period throughout the globe. Several world wars added to the complexities of environmental difficulties in that they diverted vast sums of money and great numbers of people from the peaceful pursuits of environmental adjustments. The lag in correctives resulting from these varied social phenomena dramatize the situation in which we now find ourselves.

The deterioration of the quality of the environment may be easily explained, if not excused. It should not be equated, however, with doomsday. One must recognize its realities, determine its hazards, evaluate its technical solutions and assign the moneys required to manage the environment rationally. Objectively, all of such necessities and their corrections are within the realm of practicability. Society must determine the rate at which it desires and intends to restore the desired quality to the environment. Such determination implies decisions as to what extent and degree, and in what condition, concentration, time and place potentially polluting wastes may be disposed of in the environment, without adverse effects upon human health, plant life and materials, and with minimum interference with reasonable and beneficial uses of air, water and land resources.

In an assessment of such problems, it is clear that economic development is closely linked with the generation of environmental pollution. It is equally apparent that the impact upon the environment of contaminants is not by discrete quanta of liquid, gaseous and solid wastes, neatly packaged in separate bundles.

The environment is degraded by combinations of physical, chemical and biological materials, acting in general in concert, but of eternally varying character

To this may be added such deteriorations as noise and other phenomena which add to additional stresses. Degradation of aesthetic values is another aspect which has received considerable attention. Because of obvious limitations, only water, air and soil pollution, particularly in connexion with human health, will be considered here.

The combinations of wastes, normally confronting us, all have significant health implications. Some are obvious and direct. Others are subtle, indirect and of long time lag in appearance. Still others are less well understood and perhaps less important. In any event one must view the environment and its degradation as a totality, regardless of the fact that the 'carriers of deterioration' may be liquid, gas or solid.

It is solely because of editorial convenience that the exposition which follows is treated in sections and it should be easy to find the connecting threads between water, air and soil pollutants and their receptors—the total environment.

WATER POLLUTION

NATURE OF PROBLEM

Wherever man lives and works, wastes, human and otherwise, naturally result. Where he lives in isolation and in small groups, the pollution of the adjacent waters may normally be of little significance. In the modern world, urbanization and industrialization have been the characteristics of the last quarter of the century, and the problems of water pollution have become more acute.

Throughout history the effort has been to remove human wastes as promptly and as far as possible from the place of human habitation. When the water carriage system for the transmission and disposal of domestic wastes came into use, this effort was intensified. As a consequence, the pollution of receiving bodies of water markedly increased and continues to do so until conscious efforts are made to treat and to modify these wastes at the point of disposal.

Similarly, the evolution of industrial operations added problems of the disposal of industrial wastes. These wastes have grown in magnitude and in variety, as industrial processes, particularly in the field of chemicals, have become more complex, more diversified, and potentially more dangerous.

The problems of water pollution vary according to geography, level of economic development and density of living. It is evident, therefore, that the issues in water pollution and abatement likewise should show wide global differences, depending upon the above characteristics.

Very early in the history of man, the search for water for survival was gradually paralleled by an equally persistent quest for 'pure' water. To be sure, definitions of purity varied, as users became more sophisticated in epidemiological understanding and in demands. The changes in attitude were slow and covered no small part of some 4,000 years. It is only in the twentieth century that the now familiar desires of the public were evolved. In many countries today 'clean' water for potable use, fish life, recreation, agriculture, industry and water contact sports is a desideratum, if not an accomplished reality. Control agencies, therefore, are confronted with converting degraded waters into those biologically safe, chemically non-toxic, and satisfactory to taste, sight and smell.

In spite of these rising expectations in water pollution abatement, and of real improvements in water quality in many regions, the areas of ignorance, as to how to make progress more rapidly and economically, remain great. They continue to pose challenges to designer, investigator, and manager. Decision making in water pollution control practice is highly complex, shifting in nature of problem, and always sensitively adjusting to a changing economy.

CONSTITUENTS OF WASTES

From the public health standpoint, all domestic wastes are inherently dangerous unless they are subjected to careful and efficient treatment, because they have always carried significant amounts of pathogenic organisms. The most common of these produce a wide array of enteric diseases such as typhoid fever, cholera, the general dysenteries, filariasis and bilharziasis.

In the more developed countries, the last half century has marked the period in which most of these diseases of water-borne nature have been removed by efficient water treatment, by the control of milk and other foods, the careful management of carriers, and the general use of immunization.

In the developing countries, on the other hand, these water-borne diseases still reach a level characteristic of the more favoured Western world of over fifty years ago. The primary reasons for these differences are inherent in the fact that water, when supplied, is too often polluted by human wastes, too frequently without treatment, or with less than efficient removal of dangerous organisms.

In the case of industrial wastes, similar differences occur between the less favoured and the highly developed industrial countries. In the latter, the issues in water pollution are increasingly those of a chemical nature, rather than of bacteria or viruses.

Except for limited areas in countries of low income, industrial wastes of chemical nature, in such countries, are still less significant than the more familiar biological problems of human wastes. As these move with some rapidity towards industrialization, their difficulties will parallel those of the Western world. One may hope that the lessons of corrective action now being learned and applied in the highly industrial areas will be rapidly and preventatively used in the evolving complexes of countries now moving forward.

The increasing impact of water pollution upon the total ecology of the environment is giving more and more concern to many officials. Opportunities for recreation in wide areas have been seriously disturbed in some parts of many countries. In addition, much discussion is under way on the impact of polluting materials in wastes, particularly phosphorus and nitrogen compounds, on the eutrophication of lakes, estuaries and rivers. The scientific understanding of these phenomena is less than satisfactory. Work is now under way in order to isolate more specifically the causes of such biological change, and the contributions thereto by domestic and agricultural wastes. In course of time, corrective measures may be more logically and promptly instituted.

With the advent of nuclear power and the rapidly expanding installations of power facilities using fossil fuels, the consequences of water for cooling purposes have likewise posed difficult questions. For each unit of power produced, nuclear fission plants require almost twice as much cooling waters as do those using fossil fuels.

Debate is now at its height in the industrialized countries as to the significance of these large thermal discharges upon the biological and physical behaviour of receiving bodies of water. The understanding of these phenomena is both limited and unsatisfactory for control purposes.

Radioactive wastes, on the other hand, have been well managed in the countries where they might pose problems. Wastes of low-level radioactivity have been treated and released to the environment with skill and with close monitoring. Those of high-level radioactivity have been reduced in volume, stored for containment, and permanently placed under controlled supervision for the many years during which they must be held for safety. At the present writing, no procedures for ultimate disposal of such high-level wastes are yet available. The fall-out from nuclear bomb testing, not yet under complete international control, still poses unresolved problems.

As countries develop, more sewerage systems and treatment plants appear. The dilemma of matching rate of growth of population with system installation is further compounded by the parallel increase in the *per capita* production of waste water. It is a far cry from the water used by families dependent upon carrying it from a distant source to the amount resulting from the increased availability when it is piped to the house.

As improved standards of living occur, no country, apparently, is immune to the lure of water-using labour-saving devices, such as clothes and dish-washing machines and garbage grinders. The future holds no promise of the disappearance of the necessity of water pollution abatement, even if the rate of population growth were materially reduced.

Not only is the volume of waste water very large, but its content of organic and mineral pollutants is also large. Exclusive of industrial wastes, this amounts to up to 10 litres of wet sludge *per capita* daily, or about 50 kg *per capita* of dry solids annually. These wastes could even result in clogging of river beds and modify infiltration and recharge of ground water. The management of such materials can be successful, but only when the problem is recognized as a fundamental part of pollution abatement.

LEGISLATIVE EFFORTS AT CONTROL

Almost every country in the world has tried to meet the threats of water pollution by means of legislative actions. It has often been presupposed that the passage of a legislative act would automatically result in bringing the situation under control. The results however have been rather distressing throughout the world. It is by no means assumed that the legislative underpinning of administrative action is neither useful nor helpful, but reliance upon law alone is unrealistic. In some instances, in fact, rigid legislative requirements have sometimes served as opiates to administrative action. Unless decisions are accompanied by a strong climate of supporting public opinion, by adequate manpower for implementation and by financial resources, results are normally far from satisfying.

Because of the importance of legislative measures, both national and international, attention has been directed towards this feature of pollution abatement. In recent years, the International Water Supply Association has devoted much time to the legal aspects of this problem. Similarly, the International Law Association, the International Association of Legal Science and the International Institute of Administrative Sciences have concerned themselves with various facets of the same issues.

Where water courses have formed the boundaries of, or have crossed States, agreements, conventions and treaties have been entered into. Significant examples are those between Belgium and France, Bulgaria and Yugoslavia and Switzerland and Italy. The ECE provides a fairly comprehensive list of such agreements in Europe.

Experience in the joint international management of watercourses, including pollution control, is long and sometimes satisfactory. More often, in so far as pollution abatement is concerned, a time lag has occurred in the actions required to maintain an agreed quality acceptable to all parties. Examples of such delayed correctives may appropriately include the international arrangements on the Rhine, Lake Constance, the Great Lakes, and the Rio Grande.

In Europe, where the density of population is usually high and hence pollution abatement continuously necessary, it is probable that persistent efforts will be made to establish at least common criteria and standards of water purity, and the principles of water classification. One might also expect increased discussion on unified methods of planning measures for preserving the purity of waters. All these efforts are unlikely to be matched in the foreseeable future by any international standardization of river quality.

The history of national legislation is replete with declarations of high aspiration unmatched anywhere by equally high implementation. Abatement has not been at a standstill. On the contrary, a great deal has been done, but not enough and not fast enough. The situation has been well summarized by a WHO expert Committee, which pointed out a few years ago that: 'Countries with severe laws against pollution have not in fact avoided the occurrence of widespread pollution. One reason for this may be that laws calling for no pollution at all do not represent a practical policy and therefore fall into disrepute. In a world becoming rapidly urbanized and industrialized, it is not possible to preserve rivers in their natural condition. The law should aim at *controlling* pollution.'

In spite of these clearly defined strictures, countries, large and small under the lash of perfectionists and opportunists, continue to pass acts designed to recapture the pristine purity of nostalgic eras. The record of such legislation is not gratifying. It is available in masterful detail in the recent survey of existing legislation by the World Health Organization entitled *Control of Water Pollution* which was issued in 1967. Another important analytical paper on the same subject has been prepared by FAO in 1968.

ADMINISTRATIVE PRACTICES

Real success in preventing or correcting water pollution lies in no small degree in the intelligence, the skill and the forces provided in administration. In this field of activity, no generalization applicable to every country in the world is possible. Many of the developing countries have assumed that all of these matters of adjustment may be most successfully managed by the central government. Where the countries are small and communications are simple, such an approach can be successful. In many of the larger countries, however, the central government is often remote, geographically and spiritually, from its local constituents. In addition, such central governments are often subject to all of the constraints of money and manpower. Hence, their opportunities for accomplishing the great tasks required are relatively small and weak.

In the more affluent countries, in the last quarter of the century, increasing emphasis has been placed upon the use of central government money grants. These have been intended as stimulants to local matching. This process, however, has already shown itself to be subject to all of the vagaries of government policy and budgetary difficulties. The principle of sustained continuity of effort has not yet been resolved anywhere. This deficiency is due not only to the cyclical changes in the economy of a country, but in many instances to the insufficiency of professional and subprofessional manpower to implement construction and operation of facilities. One of the unfortunate features of the deficiencies of pollution control is the failure to maintain adequately those plants already constructed. It has been estimated that abatement efficiency might be raised as much as 20 per cent if existing plants were operated at the level for which they were initially designed and constructed.

The availability of manpower varies widely, of course, between regions in the world. No country has all the trained personnel theoretically desired, but, as usual, some are more favoured than others. Yet, some, having reasonably adequate resources, make less effective use of them than might be desired. No authentic record of people available for the tasks here discussed is at hand. The classification of 'sanitary engineers' is not characteristic universally, but it does serve as an index of the great variation in availability.

In Central and South America, for example, the number of sanitary engineers averages about one to 30,000 inhabitants. In Africa, on the other hand, it would be one per 300,000 persons, or less. Certainly, increasing urbanization and industrialization demand greater numbers and skills of professional workers, if pollution is to be abated and prevented. In almost all countries the block to progress is not in deficient technology, but in competent personnel and, of course, in money. Reasonable technological solutions are generally at hand, which may be well adapted to local requirements.

CRITERIA OF QUALITY

In recent decades it may be assumed that all people, everywhere, would like to have 'clean water'. In the movement towards abatement, however, every regulatory official is at once confronted with the task of determining more neatly the definition of 'clean water'. For administrative action he needs a tool more concrete than the abstract definition usually provided in legislative acts. The criteria may be the same for all parts of the country, but they may vary according to hydrological differences, according to variations in industrial and urban character, or according to use of the water. Underlying the hopes of the public is usually the assumption that 'clean water' really signifies the absence of any contaminating constituents. Since this would represent an unreal world, either in nature or in artificial adjustment of wastes, permissible values have become essential for intelligent regulation. The universalization of the same limits poses a number of social and economic difficulties.

The record in criteria making is not a very gratifying one, in so far as correctives are concerned. As might be expected, the existence of a rigid ceiling does not inhibit its violation. Every country demonstrates such confrontations in its historic effort to prevent or eliminate water pollution. Each country has striking examples where adjustments in requirements have been conceded to the realities of the situation. This has been the case, primarily because considerations of national economic advantage have transcended the desire for abatement.

Lip-service to the necessity of formulating values varying with time, place and use of waters, invariably gives way to uniformity. This concession comes about from the fact that administrators welcome uniform requirements, which presumably simplify decision making. Such desire inevitably has led either to manifold exceptions, or to frank violations. As has already been pointed out, this sequence of events, illustrated almost everywhere, leads to a general collapse of action or *ad hoc* adjustments to relate reality to abstract policy or desire.

Since standard methods of analyses are internationally available, it is not surprising that criteria are likewise virtually synonymous, at least on paper, throughout the world. The more common parameters in virtually all laws or regulations are dissolved oxygen, biochemical oxygen demand, suspended matter and some form of enteric organisms. The limits for these tend to approximate uniform values for most countries. Classifications of waters vary to a greater degree. Microchemical constituents are noted, as to maximum permissible values, in great detail in some countries. In others, they are more generally restricted to composite figures. In all of these regulatory exercises, the gap between criteria and reality is unfortunately wide. The only hope for keeping ahead of the problem of abatement is to maintain a continuity of high purpose, supported by public acceptance and intention. Only by such difficult and sustained effort are budgetary supports likely to emerge and to persist. One can never ignore the fact that water pollution abatement is only one, though significant, social necessity in daily competition with other requirements of high and pressing importance.

ECONOMIC ISSUES

With the best of intentions, every country, regardless of its political ideology, has found itself in the position of determining whether water quality criteria must be violated periodically in order to proceed rapidly with economic development. Even where strenuous efforts have been made to reconcile these diverse interests, the results have not always been happy.

Countries with limited water resources, and with highly developed industrialization, have inevitably been driven into tailoring the levels of quality to the conditions which have confronted them. Economic development and water pollution abatement of high degree are unfortunately not always immediately compatible. It comes about, therefore, that whether one likes it or not, comparisons of costs and of benefits and of economic and social values, must be taken into account. Since no country is blessed with unlimited money or manpower, calculations are inevitable as to the relative values to society inherent in any pollution abatement decision.

The basis for such decisions are, of course, variable and subject to evolving adjustment, depending upon the economic status and the public desire of each country. Escape from realistic assignment of priorities and of values has not been demonstrated historically in any country, even though the quantitative determinations have usually been fuzzy or highly general in character. As a matter of fact, in too many instances, economic considerations in decision making have been ignored, particularly in the case of industrial wastes. Administrators who have the responsibility for corrective measures have sometimes taken the untenable position that they are not interested in control costs. Inevitably, society cannot escape such interest. Effort is increasingly directed, therefore, toward sharpening the tools of economic determinants in both the areas of domestic and industrial waste management.

In the next few decades, public agencies and industry will spend many tens of billions of dollars, pounds, rupees, pesos, etc., on new, and extension of old water pollution abatement facilities. Their operation and maintenance will require added billions. Can these costs be reduced by improved science and technology? And can social science provide more effective means of disclosing the wisdom and soundness of objectives *vis-à-vis* other requirements or alternatives of society?

Fortunately, inquiries directed towards clarifying such questions are under way in several countries. It is not to be assumed that economic reasoning will resolve all the difficulties. It can, on the other hand, assist in providing some unification of approach to policy making and provide guidelines for pertinent research on tangible and intangible values in pollution abatement. After all, waste disposal is only one aspect of activity in an economy where the allocation of resources to alternative use is accomplished primarily by market processes. The special circumstances surrounding waste disposal are recognized as grounds for public intervention and for the insertion of some politically determined values into the processes of public policy formation. The primary purpose is to conceptualize the pollution problem in a way that helps to identify types of physical, economic and social knowledge that are basic to intelligent policy in the pollution field.

AIR POLLUTION

The term 'air pollutant' is generally used with reference to contamination of the ambient air by substances that are released into the atmosphere as a result of human activities. The term frequently implies that the pollution involves a risk of unfavourable effects on the health or well-being of individuals or of damage to plant life or materials.

As with water pollution, the problem of air pollution has been rendered acute by the industrial revolution, the consequent increase in the production of organic chemicals, the increasing use of fossil fuels, and the rapid adoption of the motor car in recent decades. Another predisposing factor undoubtedly lies in urbanization, with larger and larger numbers of people residing in limited geographical areas.

NATURE AND SOURCES

Air pollutants occur in solid form (e.g., dust or soot particles), as drops (e.g., sulphuric acid mist) or as gases (e.g., sulphur dioxide, oxides of nitrogen and carbon monoxide).

The composition of air pollution varies from place to place. The chief characteristic of so-called London smog is a high content of soot, SO_2 and SO_3. Photochemical smog, of which Los Angeles smog is an example, has an entirely different composition and genesis. NO in exhaust gases is oxidized to NO_2 during the interaction of various hydrocarbons, chiefly olefins. Photochemical reactions lead to the breakdown of NO_2 and ozone is formed through reactions with different organic substances.

Increasingly, high contents of carbon monoxide are present during the rush hour in all major centres in countries where the automobile is more and more in use. Lead is emitted in exhaust gases owing to the increasingly common practice of adding tetraethyl lead to motor fuel.

A wide variety of stack gases may be formed locally by industrial plants, e.g., from chemical factories, smelting plants, slaughter-houses, cellulose factories and cement works. The emission of metals (e.g., iron, mercury and lead), as well as many organic and inorganic compounds often results. Some of these, such as mercaptans, hydrogen sulphide and dimethyl sulphides, are malodorous even at very low concentrations (in the case of hydrogen sulphide, approximately 1 microgramme/m^3).

Air pollution frequently constitutes a local problem, but pollutants may sometimes be transported long distances. In the United States, for instance, air pollutants formed in Texas have been demonstrated more than 1,000 miles away at Cincinnati, Ohio. Scandinavian studies at lighthouses on the south and west coasts of Sweden suggest that air pollutants from Germany and possibly from Great Britain as well, reach Scandinavia under certain meteorological conditions. Also, in Sweden, as a result of air pollution, there has been an increase in acidity of inland waters which has injured freshwater fisheries.

Complex legal problems may arise in the case of industrial districts and cities close to one another, but in different States, with different control legislations. Such problems become still more complicated in the case of countries where the various states, regions or even municipalities, have different regulations. An industry located in one district sometimes pollutes the air chiefly in another district.

HEALTH EFFECTS

One of the most frequently noted effects of air pollutants occurred in the London smog of December 1952. The effluent from coal-fires and industries in London accumulated during an inversion period of a few days. It has been calculated that some 4,000 people died as a result of the air pollution. The increased mortality occurred chiefly among elderly people, particularly those who already had chronic diseases of the lungs or heart. Similar acute episodes, although few in number and on a smaller scale, have occurred in Donora, Pennsylvania, the Meuse Valley in Belgium and in a mining area in Mexico. It has been assumed that the chief factors in these episodes have been fog, high contents of sulphur oxides and soot, as well as possible synergistic effects between various substances.

In the case of Los Angeles another mechanism is presupposed. The clinical manifestations also differ from those observed after exposure to London smog. The predominant symptoms are irritation in the upper respiratory tract and the eyes.

An acute effect often overlooked comes from air pollution with aeroallergenes. The clinical manifestations consist of asthma and/or allergic rhinitis. The best documented changes attributed to air pollution are probably the allergic manifestations that follow the inhalation of various pollens.

The causal connexion in some regions between exposure to air pollutants and chronic bronchitis is well-documented. The condition of chronic bronchitis is, of course, not due to air pollutants alone. It may even arise without any specific demonstrable cause. Constitutional factors are credited to be of some importance in this respect. Cigarette smoking is also a very common cause of this disease. The strong increase observed in recent years in some countries is chiefly attributed to cigarette smoking, aggravated perhaps by air pollutants.

The incidence of lung cancer has increased substantially all over the world in recent decades, with a marked correlation with cigarette consumption. The correlation between a high incidence of lung cancer and urbanization has been suggested by some investigators, although the evidence against air pollutants is still debatable.

Carbon monoxide forms an important percentage of exhaust gases from combustion. High motor vehicle density often results in not inconsiderable contents of carbon monoxide in the ambient air. In certain American cities, for instance, concentrations of more than 100 ppm have been repeatedly measured during the course of several traffic peak hours. The concentrations which obviously constitute a health risk are increasingly becoming clearer. The central nervous system is first affected. There is also some danger that even a slight reduction of the oxygen-carrying capacity of the blood may cause injury to those who suffer from coronary diseases and already have an impaired circulation. Carbon monoxide may well prove to be a critical substance in city air.

Lead is emitted on a considerable scale with automobile exhausts whenever petrol to which tetraethyl lead has been added is used as a fuel. Some idea of the magnitude of this emission can be gathered from the fact that California with 18 million inhabitants, has more than 9 million vehicles. The consumption of motor fuel amounts to more than 25,000 million litres per annum. In Sweden, with about 1.8 million passenger cars, petrol consumption is rather more than 3,000 million litres per annum. The emission of lead amounts to about 1 kg per vehicle per year.

Studies have shown that a correlation exists between the emission of lead via exhaust gases and the content of lead in man. Individuals who live close to busy highways have a higher content of lead than others. The total lead burden in the individual is admittedly still safely below the probable toxic level. At the same time, growing interest and importance will no doubt be attached to such accumulations of potentially dangerous substances.

Cadmium is another metal attracting attention in recent years. Once it has been deposited in the body, cadmium is stored to an even greater extent than lead. Several studies have shown that the content of cadmium in the kidneys increases a hundred to a thousand times during a person's life. In some instances exposure is not confined to cadmium in the air. Water, on occasion, as in a region in Japan, has been the carrier.

Air pollutants can affect people in other ways than by frank disease causation. Frequent complaints are made concerning bad smells and soiling. In Sweden in 1963 complaints had been received by the public health authorities concerning more than 900 point sources, of which more than 300 involved heating plants. The complaints chiefly concerned the emission of soot and malodorous substances. Interview surveys in the vicinity of sulphate plants (emitting malodorous sulphur compounds) have shown that half the population around the factories suffer discomfort from the smell. Half of those reported suffer severe discomfort.

DAMAGE TO PLANT LIFE AND MATERIALS

Several of the substances in polluted air are capable of causing acute or chronic damage to plant life. The first pollutants that were found to be injurious were sulphur dioxide and fluorides. Serious damage may be caused by substances typical of photochemical smog. The total costs in the U.S.A. alone are estimated by the Department of Agriculture to be about $500 million a year.

Sulphur dioxide is particularly harmful to alfalfa, barley and cotton. Many fruits and flowers, including citrus fruits, are particularly sensitive to fluorides. Damage may be caused in many cases by relatively low concentrations. Acute damage to conifers has been observed after only 15-30 minutes exposure to sulphur dioxide concentrations in the region of 30 pphm. Chronic damage has been reported at monthly averages of less than 5 pphm.

Many air pollutants have a deleterious effect upon material. Metals are corroded, buildings become discoloured and eroded, textiles, leather and paper become brittle and discoloured, rubber cracks and loses its elasticity. The costs incurred by these effects are probably large. Exact estimates are by no means easy to record, although attempts at such figures are frequently made.

CURRENT PROBLEMS—ACTION

The present emphasis on air pollution in many countries is a relatively new phenomenon. Industrialization, urbanization and motorism have all contributed to an aroused interest. Los Angeles smog was unknown or at least not dramatized as recently as at the end of the Second World War. Yet this type of smog has already arisen in many places besides Los Angeles. Further instances can be expected if the motorized vehicle in many parts of the world continues to increase at 5-10 per cent per annum.

A European network of stations for atmospheric chemistry has been in existence for several years. It has been found that the present emission of sulphur dioxide is very extensive. Measurements of atmospheric content of sulphur and the acidity of precipitation have shown that conditions were largely constant during the first few years. Since the beginning of the present decade, however, sulphur oxide contents have steadily increased and the pH of precipitation has correspondingly declined.

In the industrial countries, the next twenty years will probably see a doubling of the industrial production with corresponding potential air pollutant emissions, unless substantial counter-measures are taken. Strong control measures will have to be instituted, in the first place, for all new industrial plants, since it is considerably easier to take protective measures at the planning and design stage. At the same time, action must obviously be taken against air pollution from existing plants. This may often be done quite simply, but considerable difficulties will be encountered in certain more troublesome cases.

Measures to prevent damage from air pollution cannot be built up effectively without public support in the form of legislation, administration and finance. In many instances, a considerable measure of international co-operation will be required in densely populated urban and industrial areas, which cover several countries.

The necessary measures include an application of existing technology as well as an intensification of research and development. Such studies should not be restricted only to technology, but must be pursued in medicine and allied biological fields in order to clarify relationships and mechanisms of the effects of air contaminants.

In many cases the emission of air pollutants can be reduced on the basis of existing knowledge. The problems are of an economic nature. It is possible, for instance, to reduce the emission of sulphur oxides from heating plants. This can be done either by removing the sulphur from the fuel oil or by purifying the effluent gases. The costs are high. The sulphur compounds emitted from sulphate factories may also be substantially reduced. Such methods as combustion, or oxidation by means of chlorination, in addition to the conventional techniques, are available. The economic aspects, however, predominate, since increased costs are related to international competition in fuels, and the fact that different countries have different attitudes towards the problem of air pollution.

Motorism provides another instance where existing knowledge is sufficient to reduce substantially the emission of air pollutants. Several types of exhaust purifiers are already commercially available. In the U.S.A. all new automobiles must be equipped with such purifiers as of 1968. At the same time, the performance of internal combustion engines is being greatly improved. The need for wider geographical coverage of legislation is also evident from the fact that European cars exported to the U.S.A. have to be fitted with exhaust purifiers. They are still being marketed in their home countries without such devices.

Many fields still require technological research. New methods—taking economic factors into account—need to be developed for the purification of effluent gases. Methods of analysis need to be refined for all aspects of air pollution. Standardized techniques for sampling and analysis have to be developed for particulate pollutants. More efficient and inexpensive, reliable transportable recording instruments are greatly needed to produce measurements in a form directly suitable for electronic computers.

Such questions as the interaction between particles and gases, atmospheric dispersion under various meteorological conditions, as well as purely descriptive studies on the existence of various kinds of air pollutants in different places, all remain fertile fields for exploration. Our knowledge of the relationship between air pollutants and their effects—particularly those of a medical nature—is very incomplete, although intensive laboratory and field studies have been greatly expanded in recent years. As a rule, epidemiological studies can only demonstrate the existence of an effect and do not usually show which substance or substances are responsible therefor. Furthermore, it is even more difficult to use epidemiological studies to demonstrate that an effect does *not* exist.

Against this background and because it is often essential to take action before effects materialize, it is necessary to conduct experimental animal invistigations. These suffer from the drawback that the results of animal experience are not automatically applicable to man.

In many cases, it is undoubtedly reasonable to take preventive action before all the relationships between exposure and effect have been fully investigated. In the long term, however, it is extremely important to obtain as reliable dose-response curves as possible. This applies not only to medical effects, but equally to damage to plant life, materials, etc. A reasonable generalization is that one should take all preventive measures that are practical and economic. The question of what is practical and economic is bound up with the protective effect to be expected from a specific control measure. In other words, the ultimate assessment must be based upon dose-response curves. Since each assessment may have considerable economic consequences, the demand for increased accuracy of benefit-cost ratios will be high. There is no escape, however, from informed value judgements, in order to ensure that important intangible assets accrue to society by corrective air pollution measures.

SOIL POLLUTION

Human infestations with worms, transmitted mainly by polluted soil, in certain semi-tropical areas of the world, are so massive that over half the food produced and consumed is metabolized by the parasitic worm population infesting man. Half the work of the sick peasantry therefore goes into the cultivation of food for the worms that make them sick.

Soil pollution is not only the problem of the rural unsanitized areas of the world, but of the densely populated industrialized areas as well. In a recent report dealing with increasing pollution of the air, water and land, the United States National Academy of Sciences, National Research Council, stated: 'Pollution is an undesirable change in the physical, chemical, or biological characteristics of our air, land, and water that may or will harmfully affect human life or that of other desirable species ... Pollution increases not only because as people multiply the space available to each person becomes smaller, but also because the demands per person are continually increasing, so that each throws away more year by year. As the earth becomes more crowded there is no longer an "away". One person's trash basket is another's living space.'

From the earliest periods of history the potential role of polluted soil in transmitting disease from man to man has been appreciated. The biblical edict on the importance of hygienic disposal of excreta is one illustration of man's early attempts to control the pollution of the soil.

Today in our complex world we must deal not only with soil polluted by biological disease-causing agents, but with chemical and radioactive agents which can pollute the soil and expose man to new types of health risks.

SOIL POLLUTION BY BIOLOGICAL DISEASE AGENTS

Biological agents which can pollute the soil and lead to disease in man can be classified in three groups:

1. Pathogenic micro-organisms excreted by man and which are transmitted to man by direct contact with contaminated soil or by the consumption of fruits or vegetables grown in contaminated soil (man-soil-man).
2. Pathogenic micro-organisms of animals transmitted to man by direct contact with soil contaminated by the wastes of infected animals (animal-soil-man).
3. Pathogenic micro-organisms found naturally in soil which are transmitted to man by contact with contaminated soil (soil-man).

Enteric bacteria and protozoa can contaminate the soil as a result of insanitary practices of excreta disposal or as a result of soil fertilization techniques using night soil, sewage sludge or the direct irrigation of agricultural crops with sewage. Soil and crops can become contaminated with the bacterial agents of cholera, salmonellosis, bacillary dysentery (shigellosis) and typhoid and paratyphoid fever or the protozoan agent of amebiasis. However, these diseases are most often waterborne, transmitted by direct person-to-person contact or by the contamination of food. Flies which breed in or come into contact with faeces-contaminated soil can serve as mechanical carriers of the disease organism, although epidemiological evidence suggests that flies do not generally play an important part in the transmission of this group of diseases.

Parasitic worms or helminths are adversely affecting the health status of human populations in essentially all parts of the world. Even in the most highly developed countries where worm infections are relatively mild or few in number, the ones occurring will be rightly regarded as harmful. Helminths transmitted by polluted or contaminated soil can be grouped into two categories:

1. Contagious or faecal-borne—where eggs or larvae are infective when passed from the faeces to the soil; therefore infection is transferable directly from person to person by contact with contaminated soil.
2. Soil-transmitted or geohelminths—in this group, eggs or larvae become infective after a period of incubation in the soil.

Helminthic infections on the whole can be viewed as providing by their prevalence an index of a community's progress towards a desirable level of sanitation. Successful management of pollution problems will eliminate essentially all of the helminths.

The WHO Expert Committee feels that a direct relationship between anaemia and hookworm infection and to a lesser extent other helminthic infections, though for many years obscure, has now been generally accepted. Helminthic infections may cause losses of iron, protein, or other essential constituents of the red blood cell. It may also induce a failure to absorb these substances. It may damage the liver and have other pathological effects. Malnutrition may be induced or aggravated by such helminthic infections, for worms may not only produce secretions known to interfere with protein digestion, but may themselves compete with their hosts and absorb essential nutrients. By causing bleeding they may bring about further very important losses which increase nutritional demands.

ENVIRONMENTAL CONTROL

Early attempts to control hookworm infection were initiated in mines in Europe and considerable success was achieved. The provision of sanitary facilities and the treatment of infected persons reduced the prevalence of hookworm infection and disease to a point where it is now negligible in Europe, except for certain parts of Portugal and among agricultural workers in Italy. This success was possible partly because the population was either amenable to advice, or could be disciplined, and partly because of the relatively cold climate. These early successes led to the inauguration of hookworm eradication campaigns in other parts of the world. This work, largely under the auspices of the International Health Board of the Rockefeller Foundation, consisted of sanitary and prevalance surveys, chemotherapy, installation of latrines, and public health education. Campaigns of this kind were undertaken by health agencies in practically all countries where hookworm was endemic. These campaigns have reduced the over-all intensity of hookworm infection in Europe and the United States. However, in most places where the environment is particularly favourable there has been little change in prevalence. Recently, it has been estimated that throughout the world hookworm still causes a daily blood loss equivalent to the total exsanguination of about 1.5 million people. While many feel that preventive medicine has proved successful in tropical areas in general, the success in the control of soil-transmitted helminths has lagged behind.

CHEMICAL CONTROL

Chemical control of the free-living stages of the helminths has been studied and investigations of the chemical destruction of the eggs and larvae of ascaris and hookworm have been conducted. The chemical treatment of sewage and night soil is technically possible; however, such chemicals are expensive and their application is often impractical. Killing eggs and larvae in the soil is difficult because the eggs may be washed down into it by rain or the larvae may migrate downward so that they are protected by 3 cm of soil or more. It is necessary in applying chemicals to make sure that they penetrate to a sufficient depth. For this reason, many of the chemicals that kill eggs when applied directly under laboratory conditions are ineffective when applied to the soil.

SANITARY CONTROL

The prevention of soil-transmitted helminth infections is in a large part a problem of proper sanitary faeces disposal. In all control programmes this matter must be given high priority. Control measures should be directed towards the disposal of faeces in such a way that they become inaccessible and harmless, or they should be treated in a way that will render them innocuous even if they become accessible. Even in economically advanced countries, sanitary sewage disposal is far from adequate, while the key to the control of these infections in other areas is the installation of latrines in both urban and rural areas. However, in many instances where such a programme has been carried out there has not been a commensurate decline in the prevalence of the infection. This does not mean that the measures adopted are wrong in principle, but indicates that the facilities provided are not being used properly.

CONTAMINATION OF AGRICULTURAL SOIL AND CROPS

Human faeces are a valuable fertilizer when this commodity is in short supply as is the case in most parts of the world. The contents of latrines, septic tanks and sewage systems are frequently used for the fertilization of crops. In water-short areas, the reclamation of waste water for irrigation often provides a valuable source for additional water supply. Unless certain precautions are taken such practices can be dangerous to the public health. Hookworm and ascaris as well as other helminths may survive for a relatively long period in the soil and contaminate vegetable crops consumed uncooked, thus spreading these diseases. In addition, pathogenic enteric bacteria and other protozoan parasites, such as *Entamoeba histolytica*, may contaminate the soil and crop by such practices. Many studies have been carried out which show that before treatment, domestic sewage or night soil usually contains the complete spectrum of pathogenic micro-organisms eliminated by the community served. In one such study, species of pathogenic organisms, such as the causative agents of typhoid fever, bacillary dysentery, amoebic dysentery, ascaris and other protozoan and helminthic diseases, were isolated in raw sewage as well as in the effluent of the high-rate trickling filter plant. Sewage treatment processes do have the ability to remove some of these pathogenic organisms. The removal of coliform organisms may serve as an indication of the efficiency of the process from the bacteriological point of view.

Irrigation with sewage can be expected to lead to the contamination of soil and crops with a wide variety of pathogenic organisms. Studies have also been made as to the viability of various indicator and pathogenic organisms in the soil or on crops irrigated with waste water. The viability of such organisms varies from a number of days to a few months, depending on the type of organism and its resistance to detrimental environmental factors, climatological conditions, soil moisture, degree of protection provided by the crops, etc.

Some countries have drawn up health regulations confining irrigation with waste water to certain crops not used for human consumption or to crops consumed only after cooking and processing. If such regulations are administratively feasible and farmers can be educated to adhere to them, potential public health hazards resulting from sewage irrigation and soil pollution can be limited. Enforcement of these regulations has shown that, despite their restrictive nature, organized large-scale farms irrigated by sewage can run a fairly balanced agricultural programme under adequate rotation schemes. There is always a temptation for small-scale farms to irrigate with sewage the more lucrative vegetable crops, despite the fact that this practice is forbidden by regulations. Even food crops consumed after cooking, and which have been irrigated with sewage or come into contact with contaminated soil, may contaminate working surfaces or utensils in the kitchen and thus cause the contamination of other foods eaten raw.

Another problem concerns the health protection of the agricultural worker involved in sewage irrigation practices. In many Western countries the health of agricultural workers on sewage farms does not appear to be adversely affected. However, reports from India indicate that farmers on sewage farms have been shown to have a much higher incidence of hookworm and other parasitic diseases than the population-at-large.

DISEASES OF ANIMALS TRANSMISSIBLE TO MAN

There are a number of zoonoses in which the soil plays a major role in the transmission of the infective agent from animal to man. A recent WHO/FAO Expert Group has extensively reported on this problem. Among such diseases are leptospirosis, anthrax, Q-fever, cutaneous larvae migrans, pathogenic fungi, tetanus, botulism and coccidioido-mycosis.

SOIL POLLUTION BY CHEMICALS AND RADIOACTIVE MATERIALS

In the last twenty-five years the use of chemical pesticides and herbicides applied to the soil and to plants has increased greatly. In many countries of the world the agricultural economy has become dependent on the use of such chemicals in order to maintain the high levels of agricultural production required. The United States National Research Council, in reviewing this problem, has pointed out that the excess residuals of these chemicals which appear in food for human consumption may present a health hazard to man, although to date there is little concrete evidence that soil pollution *per se* has played a significant role in this problem. Accidents, due to careless and excessive use, are of course, an exception.

Many of these chemicals do not accumulate in the soil and within a matter of months or in a year or two, they are destroyed by soil bacteria. Certain chlorinated hydrocarbons and chlorinated phenoxy compounds persist in the soil. They can be held tightly by the clay and humus fractions of the soil which prevent attack by micro-organisms. Some of the chlorinated compounds appear resistant to biological destruction. The particular structure of the molecule may determine the resistance to destruction. While the weed killer 2,4-D is rapidly destroyed by soil micro-organisms, the closely related 2,4,5-T remains intact for longer periods. Among the insecticides, DDT and dieldrin have been shown to be relatively resistant to biological degradation in the soil.

Persistent pesticides, if not fixed by the soil, are subject to possible biological concentration through the food chain. Heptachlor epoxide, for example, can be absorbed and concentrated from the soil by earthworms, either by contact or through the digestive system. Fowl feed on the worms and may concentrate the pesticide still further. While the possibility of biological concentration of pesticides from the soil remains a potential problem, the principal concern has stemmed from pesticide residuals on plants intended for human consumption. A serious problem may develop with the long-continued use of pesticides resistant to biological destruction or capable of being absorbed and concentrated by soil found and entering in some fashion the food chain of man. Most pesticides reaching the soil become unavailable or non-toxic and do not enter the food chain of animals or man.

Radioactive elements can reach the soil and accumulate there from atmospheric fallout resulting from atomic explosions or by the disposal of liquid or solid radioactive wastes from atomic industrial or research establishments. The three most important radioactive elements with long half-lives produced by atomic fission are carbon 14 with a half life of 5,600 years, radioactive strontium (Sr^{90}) with a half-life of 28 years, and radioactive caesium (Cs^{137}) with a half-life of 30 years. Carbon 14 is normally present in the soil and there appears to be no likelihood that changes in the C^{14} content of the soil will be reflected in the composition of plants, because plants get the bulk of their carbon from the atmosphere, nor should there be any adverse effect on soil fauna which feed largely on these plants.

The Northern hemisphere, site of most nuclear explosions until recently, has the highest amount of Sr^{90} in the rain and, within the hemisphere, the regions of highest precipitation have received the most Sr^{90}.

Levels of radiation from fission products deposited in the soil by fallout in the U.S.A. are about the same order of magnitude or one order lower than natural radiation from the soil. Many authorities feel that there is very limited evidence to date to prove that this increase in radiation could affect soil fauna and their predators. Increased radioactive fallout might in time result in soil contamination reaching levels sufficient to cause concern, unless restraint in testing is universal.

The disposal of radioactive wastes from atomic energy installations might cause levels of soil pollution in certain local areas to reach concentrations which may present public health problems unless carefully controlled and monitored. In general, practice is controlled with high effectiveness.

SOIL POLLUTION AND SOLID WASTE DISPOSAL

The land serves as a major repository for the solid wastes of urban and industrial areas. Solid waste disposal in metropolitan areas has a number of public health implications and has been analysed in some detail in the report on waste management and control by the United States National Research Council.

The problem of greatest concern stems from the increasing extent to which urban, suburban, and rural areas are becoming crowded together, leaving little or no land for waste deposition. This situation is forcing independent local authorities to the realization that regional planning of solid waste disposal may in the long run provide the only solution.

In highly industrialized countries, even the solid wastes of agriculture become a problem, particularly when live-stock and poultry wastes near urban centres become the source of heavy fly breeding, and causes serious odour nuisance on decomposition.

Per capita production of solid wastes varies considerably from country to country, but with higher living standards the amount of refuse produced is everywhere on the increase. In the United States and some European countries this increase is estimated at about 2 per cent per year. The problem of land pollution with wastes differs in a number of important respects from those of water or air pollution, since the polluting material will remain in place for relatively long periods of time unless removed, burned, washed away or otherwise destroyed. In many of the more developed countries, aesthetic considerations have become important in soil pollution and there is less readiness to accept unsightly open refuse dumps and junk heaps as an inevitable blot on the landscape. Insect and rodent breeding as well as odour nuisances from decomposing organic matter or from slow smouldering fires cause nuisances and in some situations public health problems.

With the increasing utilization of land areas in the large metropolitan complexes, pressure to dispose of solid wastes by methods other than land disposal has led to new pollution problems. Improper incineration can lead to severe air pollution, while disposal to the water environment had led to increased pollution loads on often overloaded treatment facilities and already heavily burdened water-courses. The simple transfer of the pollution problem from one sphere to another cannot be considered an acceptable solution.

AGRICULTURAL LAND POLLUTION

In the past, nutrient materials in the agricultural economy followed a clearly defined cycle: from the land to plants to animals and back to the land again. In some of the more industrialized countries the use of chemical fertilizers has short-circuited the cycle. Many agricultural areas now have large surpluses of plant and animal wastes whose inadequate disposal can lead to soil pollution. The problem becomes particularly severe when urban areas extended into the agricultural areas. In these fringe areas, agricultural solid wastes may ultimately have to be handled in a manner similar to that of other urban wastes.

As agriculture becomes more intensive, utilizing more and more artificial materials, such as pesticides, nutrients and control agents, chemical soil pollution, coupled with increasing amounts of excess organic waste materials, may lead ultimately to severe land pollution problems in agricultural areas. Any long-term pollution control programme must incorporate some means of ultimate safe handling of such wastes.

SANITARY DISPOSAL OF SOLID WASTES

Land disposal of urban and agricultural solid wastes may be carried out in a sanitary manner so as to minimize detrimental pollution effects. The controlled burial of such wastes in a sanitary landfill, when carefully planned and administered, can prevent pollution and lead to the ultimate reclamation of waste land areas. However, problems of ground-water pollution or nuisances do result from an improperly operated fill. The conversion of solid wastes, particularly those possessing a high organic-matter content, to compost can provide in some areas of the world a satisfactory method of preventing land pollution. A way of returning much needed organic matter to the soil, in order to maintain its structure and fertility, is thus provided. For the most part, composting operations on a very large scale pose fiscal and operating problems. Where they are successful, they are generally very heavily subsidized by governments.

INTERRELATIONSHIPS BETWEEN AIR, WATER AND LAND POLLUTION

Air-land and water-land interchanges represent transport devices by which the land moves some of its material from one location to another and discards some to the ocean. In a natural system, water is used to mine out, dissolve and disintegrate earth materials and to transfer them elsewhere. In a similar fashion the wind is used to erode land and to transport material elsewhere on the land or into the ocean. By such an interchange, the natural waste products of life and death of plants and animals are recycled to living organisms. Thus, in nature, organic wastes become the raw materials of new production and no problems of land pollution result.

The primary effect of man's activities on the land resource has been to inconvenience man himself by accumulating in his own environment concentrations of inorganic material which nature takes a long time to disintegrate and redistribute, and organic matter which nature handles in its own way relatively rapidly, but produces decomposition by-products, both chemical and living, which man considers to be major nuisances.

Nature disposes of the man-generated pollution load upon the land in the same way as it handles the natural load. Bacteria degrade organic matter usually by anaerobic processes with all of the associated odours and nuisance factors. Eventually organic wastes are thus incorporated into the soil. Inorganic wastes are broken down more slowly, while some materials such as metals and plastics may take years. The ultimate disposal of man's full range of solid wastes requires effective and stable 'sinks' capable of accepting and holding such materials without resulting in detrimental pollution of the environment.

Only the land and the ocean are considered to be capable of providing such ultimate repositories.

Natural atmospheric pollutants such as organic and inorganic dust, pollens, fungal spores, salt nuclides are returned to the soil by precipitation and natural dust-fall. The over-all effect is to spread over vast areas of land a small burden of polluting material.

The situation is similar for man-generated air pollutants. Gases and particulate matter of a wide variety are transported and deposited on the land. As most such pollutants originate at a point source and their dispersion is of a local nature, there is generally little harm to the total land resources. However, cases of extensive land pollution in the vicinity of industrial plants have been reported, including incidents which led to the damage of vegetation up to a radius of 30 km from the source of the pollution. Generally speaking, however, the magnitude of air-to-land interchange is small in comparison with the over-all storage capacity of the land.

The principal mechanisms of water-to-land movement of pollutants include: deposition of silt, clay, and other soil materials and organic residues by surface waters, including flood overflows; deposition of minerals in specific locations by ground waters; deposition of salts by intruding or flooding of land by saline waters; accumulation of salts as a result of inadequate leaching during irrigation; accumulation of residues from spray irrigation with domestic or industrial wastes. Man-generated pollution loads are likewise transported by these processes. Engineered pollution control facilities related to the water-land interchange are designed to control the location at which the interchange takes place and to direct the pollution load to the ocean rather than to the land or to remove the pollutional factors which might be detrimental.

CONCLUDING REMARKS

The environment is a dynamic interacting system, and pollution should always be considered with regard to its impact on the whole environment. A systems approach, emphasizing the air-water-land interchange, is recommended, therefore, in all environmental pollution studies.

Since a multidisciplinary approach is always essential, an improvement in collaboration between scientific and control organizations, both national and international, is urgently needed. Air and water pollution, or water and land pollution, or fresh water and marine pollution are not different problems. Their impacts upon the ecology of the earth are interrelated.

Environmental pollution is a resources problem with implications of vital importance to public health. Much of our knowledge of how to control it stems from public health research and practice. It is an economic problem, directly affecting industry and agriculture, both in developing and developed countries. Since it imposes constraints on urban and regional growth and physical planning, it is a social problem as well, with all the attendant legal, administrative, cultural and political implications.

Man often is simultaneously exposed to many adverse environmental factors and stresses. The effects on health may be additive and sometimes synergistic. The holistic approach to environmental health demands extensive exchange and retrieval of information. Control programmes should make full use of all the information developed by national and international agencies and should be closely co-ordinated with disease control programmes. In spite of considerable efforts by different international organizations, the collection and efficient use of the available information has not yet been resolved.

Comprehensive studies on the ecology of man should be particularly stimulated. Although new concepts and much new technological knowledge will be required to find optimum solutions to many control problems, much can be done to prevent and control pollution without waiting for the results of further research. This applies particularly to developing countries.

The system of international, regional and national reference centres and collaborating laboratories, applied by the World Health Organization in many areas of health promotion and disease control, could be profitably used to improve international and interdisciplinary collaboration in environmental pollution studies. Such mechanisms facilitate the co-ordination of the research programmes of specialized institutions and laboratories dealing with particular aspects of air, water and land pollution. They stimulate the exchange of scientific information. Such a network of 'environmental pollution reference centres and collaborating laboratories' should be established.

The promotion of a multidisciplinary approach to control might also be stimulated by establishing and developing applied research institutes, closely connected with operational and field work and providing consultant services where needed. Such institutes should include specialists and facilities for work on air, water and land pollution control; technology and economics of waste disposal and water supply; occupational health; ionizing radiation control; noise abatement and various disciplines in environmental biology, such as vector control. They should preferably be regional in scope and might well serve as centres for specialized training in environmental sciences and engineering.

In view of the possible irreversibility of some actions which may be taken in the next decades, some international agency should be charged with the responsibility of the continuing examination, identification and assessment of changes in the total resources picture. Their potential effects may then be regularly detected and evaluated, and guides for modified future control should result.

Essentially, we need an intelligence agency in matters of human ecology. Its development might begin in an elementary way, but should not be deferred because of the obvious difficulties involved in creating *de novo* a 'full blown' international machinery.

Man and his ecosystems; the aim of achieving a dynamic balance with the environment, satisfying physical, economic, social and spiritual needs

This paper was prepared on the basis of a draft submitted by Professor René Dubos (U.S.A.) with comments and additions by Professors Marion Clawson (U.S.A.), F. Fraser Darling (United Kingdom), F. Bourlière (France) and the Secretariats of Unesco, FAO and WHO.

THE BIOLOGICAL STABILITY OF HOMO SAPIENS

All men are migrants from a common origin. Their various races have undergone minor modifications during prehistoric and historic times as a result of the migrations that exposed them to different environmental factors and led them to adopt different ways of life. But on the whole, their genetic endowment is still much the same as it was 100,000 years ago. Furthermore, there is no indication that it will change significantly in the near future, because the normal process of genetic evolution is much too slow, even though natural selection is still at work. For this reason, human life can be sustained only within the fairly narrow range of physical and chemical limits that fit the anatomic and physiological characteristics of the species *Homo sapiens.*

The fact that modern man is constantly moving into new environments gives the impression that he is enlarging the range of his biological adaptabilities and thus escaping from the bondage of his evolutionary past. But this is an illusion. Wherever he goes, and whatever he does, man can function only to the extent that he maintains or creates around himself a microenvironment similar to the one within which he evolved. He moves at the bottom of the sea or in outer space only if he remains linked to the earth by an umbilical cord or is confined within enclosures that almost duplicate the terrestrial atmosphere. He can survive in environments polluted with chemicals, noise, and excessive stimuli, but he retains physical and mental health only if he protects himself by devices that shelter him from these environmental pollutants.

Granted these biological limitations, it remains true on the other hand that man is today as adaptable as he was during the late Stone Age when he established settlements over much of the earth. During the past few decades, countless persons have survived the frightful ordeal of modern warfare or of concentration camps.

Under normal conditions, the biological mechanisms of adaptation are powerfully supplemented by mechanisms that do not require any change in man's biological nature. All over the world, the most crowded, polluted and brutal cities are also the ones which have the greatest appeal and in which population is increasing the fastest. Economic wealth is being produced by men and women working under extreme nervous tension amidst the infernal noise of high-power equipment, typewriters, and telephones in atmospheres contaminated with chemical fumes or tobacco smoke.

Because man is endowed with such remarkable ability to tolerate conditions profoundly different from the ones under which he evolved, the myth has grown that he can endlessly and safely transform his life and his environment by technological and social innovations; but this is not the case. On the contrary, the very fact that he readily achieves biological and socio-cultural adjustments to many different forms of stress and of undesirable conditions paradoxically spells danger for his individual welfare and for the future of the human race.

It seems useful to open a parenthesis here to emphasize that the orthodox biological meanings of the word 'adaptation' are not applicable without qualifications to the adjustments that enable human beings to survive and to function under the conditions of modern life. The reason is that, in the case of man, socio-cultural forces now distort the manifestations of the evolutionary adaptive mechanisms that operate in the rest of the animal kingdom.

For the biologist, the phrase 'Darwinian adaptation' implies a state of fitness to a given environment, enabling the animal species under consideration to multiply and eventually to invade new territories. According to this definition, man seems to be remarkably adapted to the conditions prevailing both in highly industrialized societies and in underdeveloped countries, since his populations are increasing everywhere and spreading over the whole earth. But what would be biological success for an animal species is a considerable social threat for the human species. The dangers posed by the increase in human population make it clear that the Darwinian concept of adaptation cannot be used when the welfare of the human species is used as a criterium of adaptability.

For the physiologist, a response to an environmental stress is adaptive when it tends to correct the disturbing effects of the stress on the body and the mind. Physiologically and psychologically adaptive responses generally contribute to the welfare of the organism at the time they occur; in man, however, they commonly have secondary effects that are harmful in the long run. Man can achieve some form of tolerance to environmental pollution, excessive environmental stimuli, crowded and competitive social contacts, the estrangement of life from the natural biological cycles, and other consequences of life in the urban and technological world. This tolerance enables him to overcome effects that are unpleasant or traumatic when first experienced. But in many cases, it is achieved through organic and mental processes which may result in the chronic and degenerative disorders that so commonly spoil adult life and old age, even in the most prosperous countries.

Man can learn also to tolerate ugly surroundings, dirty skies, and polluted streams. He can survive even though he completely disregards the cosmic ordering of biological rhythms. He can live without the fragrance of flowers, the song of birds, the exhilaration of natural scenery and other biological stimuli of the natural world. Loss of amenities and elimination of the stimuli under which he evolved as a biological and mental being may have no *obvious* detrimental effect on his physical appearance or his ability to perform as part of the economic or technologic machine. The ultimate result, however, can be and often is an impoverishment of life, a progressive loss of the qualities that we identify with humanness and a weakening of physical and mental sanity.

Air, water, soil, fire, the rhythms of nature and the variety of living things, are of interest not only as chemical mixtures, physical forces, or biological phenomena; they are the very influences that have shaped human life and thereby created deep human needs that will not change in the foreseeable future. The pathetic weekend exodus to the country or beaches, the fireplaces in overheated city apartments, the sentimental attachment to animal pets or even to plants, testify to the persistence in man of biological and emotional hungers that developed during his evolutionary past and that he cannot outgrow.

Like Anteus of the Greek legend, man loses his strength when his feet are off the ground.

THE CREATIVENESS OF HUMAN LIFE

While the genetic endowment of *Homo sapiens* has not undergone any significant alterations since the late Stone Age, it is obvious that its phenotypic manifestations have greatly changed with time and differ from place to place. The reason is that mankind as a whole possesses a wide range of genetic potentialities, most of which remain unexpressed under ordinary conditions. These potentialities become existential reality through the creative effects of the responses that each person makes to environmental stimuli. Man cannot modify significantly the genetic constitution of the human race, but he has a large measure of control over the quality of human life nevertheless because he has learned to manipulate the environmental factors which condition the phenotypic expressions of his genetic endowment. Individually and collectively, man makes himself through responsible choices at each moment of his existence.

A few broad generalizations can serve as a theoretical basis for discussing the effects of the environment on human life:

1. To live is to respond to stimuli. Hence, the environment is best conducive to human development when it is sufficiently changeable to provide constant challenges, provided these are not severe enough to be incompatible with successful responses from the body and the mind.
2. Whether the challenges come from physical or social forces, the diversity of the environment is of crucial importance. Each person is born with a wide range of mental potentialities, but these can be actualized only to the extent that conditions are favourable for their development. Furthermore, since persons differ in their tastes and aspirations, and therefore have different needs, it is impossible to define one type of environment equally favourable for all of them.
3. It is impossible to define an environment optimum for man if one has only man in mind. Ecologically, man is part of the total environment and therefore cannot achieve and maintain physical and mental health if conditions are not suitable for environmental health. As used here, the phrase 'environmental health' refers to the state of the physical and biological system in

which man lives. It implies not only survival of the system but its ability to evolve in a desirable direction so that man can also evolve. Becoming is at least as important as being.

BIOLOGICAL NEEDS AND SOCIAL WANTS

In theory, all human beings have much the same essential biological needs; but in practice actual needs are socially conditioned and therefore differ profoundly from one human group to another. Even food requirements cannot be defined without regard to historical and social factors. The value of an article of food is not determined only by its content in protein, carbohydrate, fat, vitamins, minerals, and other chemical components. A particular food has in addition to its metabolic values symbolic values which make it either essential or unacceptable to a particular group of persons depending upon their beliefs and past experiences. These symbolic aspects of nutrition are not of importance only among primitive people. Americans are even more reluctant to eat horse meat than Frenchmen are to eat cornbread.

Furthermore, needs are not unchangeable. Some which appear almost essential today may become trivial in another generation, not because man's biological nature will change, but because the social environment usually undergoes rapid and profound modifications. It may turn out for example that the individual motor car will progressively disappear if driving loses its appeal because of traffic congestion or boredom, and if people learn to use more of their leisure time within walking distance of their homes. The individual detached house so characteristic of the American continent may also become obsolete once home-ownership loses its symbolic meaning of economic and social independence by reason of more generalized prosperity and financial security. Changes in automobile usage and in housing habits would probably have enormous effects on the fate of land areas, as would of course changes in the methods of food production.

The phrase 'essential need' is therefore meaningless because in practice people need what they want. As technological civilization develops, needs are determined less and less by the fundamental biological requirements of *Homo sapiens* and more by the social expectations. These expectations are created by the environment in which man lives and especially in which he has been brought up. The members of a given social group generally come to desire, and consequently develop a need for, whatever is regarded as most desirable by the group. The good life is identified with the satisfaction of these needs whatever their biological utility.

Wants become needs not only for individual persons, but also for whole societies. Elaborate religious institutions and ceremonies were apparently a need for the thirteenth century European towns, which devoted to the creation of churches and monasteries a percentage of their human and economic resources that appears extravagant to us in relation to the other aspects of mediaeval life. Our own societies seem particularly concerned with creating a middle-class materialism with a veneer of uplifting platitudes. This creates its own pattern of costly demands irrelevant to biological necessity—for example, costly carbonated beverages and narcotizing television programmes.

THE NEED FOR ENVIRONMENTAL DIVERSITY

The environments men create through their wants constitute to a very large extent the formula of life they transmit to succeeding generations. Thus, in addition to affecting present-day life, the characteristics of the environment condition young people and thereby determine the future of society. It is unfortunate therefore that we know so little and make so little effort to learn how the total environment affects the physical and mental development of children, and how much of the influence persists in adult life.

There is no doubt that the latent potentialities of human beings have a better chance to become actualized when the total environment is sufficiently diversified to provide a variety of stimulating experiences, especially for the young. As more persons find the opportunity to express a larger percentage of their biological endowment under diversified conditions, society becomes richer and civilizations continue to unfold. In contrast, if the surroundings and ways of life are highly stereotyped, the only components of man's nature that can become expressed and flourish are those adapted to the narrow range of prevailing conditions.

Historically, man was very slow to expand his horizons and develop his full genetic potential. Thus, surrounding early man with nature does not seem to guarantee a rich, diverse existence. Furthermore, in some present rural areas of the developed countries, man has produced a monotony of both crops and culture that stifles human development.

The present trends of life in prosperous countries are usually assumed to represent what people want; but in reality the trends are determined by what is available for choice. What people come to want is largely determined by the choices readily available to them early in life. Many children growing up in some of the most prosperous suburbs of industrialized countries may suffer from a critical deprivation of experiences and this determines the triviality of their adult lives. In contrast, some poor areas of the world provide human environments that are so stimulating and diversified that many distinguished adults emerge from them despite the economic poverty of their early years.

There is no doubt, in any case, concerning the sterilizing atmosphere of many modern housing developments which are sanitary and efficient, but inimical to the full expression of human potentialities. All over the world, many of these developments are planned as if their only function was to provide disposable cublicles for dispensable people. Irrespective of genetic constitution, most young people raised in such a featureless environment, and limited to a narrow range of life experiences, will suffer from a kind of deprivation that will cripple them intellectually and mentally.

In judging the human quality of an environment, it is essential to keep in mind that passive exposure to stimuli is not enough to elicit individual development. The stimulus becomes *formative* only if the organism is given a chance to respond to it actively and creatively. Amusement parks and zoological gardens, richly endowed as they may be, are no substitute for situations in which the developing child can gain direct experience of the world through active participation. Juvenile delinquency is probably caused to a very large extent by the failure of the modern world to provide opportunities for the creative expression of physical and mental vigour during the most active period of development.

Man has been highly successful as a biological species because he is extremely adaptable. He can hunt or farm, be a meat-eater or a vegetarian, live in the mountains or by the seashore, be a loner or a team member, function under aristocratic, democratic, or totalitarian institutions, but history shows also that societies that were once efficient because highly specialized rapidly collapsed when conditions changed. A highly-specialized society, like a narrow specialist, is rarely adaptable.

Cultural homogenization and social regimentation resulting from the creeping monotony of over-organized and over-technicized life, standardized patterns of education, mass communication and passive entertainment, will make it progressively more difficult to exploit fully the biological richness of the human species and may handicap the further development of civilization. We must shun uniformity of surroundings as much as absolute conformity in behaviour and tastes. We must strive instead to create as many diversified environments as possible. Richness and diversity of physical and social environments constitutes a crucial aspect of functionalism, whether in the planning of rural and urban areas, the design of dwellings, or the management of individual life.

Diversity may result in some loss of mechanical and administrative efficiency and will certainly increase stresses, but the more important goal is to provide the many kinds of soil that will permit the germination of the seeds now dormant in man's nature.

THE GOAL OF CONSERVATION POLICIES

It is often assumed that progress depends on man's ability to *conquer* Nature. In reality, there exist throughout mankind biological and emotional needs that require no conquest of Nature, but rather harmonious collaboration with its forces. The ultimate goal of conservation policies should be to manage the environment in such a manner that it contributes to the physical and mental health of man and to the flowering of civilization. Unfortunately, while there is much know-how concerning certain limited aspects of conservation practices, there is little understanding of what should be conserved and why. In fact, as we shall see, the goal should not be to conserve but rather to guide the orderly evolution of Man-Nature interrelationships.

Conservation certainly implies a balance between the multiple components of nature, including man. This is a doctrine difficult to reconcile with the present trends of modern civilization, built on the Faustian concept that man should recognize no limit to his power. Faustian man finds satisfaction in the mastery of the external world and is engaged in endless pursuit of success for success' sake, even when he tries to reach the unattainable. No chance for balance here.

To be compatible with the spirit of modern civilization, the practices of conservation cannot be exclusively or even primarily concerned with saving parts of the natural world or man-made artefacts for the sake of preserving individual specimens of interest or beauty. Their goal should be the maintenance of conditions under which man can develop his most desirable potentialities. Since man relates to his total environment and especially is shaped by it, conservation implies a quality of relationship rather than a static condition. Man must engage in a creative interplay with his fellows, animals, plants, and all the objects of nature that directly or indirectly affect him, and which he affects.

From the human point of view, the total environment, including the remains of the past, acquires its full significance only when harmoniously integrated with the living tissues of man's life. It can even be demonstrated that because they shape irreversibly all aspects of human development, environmental forces are so to speak woven in man's physical and mental fabric.

The ill-defined meaning of the word nature compounds the difficulty of formulating a scientific basis for the philosophy of conservation. If we mean by nature the environment as it would exist in the absence of man, then very little of it survives. Not even the strictest conservation policies could restore the primeval environment; nor would this be necessarily desirable if it could be done. Nature is never static. Physical forces and living creatures alter it continuously; animals especially modify parts of it to fit their biological and behavioural needs.

For animals as well as for men, the kind of environment which is most satisfactory is one with which they are familiar and in which they have introduced modifications that facilitate their biological and social life, such as territorial marks, trails for exploration, access to water supplies, retreats for mating, sheltered areas to protect the young. In general, the ideal conditions imply a complementary cybernetic relationship between a particular environment and a particular living thing.

Civilized nature should be regarded not as an object to preserve unchanged, not as one to dominate and exploit, but rather as a kind of garden to develop according to its own potentialities and in which human beings develop according to their own genius. Ideally, man and nature should be joined in a non-repressive and creative functioning order.

Nature can be tamed without being destroyed. Unfortunately, the word taming has come to imply subjugating animals and nature. Like men and animals, landscapes tamed in this manner lose their real essence, and become spiritless. To be biologically successful taming demands the establishment of a relationship that does not deprive the tamed organism—man, animal or nature—of the individuality that is the *sine qua non* of survival.

MAN-NATURE INTERRELATIONSHIPS

There are two kinds of satisfactory landscape. One is a landscape disturbed as little as possible by human intervention. We shall have less and less of it as the world population increases, but we must make a strenuous effort to preserve some specimens of primeval nature lest we lose the opportunity to re-establish contact now and then with our evolutionary past. A sense of continuity with the biological origins of mankind and with the rest of creation is probably essential to mental sanity.

The other kind of satisfactory landscape is one created by man and in which he has achieved harmony with natural forces. Most commonly, this has been achieved through centuries of interplay between human societies and the land on which they have settled. All over the world, the human charm of certain long-settled areas testifies to the emotional and aesthetic power of this prolonged and largely subconscious 'wooing' of the land. Whether similar qualities can be created by rapid and rational manipulation of Nature remains to be investigated.

What we long for most often is not nature in the raw, but a landscape adjusted to human limitations and expressing the aspirations of civilized life in its many different forms. For this reason, each people has its preferred landscape, constituting an integration and synthesis of natural forces and of cultural traditions. Indeed, much of what we regard today as natural environment is in fact a product of history. The valleys of the Nile and Euphrates were shaped by human labour during the Neolithic period. And much of the arable land all over the world is also the product of man's management of the primeval forest. Many of the plants now considered typical of the Mediterranean landscape, the olive tree for example, were in fact introduced from Iran. As to the tulip which is now such a characteristic of the Netherlands, it was first brought there from Turkey as late as the sixteenth century.

Irrespective of social changes, cities and their streets, the highways linking them, as well as the countryside surrounding them, also retain traces of the character imposed on them by early historical influences. The future development of new cities, especially in the U.S.A., is bound to be constrained by the grid-iron pattern and the network of highways that shaped their early growth.

Since most of the environment as it exists today is a creation of man, and in turn influences the subsequent development of human societies, environmental quality must take into consideration not so much the preservation of the natural state, as the effects of the environment on the future of civilized life. From this point of view, the situation looks very dark in most parts of the world. Everywhere, societies seem willing to accept ugliness for the sake of increase in economic wealth. Whether natural or humanized, the landscape retains its beauty only in the areas that do not prove valuable for industrial and economic exploitation.

The change from wilderness to dump heap symbolizes at present the course of technological civilization. Yet the material wealth we are creating will not be worth having if creation entails the raping of nature and the destruction of environmental charm. In the past, the primeval wilderness progressively evolved into a humanized form of nature through the continuous 'wooing' of the earth by peasants, monks, and princes. We must now learn to convert the drab wilderness generated by technology into a new kind of urbanized and industrialized nature worthy of being called civilized.

Obviously, transformation of the land by brutal conquest is not the only approach to planning the environment nor is it the best. Man should instead try to collaborate with natural forces. He should insert himself in the environment in such a manner that he and his activities form an organic whole with nature. Moreover, humanized landscape and the wilderness have a place in human life, because they satisfy two different but equally important needs of man's nature. On the one hand, modern man retains from his evolutionary past a longing for the wild manifestations of nature which first shaped his biological and mental being; on the other hand, civilization has made him desire farmland, parks, gardens and urban areas. Conservation policies must take into account all these biological and socio-cultural aspects of the human past.

In the huge urban areas of the modern world we must supply their inhabitants with something more than amusement parks, highways for sightseers and paved grounds for weekend campers. No social philosophy of urbanization can be successful if it does not deal with urban man as part of the highly-integrated web which unites all forms of life. There have been many large cities in the past, but until recent times their inhabitants were able to maintain fairly close and direct contacts with the countryside or with the sea, and thus could satisfy the physiological and psychological needs acquired during the human past. Historical experience, especially during the nineteenth century, shows that urban populations are apt to develop ugly tempers when completely deprived of such contacts. Saving nature in both its wild and humanized aspects is thus an essential part of urban planning.

Wherever man has been successful in 'wooing' the land and assuring its biological viability, success has resulted from his ability and willingness to plan his creations within the constraints determined by climate, topography, and other local characteristics of Nature. In the past, this was also true of cities which were planned in accord with certain geographical imperatives. Modern cities are in contrast developing without any regard to physical and biological constraints and only under the influence of economic and political imperatives. The belief that man can 'master' the environment and achieve independence of his innate biological limitations has generated the impression that there is no need for disciplines in the development of cities. Most urban problems derive precisely from such a misapplied interpretation of freedom. Town planning as well as country planning will not be successful until we learn again to recognize and accept the restraints that are inherent in man's biological nature and in geographical conditions. In fact, the whole concept of planning, the use of our environment, or perhaps what is better described in French as *aménagement du territoire*, is only emerging as a new discipline and it is high time that it be developed all over the world on sound ecological principles.

THE SPACESHIP EARTH

One hears a great deal these days concerning the possibility of improving the genetic constitution of man, but there is no chance that this can be done in the foreseeable future and there are compelling reasons to believe that it should not even be attempted. In contrast, the experience of individual life, as well as social and historical experience, make it obvious that physical and mental individuality can be rapidly and profoundly altered by environmental factors, especially when these act on the organism during the early formative phases of its development. The practical way to improve human life therefore is by manipulating the social and physical factors of the environment; to this end it is essential to diversify the conditions and ways of life so as to take best advantage of man's genetic diversity.

Rational environmental planning cannot be done by acting under the pressure of emergency as is now the general practice. Unfortunately, the construction of great dams all over the world is prompted not by comprehensive, integrated programmes of water and land use but by the threat of floods or of water shortages. Policies for the control of soil erosion are enacted only after irreversible damage has been done. There is a general awareness of the dangers posed by noise, environmental pollution, and the misuse of drugs, but effective measures are rarely taken before some catastrophe creates an atmosphere of panic. In fact, most environmental programmes emerge as empirical adaptive responses to acute crises and usually take the form of disconnected palliative measures designed to minimize social unrest or the depletion of a few natural resources.

The failure to develop comprehensive environmental programmes is due in large part to intellectual shortsightedness and social negligence, but also to the fact that problems involving human welfare have such complex determinants that they do not lend themselves to tidy planning or to study by the orthodox analytical methods of the natural sciences. From the point of view of total human welfare, efforts to improve the rural and urban environment will remain empirical until they can be based on better knowledge of the long-range effects that environmental factors exert on physical and mental health. This will require the development of a science of human life as affected by the environment, very different from the science of things which now monopolizes the world of learning.

For lack of adequate knowledge, the environment is being manipulated almost exclusively on the basis of technological criteria without much concern for its biological and psychological effects. These effects should be considered not only in the here and now, but in their long-range consequences and in their relevance to mankind as a whole.

Before long, all parts of the globe will have been occupied or exploited by man and the supply of natural resources will have become critical. Careful husbandry of the spaceship, rather than exploitation of natural resources, will then be the key to human survival. Developing stations in outer space or on the bottom of oceans will not modify significantly if at all the physical limits of human existence. Man emerged on the earth, evolved under its influence, was shaped by it, and biologically he is bound to if forever. He may dream of stars and engage in casual flirtations with other worlds, but he will remain wedded to the earth, his sole source of sustenance.

As the world population increases, the topographical limitations of the spaceship Earth and the inevitable exhaustion of its natural resources will inevitably require that its economy be based on strict ecological principles. This imperative necessity, however, is not yet widely recognized. The very word ecology was introduced into the scientific language only 100 years ago by Haeckel—so recent is the awareness that all components of nature are interwoven in a single pattern and that we too are part of the pattern! Until now, man has behaved as if the areas available to him were unlimited, and as if these were infinite reservoirs of air, soil, water, and other resources. He could do this with relative impunity in the past because there was always some other place where he could go, start a new life, and engage in any kind of adventure that he chose. Since the evolutionary and historical experiences of man are woven in his mental fabric he naturally finds it difficult *not* to behave as a nomad and hunter. It is not natural for him to rest quietly in a corner of the earth and husband it carefully. His thoughtlessness in provoking ecological situations that are potentially dangerous originates partly from the fact that he has not yet learned to live within the constraints of the spaceship.

The ecological attitude is so unfamiliar, even to many scientists, that it is often taken to imply acceptance of a completely static system. Students of human sociology have expressed concern lest the ecologist's professional interest in the well-balanced smoothly-functioning, steady-state ecosystem of the pond be extrapolated uncritically to the whole Earth and its human population. They are right in emphasizing that man's relation to his total environment cannot be regarded as a steady-state ecosystem because this would imply that the human adventure has come to an end.

The physical forces of the environment are forever changing slowly, but inexorably. Furthermore, all forms of life including human life are continuously evolving and thereby making their own contribution to environmental changes. Finally, it seems to be one of man's fundamental needs to search endlessly for new environments and for new adventures. There is no possibility therefore of maintaining a *status quo*. Even if we had enough learning and wisdom to achieve at any given time an harmonious state of ecological equilibrium between mankind and the other components of the spaceship Earth, it would be a dynamic equilibrium, and this would be compatible with man's continuing development. The important question is whether the interplay between man and his natural and social surroundings will be controlled by blind forces as seems to be the case for most if not all animal species, or whether it can be guided by deliberate, rational judgements.

Admittedly, all of man's biological evolution so far and much of his history have been the result of accidents or blind choices. Many deliberate actions have had consequences that had not been foreseen and often proved to be unfortunate. In fact, most of the environmental problems that now plague technological civilization derive from discoveries and decisions made to solve other problems and to enlarge human life. The internal-combustion engine, synthetic detergents, durable pesticides and medicinal drugs, were introduced with a useful purpose in mind, but some of their side-effects have been calamitous. Efficient methods of printing have made good books available at low prices, but are cluttering mail boxes with despicable publications and useless advertisements; these burden waste baskets with mountains of refuse which must be burned and thus pollute the air.

Waste disposal is becoming as critical as resource production. It is obvious, from the law of the conservation of matter, that waste is produced exactly in the amount that resources are used. What is not so obvious is that, in the long run, the reverse must also be true: resource production depends upon the utilization of waste. Otherwise man will convert the biosphere into a global dump. Waste that nature cannot process accumulates and pollutes the environment. Converting such waste into a usable form not only solves a problem of pollution, but also contributes positively to environmental quality and the production of future resources.

Hopefully, we shall learn to develop techniques for predicting or recognizing early the objectionable consequences of social and technological innovations so as to minimize their effects, but this kind of piecemeal social engineering will be no substitute for a holistic philosophy of the environment, formulated in the light of human aspirations and needs. We cannot long continue the present trend of adding trivial comforts of life and correcting minor inconveniences without due regard to increasing the likelihood of environmental disasters. If the goal of technological civilization is merely to do more and more of the same, bigger and faster, tomorrow will only be a horrendous extension of today.

ENVISIONING THE ENVIRONMENTAL FUTURE

Like animal life, human life is affected by evolutionary forces that blindly fit the organism to its environment. Human history, however, involves also the unfolding of visionary imaginings. Creating a desirable future demands more than foresight; it requires vision.

The philosophers of the Enlightenment, all over the world, had imagined new ways of life long before there was any factual basis for their vision. They prepared the blueprint for most of what is new and desirable in modern societies on the faith that objective knowledge, scientific technology, and social reforms, could someday liberate human beings from fear and destitution. Throughout human history, progress has been a movement towards imagined utopian goals; the realization of these aims has in turn inspired new goals.

Mankind's greatest achievements are the products of vision. One need think only of the marvellous parks, gardens, and monuments that have survived from all great civilizations to realize the creative force of a long-range view in shaping desirable humanized environments.

The great parks and gardens all over the world originated from that extraordinary sense which is peculiar to man, the imaginary vision of things to come. For example, several books by European landscape architects of the eighteenth century show drawings of parks as they appeared at the time of their creation, with the naked banks of newly-created brooks and lakes, among puny trees and shrubs. In these drawings, the landscapes have an abstract and cold elegance, but lack substance or atmosphere. One has to assume that the landscape architects had composed the expanses of water, lawns, and flowers to fit the silhouettes of trees and the masses of shrubbery not as these components of the landscape existed when first organized but as they were to become with the passage of time. The architects had visualized the future appearance of their intellectual imaginings and planned their actual designs and plantings so as to give scope to the creative effects of natural forces.

Similar visionary anticipations account for most of the great urban sites and vistas throughout the world. To quote two examples with which I have personal familiarity, detailed historical documents (with plans going as far back as the eighteenth century) prove that the Piazza del Popolo in Rome and the Tuileries-Champs-Elysées-Étoile complex in Paris had been visualized long before social conditions and economic resources justified their existence or made them possible.

While the great gardens, parks, and urban vistas created by past civilizations still delight our senses and minds, other kinds of landscapes must be conceived to meet present and future needs. The old country roads, lined with stately trees, provided poetic and practical shelter for the man on foot or horseback and for slow-moving coaches. A modern highway, however, must be designed in such a manner that horizons, curves, trees and other objects of view are related to the physiological needs and limitations of motorists moving at high speed. The evolution of parkways and super highways involves aesthetic factors based on physiological imperatives, as much as economic and technologic determinants.

Envisioning an environment satisfying the needs of an immense technological society is of course vastly more complicated than visualizing the future appearance of a park or designing a super highway. But certain principles hold true for all environmental planning, because they are based on the unchangeable and universal aspects of man's nature that were considered in the introduction of this essay.

On the one hand, the genetic endowment of *Homo sapiens* has changed only in minor details since the Stone Age, and there is no chance that it can be significantly, usefully, or safely modified in the foreseeable future. This genetic permanency defines the human race, and determines the physiological limits beyond which human life cannot be safely altered by social and technological innovations. In the final analysis, the frontiers of cutlural and technological development are determined by man's own biological frontiers and therefore by the genetic constitution he acquired during the evolutionary past.

On the other hand, mankind has a large.reserve of potentialities that become expressed only to the extent that circumstances are favourable. The physical surroundings condition not only the biological aspects of phenotypic expressions but also their mental aspects. Environmental planning can thus play a key role in enabling human beings to realize their potentialities. One can take it for granted that there is a better chance to convert these potentialities into actual realizations when the physical environment is sufficiently diversified to provide a variety of stimulating experiences and opportunities, especially for the young.

Any change in mental attitude and in the ways of life becomes incorporated in the human group concerned through socio-cultural mechanisms, and from then on it conditions the future development of the group. Socio-cultural evolution is as much under the influence of the environment as is biological evolution, and almost as irreversible.

Living organisms can survive—whether as species or as individual specimens—only by continuously modifying some aspects of their essential being through the agency of adaptive responses to changes in the ways of life. Similarly, social structures can remain vigorous and survive only by evolving. Houses grow organically through the addition of rooms, gables, and appendages to accommodate new members of the family and new social habits, by making use of new technologies. Rural and urban environments also evolve because changing human needs, goals, and instrumentalities constitute as many forces to which environmental forces respond in an endless series of feedbacks. The word 'conservation' can be operational only if used with a meaning broad enough to imply a dynamic equilibrium between man and his environment.

From wilderness to ecologically-balanced agricultural or forested land, from princely estate to integrated rural area, from national park to city playground, from slow-paced country road to multi-lane parkway, from village to city and from suburb to satellite community, the environment endlessly evolves in response to changing human needs and aspirations. The concept of an optimum environment is unrealistic because it implies a static view of the interplay between man's nature and genetic endowment. Planning for the future demands an ecological attitude based on the assumption that man will continuously bring about evolutionary changes through his creative potentialities. The constant feedback between man and environment inevitably implies continous alterations of both—alterations that should always remain within the constraints imposed by the laws of Nature and by the unchangeable biological and mental characteristics of man's nature.

Final report

INTRODUCTION

1. The Intergovernmental Conference of Experts on the Scientific Basis for Rational Use and Conservation of the Resources of the Biosphere was held at Unesco House in Paris from 4 to 13 September 1968 in pursuance of resolution 2.23, adopted by the General Conference of Unesco at its fourteenth session.

2. In accordance with decision 4.3.3. taken by the Executive Board at its 77th session, the conference was convened and organized by Unesco, with the United Nations, the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) participating, and with the co-operation of the International Union for Conservation of Nature and Natural Resources (IUCN) and of the International Biological Programme (IBP).

3. A committee to prepare for the conference, made up of representatives of the above-mentioned organizations, met twice, in March 1967 and January 1968, to define the forms which preparatory work for the conference should take. In this connexion, it was decided that, in the context of the conference, the biosphere was to be taken as meaning that part of the world in which life can exist; it therefore includes certain parts of the lithosphere, hydrosphere and atmosphere. Work bore mainly on the terrestrial part of the biosphere, including inland waters and coastal areas, but excluding oceanic resources, which are the particular province of other international conferences; the only resources considered were biological ones, including the soils and waters on which they depend; they did not include inorganic resources, except in so far as these provide a medium for the support of plant and animal life.

4. The inaugural meeting was opened by Mr. Malcolm S. Adiseshiah, Deputy Director-General of Unesco, in the presence of Mr. A. H. Boerma, Director-General of FAO, Dr. M. G. Candau, Director-General of WHO, Mr. G. Gresford, representing the Secretary-General of the United Nations, Mr. H. Coolidge, President of IUCN and Mr. J. Baer, President of IBP.

5. In his address of welcome to the participants, Mr. Adiseshiah first presented the apologies of Mr. René Maheu, Director-General of Unesco, who was indisposed and was unable to be present on this occasion. He went on to recall that *the main aim of the conference was to seek the area in which, and show the*

means whereby, modern science might help select and develop rational methods for the use of the resources of the biosphere, while ensuring their conservation. He said that the first task of the conference would be to use the reports of Member States and the synthesizing reports drawn up by the Secretariat as a basis for evaluating the existing situation and the role of present scientific knowledge in planning the rational use of resources. He stressed that it should then determine the main lines of action to be taken, at national and international level, to ensure the rational use and conservation of these resources, with particular reference to problems of research and education, and to those of scientific policies and structures which bore on such use and conservation.

6. During the inaugural meeting, the conference heard three speeches delivered by Dr. Candau, Mr. Boerma and Mr. Gresford.

Dr. M. G. Candau, Director-General of WHO, spoke on 'Human health in relation to the biosphere and its resources'.

Mr. A. H. Boerma, Director-General of FAO, spoke on 'Food requirements and production possibilities'.

Finally, Mr. G. Gresford, representing the Secretary-General of the United Nations, dealt with the 'qualitative and quantitative living space requirements of society'.

The texts of these speeches and the address of welcome are printed in the following chapter.

7. The conference then elected its chairman. Nominated by Australia, with the support of Madagascar and Brazil, Professor François Bourlière, head of the French delegation, was elected Chairman of the Conference.

8. The conference adopted its rules of procedure, which provided, in particular, for the setting up of three commissions on research, education and scientific policies and structures respectively. The conference then elected its Steering Committee, which was made up as follows:

chairman: Professor F. Bourlière (France);
vice-chairmen: Professor C. Chagas (Brazil); Professor I. Gerasimov (U.S.S.R.);
rapporteur-general: Professor Stanley A. Cain (U.S.A.);
chairman of the Research Commission: Professor A. R. Clapham (United Kingdom);
chairman of the Education Commission: Mr. Jan Cerovsky (Czechoslovakia);
chairman of the Policies and Structures Commission: Mr. C. S. Christian (Australia);
members elected by the conference: Professor Hans Luther (Finland); Professor T. Watanabe (Japan); Mr. M. G. Ramalanjoana (Madagascar).

The delegate of Belgium expressed reservations regarding the election of the chairmen of commissions by the conference itself.

9. The following sixty-three Member States were represented at the conference:

Algeria
Argentina
Australia
Austria
Belgium
Brazil
Burundi
Byelorussian S.S.R.
Cambodia
Canada
Ceylon
Chile
China
Congo, Democratic Republic of
Czechoslovakia
Denmark
Dominican Republic
Ecuador
Finland
France
Gabon
Federal Republic of Germany
Guatemala

Honduras
Hungary
India
Indonesia
Iraq
Ireland
Israel
Italy
Ivory Coast
Japan
Kenya
Lebanon
Madagascar
Mali
Monaco
Morocco
Netherlands
New Zealand
Nicaragua
Norway
Peru
Poland
Romania
Saudi Arabia
Senegal
Somalia
Spain
Sweden
Switzerland
Thailand
Togo
Turkey
Ukrainian S.S.R.
U.S.S.R.
United Kingdom
United States of America
Upper Volta
Uruguay
Venezuela
Republic of Viet-Nam

The Holy See, a non-Member State, was also represented.

The composition of delegations will be found in 'List of participants' at the end of this volume.

In addition to the United Nations, the Food and Agriculture Organization of the United Nations (FAO), and the World Health Organization (WHO), which took part in organizing the conference, and the International Union for Conservation of Nature and Natural Resources (IUCN) and the International Biological Programme (IBP), which co-operated therein, three organizations of the United Nations system were represented: the United Nations Development Programme (UNDP), the International Labour Office (ILO), and the World Meteorological Organization (WMO). Also represented were six intergovernmental organizations and twelve non-governmental international organizations, as well as three foundations, as shown in the 'List of participants'.

10. After considering the proposals regarding the agenda submitted by the Secretariat, the conference adopted the following agenda:

1. Opening of the meeting by the Director-General of Unesco.
2. Election of the chairman.
3. Adoption of the Rules of Procedure.
4. Election of vice-chairmen, the rapporteur-general and the chairmen of commissions.
5. Adoption of the agenda.
6. Setting up of the Steering Committee (election of three additional members)
6. Setting up of the Steering Committee (election of three additional members).
7. Setting up of commissions.
8. Introductory addresses to the conference.
9. Scientific concepts relating to the biosphere.
10. The impact of man on the biosphere.
11. Consideration of reports presented by Member States.
12. The role of scientific knowledge in planning the rational use of the resources of the biosphere.
    (a) Soils and maintenance of fertility as factors affecting the choice of land use;
    (b) Water resource problems in the light of present and future biological needs;
    (c) Non-oceanic aquatic environments, their preservation and the harnessing of their resources on a rational basis;
    (d) Natural vegetation and its modifications for rational land use;

(e) Animal ecology, animal husbandry and effective wild-life management;
(f) Preservation of natural areas and ecosystems; protection of rare and threatened species;
(g) Problems of environmental deterioration: air, water and soil pollution;
(h) Man and his ecosystems; the aim of achieving a dynamic balance with the environment, satisfying physical, economic, social and spiritual needs.

13. Main lines of action for securing more rational use and conservation of resources at national and international level;
   (*a*) Research Commission;
   (*b*) Educational Commission;
   (*c*) Scientific Policies and Structures Commission.
14. Recommendations to Member States and international organizations.
15. Adoption of final report and closure.

SCIENTIFIC CONCEPTS RELATING TO THE BIOSPHERE

11. This working paper on item 9 of the agenda was prepared on the basis of a draft submitted by Professor V. Kovda and his collaborators (U.S.S.R.) with comments and additions by Professor Frederick Smith (U.S.A.), Professor F. E. Eckardt (Denmark), Dr. M. Hadley (United Kingdom), Dr. E. Bernard (Belgium) and the Secretariats of Unesco and FAO, and was presented by Professor V. Kovda.

12. The document introduced the principal concepts concerning the structure, functioning and genesis of the biosphere. Five basic principles were broughtout: (a) the biosphere has evolved as a whole and functions as a whole; (b) it is endowed with a considerable plasticity enabling it to re-establish its functional equilibrium when certain modifications occur, whether natural or induced by man; (c) the plasticity of the biosphere is limited, depending on the type of ecosystem considered, the mode of intervention applied and the rate of change; (d) the demographic pressure and the evolution of the structure of society will entail, inevitably, increasing modifications of the biosphere; (e) a rationalization of use of the resources of the biosphere on a world-wide scale is imperative if satisfactory living conditions of future generations are to be guaranteed. Examples were given of the structure and functioning of various ecosystems, special stress being laid on the biogeochemical role of living organisms. The importance of losses in the food chain between primary producers and man was underlined. The promotion of research on ways and means to increase in quantity and improve in quality, food products essential to man, was recommended.

13. The delegates of Australia, Belgium, Brazil, the United States of America, Hungary, Israel, Italy and the Netherlands, as well as the representatives of FAO and WMO took part in the discussion. Views were expressed emphasizing the importance of research being undertaken on the genesis of the biosphere and its components both on the geological and human scale, that global and analytical studies of the structure and functioning of the ecosystems should be carried out side by side, that closer collaboration between mathematicians,

physicists and biologists should be promoted, that feasibility studies on artificial closed ecosystems should be initiated, that the ecological data presently available be better exploited (data banks) and present experience better used, for instance the meteorologists' handling of their data, that ecological research be organized on a regional or a world-wide basis, that effects of ionizing radiation resulting from nuclear experiments be more thoroughly studied, that models for prediction be established, that data on actual and potential production, on the degree of stability of the ecosystems as well as their response to management and economic value, be mapped. Particular emphasis was laid on the importance of the integrated research approach in the field of ecology.

IMPACT OF MAN ON THE BIOSPHERE

14. The working paper on item 10 of the agenda was prepared by Dr. F. Fraser Darling (United Kingdom), with comments and additions by Dr. Vladimir Sokolov (U.S.S.R.), Professor Frederick Smith (U.S.A.), Professor François Bourlière (France) and the Secretariats of Unesco and FAO, and was presented by Dr. F. Fraser Darling.

15. The document emphasized the importance of man as a major factor in modifying the biosphere, in keeping it in health or in disarrangement. Regarding man's past and present impact on the biosphere, even in his early food gathering, hunting, fishing and farming stages man had the capacity to modify drastically his local environment. Depletion of natural resources has taken various paths such as deforestation, over-hunting and over-fishing, drainage of wetlands and deliberate extinction of species. Special emphasis was given to the impact of present civilizations on the biosphere by discussing the consequences of mining and other industrial processes and the consequences of human population crowding. Pollution was featured as a major international issue; it affects air, water and soils, and has consequent deleterious effects on vegetation, animals and man. The need to develop multidisciplinary teams to find satisfactory solutions to development problems was emphasized. As evidence of positive accomplishment and man's ability to improve his environment and his health, several examples were described in which man's activities have contributed to the maintenance of environmental quality and the guarding against unbalanced technological action.

16. The delegates of Argentina, Federal Republic of Germany, Senegal, Ireland, Italy, France, Kenya, U.S.A., and the representative of FAO participated in the discussion. Delegates confirmed that pollution is one of the major problems facing humanity at present and that it may ultimately be important in limiting the earth's population through deterioration of man's physical and mental health. Decreasing living space was suggested as of even greater long-term significance. Positive ideas for improving man's use of the biosphere included genetic improvement of plant and animal species (including fish), creation of gene pools, reclamation of waste lands, stabilizing marginal lands which are being downgraded (especially those subject to over-grazing or destructive forest exploitation), and preventive regulations on pollution and damage, as well as mismanagement of natural resources, to be enforced long before social, economic or ecological conditions become critical, especially in developing countries.

The important question of plant and animal introductions was mentioned and it was noted that the resulting changes usually simplified ecosystems. Consideration of the productivity of natural ecosystems and how best they can be cropped before they are exchanged for something which may be less desirable in the long view, was suggested as a principle for serious consideration. Conversely, the possibility of modifying ecosystems so as to improve productivity was recognized. With these ideas in mind the tremendous difference in susceptibility to damage between various ecosystems was noted. Although integrated surveys and planning were recognized as laudable recent trends in the approach of biologists and land use planners, the great need for this common-sense approach to be adopted by politicians and by the general public was emphasized.

CONSIDERATION OF REPORTS PRESENTED BY MEMBER STATES

17. Some twenty Member States distributed prepared national reports highlighting their past work, present problems, and future prospects in regard to the rational use and conservation of their environmental resources. Delegates from the following thirty Member States made oral presentations, in the following order, to the conference:

Australia	Spain	United Kingdom	Belgium
Argentina	Hungary	Israel	Iraq
Finland	Lebanon	Poland	Ireland
U.S.S.R.	Japan	Madagascar	Democratic Republic of the Congo
Federal Republic of Germany	Byelorussian S.S.R.	Romania	Thailand
United States of America	Ukrainian S.S.R.	Canada	Italy
Mali	Sweden	Senegal	
	Morocco	France	
		Czechoslovakia	

18. From this general debate some recurring themes emerged which can be summarized as follows:

(a) A new awareness of the loss of environmental quality is occurring throughout the world. Although some of the changes in the environment have been taking place for decades or longer, they seem to have reached a threshold of criticalness, as in the case of air, soil and water pollution in industrial countries; these problems are now producing concern and a popular demand for correction.

(b) Parallel with this concern is a realization that traditional ways of developing and using natural resources must be changed from simple purpose efforts, both public and private, with little regard for attendant consequences, to other uses of resources and wider social goals, and must give way to recognition that the biosphere is a system all of which is widely affected by action on any part of it. As a result, one of the constantly recurring themes was that planned use of natural resources must be based on an integrated interdisciplinary approach.

(c) A further consequence of this new awareness is that man is a key factor in the biosphere and that natural science and technology alone are inadequate for modern solutions to resource management problems; one must also consider social sciences in particular, politics and public administration, economics, law, sociology and psychology, for after all, it is resources as considered by man with which we are concerned.

(d) These conclusions lead also to recognition of a need for improved education and public information. Scientists and technicians must be prepared to work in integrated teams, young people must be prepared to accept responsibility, the public must understand the requirements for an environment suitable for man, and decision-makers must be provided with the facts upon which they can base their decisions. The biosphere must be repaired where it has deteriorated and its productivity must be enhanced wherever possible, particularly the intensification of agriculture, not only because of present and projected needs but also because of the growing population which cannot be quickly checked no matter what efforts may be taken in the foreseeable future.

(e) In order to accomplish these purposes a vast amount of research is necessary in all aspects of the biosphere, including especially the integrative synthesizing science of ecology. This is needed in the developed as well as the developing countries where assistance is indicated, and in many instances co-operatives international efforts are required. The need to create, in developing countries, satisfactory conditions for undertaking necessary studies and research, was stressed. Since there is no universal solution to the problems of the biosphere, understanding and techniques will have to be adapted to areas within countries and regions involving two or more countries, as in the case of arid regions, countries surrounding the Amazon Basin, the Baltic, the Mediterranean, and international lakes and rivers, industrialized countries contributing widespread pollution of air, water and soil, and for purposes of nature protection as for migratory water fowl, fishery resources and international parks. Many delegates said that a wide range of facts must be brought to bear on planned resource use and that knowledge is needed as a basis for management and policy decisions affecting the biosphere. There being a wholeness in nature, as shown by ecosystems, there must be consideration of the entire systems of nature because limited single-purpose actions are no longer tolerable. Conservation started as ameliorative efforts and attempts to repair past mistakes; it is now moving on to the prevention and the avoidance of undesirable changes and the enhancement of the productivity of ecosystems.

(f) Another constant theme in the remarks of Member States was the need for nature protection, and a most encouraging report is that many nations are now establishing national parks, wildlife and plant refuges, and numerous smaller natural areas for the protection of gene pools, rare and threatened species and ecosystems. In general, such areas are available for research to provide baselines for comparison with managed and artificial ecosystems.

19. Many specific situations were described, and recommendations made, in order to illustrate the nature of problems being studied, and to indicate successes achieved. Several delegations also made specific suggestions for broad plans for international action. All appropriate suggestions were referred to the commissions for further consideration.

THE ROLE OF SCIENTIFIC KNOWLEDGE IN PLANNING THE RATIONAL USE OF THE RESOURCES OF THE BIOSPHERE

20. This discussion of item 12 of the agenda set out to highlight the scientific bases, ecological ones in particular, for the rational use of the resources of the biosphere. The conference had at its disposal for this purpose eight review papers which were used as a basis for discussion. The content of each paper, and the resulting discussion, are summarized below.

SOIL RESOURCES

21. The review paper on soils and maintenance of fertility as factors affecting the choice of land-use was prepared by Professor G. Aubert (France), was commented upon and supplemented by Dr. F. Fournier (France) and Dr. B. Rozanov (U.S.S.R.) and by the Secretariats of FAO and Unesco, and was presented by Professor G. Aubert (France).

22. The document defined the general role of the soil in the biosphere, and then dealt with the concept of fertility, emphasizing the distinction between existing and potential fertility. The need for familiarity with soils and their distribution, accompanied by their appropriate mapping, was stressed. The problem of using soils under their various aspects, for vegetation, for industrial and urban activities, as the provider of minerals or building materials, was discussed. The fact that the soil and fertility develop in accordance with each type of use was underlined. In conclusion, the possibilities of choice in using the soil and suggested priorities for such use, varying with economic and political circumstances were indicated and several topics which ought to be considered by the commissions were suggested.

23. The delegates of the Federal Republic of Germany, Hungary, Spain, Belgium, Israel, the Byelorussian Soviet Socialist Republic, Poland, Netherlands, Italy, Australia, Lebanon and Canada, and the representatives of FAO and IUCN participated in the discussion or submitted written notes.

24. In the course of the debate, emphasis was placed on the usefulness of inventories and of pedological maps on different scales and for a variety of applications, and also on the study of the characteristics which determine productivity. With regard to basic research, four main points were stressed: (a) the importance of an over-all study of the environment and of the relationship of the soil to the ecosystem as a whole; (b) the general evolution of soil as a result of cultivation and the studies of balances (water balance, the carbon balance, the comparison of pedogenesis and erosion, the nitrogen cycle); (c) soil biology; and (d) the factors that favour or limit productivity, including socio-economic ones. Emphasis was also placed on the importance of certain regional and development studies (organic matter in arid zones, crop rotation and intensive cultivation, salinization) and on research on certain special subjects such as the variable requirements of plants in the course of their development, the abusive use of fertilizers in intensive cultivation and their eventual polluting effect, the best use of organic fertilizers including composts, and the possibility of producing soils artificially. Attention was drawn to the fact that immense

quantities of nitrogen in the atmosphere are not sufficiently utilized in biological fixation of this element as, for example, in legume-rhizobium symbiosis. Finally, the importance of correctly allocating soils to specific uses (construction of towns, landscapes planning, location of cultivated areas) and the need for general and technical education, were also underlined.

WATER RESOURCES

25. The review paper on water resources problems—present and future requirements for life—was prepared by Dr. H. C. Pereira (United Kingdom), commented upon and supplemented by the following experts: Dr. S. Dumitrescu (Romania), Dr. H. L. Penman (United Kingdom), Dr. K. Szesztay (Hungary), Dr. J. Nemec (Czechoslovakia) and Dr. R. L. Nace (U.S.A.), and by the Secretariats of Unesco, WHO and FAO, and was presented by Dr. K. Szesztay (Hungary).

26. The extent to which water is essential to man and its central role in the biosphere was emphasized. This was followed by an analysis of water balance and a short description of what had been done on an international scale both to awaken public opinion and to co-ordinate studies such as those of the International Hydrological Decade or those concerning international legislation on water. The necessity of combining economic and scientific approaches in studies of water resources was stressed. The conclusion referred to the research disciplines relevant to the study of water, the importance of knowing the minimum stream flow to be maintained for biological requirements and, finally, the utility of studies on the origin of water in the biosphere. Dr. Pereira, invited to speak on this presentation, underlined the danger of a water shortage should *per capita* consumption of water and the population continue to increase. He mentioned the importance of watershed protection and management, the need to control vegetation and wild life as factors in the hydrological cycle and, lastly, the high proportion of water resources already suffering from pollution.

27. The delegates of the United Kingdom, the Federal Republic of Germany, Italy, Israel, Australia, France, Hungary, Byelorussian Soviet Socialist Republic, Netherlands, Canada, Brazil and Belgium, and the representatives of FAO and IUCN participated in the discussion or submitted written notes.

28. During the debate, emphasis was placed on the usefulness of inventories and maps, in particular quantitative and qualitative studies of surface and underground waters, maps showing the quality of water, and an international system for classifying waters. Studies concerned with the water balance were recommended, in particular those concerned with treating vegetation to reduce evapo-transpiration, and scientific studies of watersheds. Stress was also placed on management and storage of water, particularly in water basins and for agricultural, grazing and forestry purposes as well as for wild animals and fish. Reference was made to the problems concerning water pollution, the effect of polluted water, the purification of water, the use of purified water and the fight against pollution, as well as the desalinization of water, especially that of brackish waters. Supplementary action in regard to hydrological observations and exchange of information on water resources, stimulated by the International Hydrological Decade, were regarded as of major importance in view

of the increase in world requirements. There was no further discussion as to future action, in view of the special meeting scheduled for 1969, midway in the Decade, when this question will be examined. Finally, mention was made of the problem of training highly competent experts to study and develop water resources.

LIVING AQUATIC RESOURCES

29. The working document on the scientific basis for the conservation of non-oceanic living aquatic resources was prepared on the basis of a draft submitted by Dr. W. A. Dill and Dr. T. V. R. Pillay of FAO, with comments by Messrs. A. E. Bonetto (Argentina), K. Kuronuma (Japan), J. Lemasson (France). H. Sioli (Federal Republic of Germany), R. H. Stroud (U.S.A.), G. Swärdson (Sweden), and E. B. Worthington (United Kingdom) and the Secretariats of FAO, WHO and Unesco, and was presented by Dr. G. N. Mitra (India).

30. As explained in this document, non-oceanic living aquatic resources consist of fish and various other fauna and flora. The annual reported commercial harvest of fish from inland waters is estimated at 7 million metric tons, plus possibly 2-3 million tons from fish culture. The level of exploitation of the resources is low, mainly for lack of a proper scientific basis for conservation, the latter being interpreted to mean 'wise management and utilization of natural resources for the greatest good to the greatest number'. The ecosystems of inland waters are particularly fragile and hence susceptible to man's activities which cause environmental changes affecting the living resources. It is therefore necessary to control as much as possible the environmental factors. This appears particularly promising in relation to the physiochemical and biological features. Better knowledge of aquatic fishery biology and management, harvesting and processing methods, participation of aquatic biologists in planning and execution of aquatic and terrestrial development projects (hydroelectric and irrigation projects), co-ordination among various agencies and adequate trained personnel at all levels, are some of the most urgent needs.

31. The delegates of Finland, Kenya, Madagascar, Canada, and the representatives of FAO and the IUCN participated in the discussion or submitted written notes.

32. The discussion centred mostly around the desirability of considering multiple uses of streams, lakes and wetlands where incompatibilities may arise in some cases. Besides the production of living aquatic resources, doubtless a primary beneficial use of water, many different aspects such as recreation, aesthetic considerations and the use for scientific reasons, should be considered. Hence co-ordination in management and planning of aquatic resources for present and potential users or in connexion with interested agencies is indispensable. The present scope of international projects AQUA and MAR was explained and attention was drawn to the preservation of a network of samples of natural aquatic ecosystems. It was also stressed that better information is needed as a basis for management before effective legislation can be enacted. Biologists should participate in policy making and in planning for development. Finally, the need to train specialists for developing countries was advocated.

VEGETATION RESOURCES

33. The working document on natural vegetation and its management for rational land use was prepared by Professors H. Ellenberg (Federal Republic of Germany) and J. Lebrun (Belgium), with comments and additions by the Secretariats of FAO and Unesco, and was presented by Professor J. Lebrun.

34. This document analysed the increasing impact of man on vegetation over the millenia from the early forms of protoculture to the 'anthropization' of nature in our industrialized world as well as the main cultural systems adopted with their repercussions on the equilibrium of ecosystems. Extreme examples of failure of some low productive agricultural systems and the success of highly intensified ones were given and explained by the same fundamental ecological laws which govern both natural and man-made ecosystems. The wise and profitable use and management of vegetation should not contradict the fundamental processes of energy flux and geochemical cycling. Some main causes of disequilibrium in ecosystems were described, such as soil degradation, alteration of geochemical cycles, salinization, changes in water balance, changes of biotic relations in biocenoses, etc. The improvement of the productive capacity of ecosystems or the creation of new ecosystems implies their rational management based upon a good knowledge of local plant species and their most suitable exploitation techniques, and a thorough study of plant-environment relationships. The best results can only be obtained through an interdisciplinary approach to the problems raised by agricultural and forestry planning. The final conclusion emphasized the essential role of ecologists in the management of rural areas.

35. The delegates of the Ukrainian Soviet Socialist Republic, United Kingdom, Hungary, Federal Republic of Germany, Spain, Belgium, Algeria, and the representatives of FAO and IUCN participated in the discussion or submitted written notes.

36. In this debate the need for the development of an integrated and interdisciplinary approach to the problem of management of vegetation, both natural or 'domesticated', was repeatedly emphasized and specific proposals were made for intensified research on the biology of adaptation of economic species, both in natural and man-made ecosystems. The collection of precise data on the structure and productivity of various ecosystems and in as many countries as possible was recommended. It was felt that new standardized methods for the assessment of plant resources and their potential reserves for further utilization should be developed and also that more attention should be paid to the economic parameters which should be taken into consideration for any rational exploitation. The necessity for strengthening international co-operation in promoting the collection, conservation, evaluation and use of genetic resources, either primitive or already improved and domesticated, was pointed out. With reference to the need for more efficient agricultural and forestry planning, the availability of inventories of vegetation, both quantitative and qualitative, as well as more elaborate maps providing in as simple form as possible integrated information on the main components of the environment, synthesizing data on soils, climate, vegetation and other factors, was stressed. A plea was made for 'management maps'.

ANIMAL RESOURCES

37. The working document on animal ecology, animal husbandry and effective wildlife management, prepared by Dr. D. Tribe (Australia) with comments and additions by Dr. K. Curry Lindahl (Sweden), Dr. J. Pagot (France), Dr. V. Sokolov (U.S.S.R.), Professor F. Smith (U.S.A.) and the Secretariats of FAO, WHO and Unesco was introduced by Dr. D. Wasawo (Kenya).

38. This document emphasized that the problems of animal husbandry and wildlife management deserve high priority in terms of scientific and economic planning. Animals need to be managed and controlled in ways that in the long run will maintain an ecological balance favourable to human well-being. The need to use efficiently animal protein resources has never been more urgent and the global shortage of animal protein is serious. In many efficient forms of land-use, animals form an essential part of the ecosystem. Of the sixteen major domestic animals most are chosen not for their ecological suitability but by the traditional demand for well-known products and a familiarity with basic techniques of husbandry. Moreover, production from these domestic species may be increased by modern techniques of nutrition, genetic selection and disease control. Wildlife may contribute as a supplementary or major form of land-use, as a source of protein, leather, fur, hunting for sport or by attracting tourists to see and photograph animals, particularly in parks and reserves. Recent progress in the selection of a wide spectrum of wild herbivores and their management to produce protein and other products from degraded or marginal lands shows great promise and is an important subject for future research and application for development.

39. The delegates of Czechoslovakia, U.S.A., U.S.S.R., Italy, Madagascar, and the representatives of FAO and IUCN participated in the discussion or submitted written notes.

40. Delegates recognized the present and increasing importance of wildlife as a source of protein and other values and with a capacity for integration into a variety of ecosystems, especially those in imbalance through other forms of land-use. Its importance as a tourist attraction was strongly emphasized. Wildlife requires consideration in the early stages of land-use planning. The lack of an all-purpose beast to satisfy all needs was noted. The importance of mixed herds of domestic and wild animals was stressed. Attention was drawn to the wide spectrum of ecologically adapted wild African herbivores in maintaining stable ecosystems and in producing a high biomass as a result of over thirty species co-existing in some areas. The need for plant and animal genetic research to be oriented ecologically was noted, as was the need for research on the ecology of both domestic and wild animals, the potential capacity of various ecosystems to produce wildlife, problems of competition and the exchange of disease between wild and domestic animals. The role of invertebrates and micro-organisms in the cycling of elements was mentioned. The need for education and training at all levels was advocated.

PROTECTION OF AREAS AND SPECIES

41. The working document on preservation of natural areas and ecosystems and the protection of rare and endangered species was prepared by Professor

Stanley A. Cain (U.S.A.) with comments and additions by Dr. V. Sokolov (U.S.S.R.), Professor F. Smith (U.S.A.), Dr. K. Curry Lindahl (Sweden), Dr. J. C. de Melo Carvalho (Brazil), Sir Otto Frankel (Australia) and Mr. P. Scott (United Kingdom), and the Secretariats of Unesco and FAO, and was presented by Dr. J. C. de Melo Carvalho.

42. This document dealt with the definition of natural as well as man-dominated natural areas and ecosystems, their characteristics and significance to man, particularly in connexion with their present role in the functioning of the biosphere. Problems relating to their conservation were highlighted and stress was laid on the urgency of action, based on sound ecological planning involving multidisciplinary, multi-agency, public-private action. Such planning must also be compatible with historical and cultural characteristics of different nations. In relation to the survival or protection of rare and endangered species, the need for research was strongly emphasized since extinction is due not only to the action of man but also to natural processes (geological, climatic, hydrological, biological). Laws and regulations, as well as international collaboration are most useful tools but the first requisite for survival of any living organism is an appropriate and adequate habitat. Protection must be clearly recognized as a valid objective not only for economic reasons but also for aesthetic appreciation and ethical beliefs. The present heritage must be transmitted within the limit of existing possibilities through the preservation of adequate samples which will anticipate the demands of future generations.

43. The delegates of the Byelorussian Soviet Socialist Republic, U.S.S.R., New Zealand, Spain, Australia, Senegal and the representative of IUCN participated in the discussion or submitted written notes.

44. It was pointed out that some species formerly in danger of extinction such as the mink and the Saiga antelope are at present being bred in such numbers that they may be exploited commercially. The dangers of introduction of exotic species without previous exhaustive studies was emphasized, since this may cause serious damage to local ecosystems. The diminishing or even extinction of local genotypes was also considered, especially when these are not yet well known. There are fragile species and ecosystems that require special attention. Moreover, the legitimate interest in conservation should not outweigh the need for ecological control of certain obviously harmful species that are neither rare nor in danger. However, the choice of methods to achieve this aim should be based on detailed ecological studies that will take into full account the consequences of such action. In this connexion the study of ecological problems involved by crop parasites that take refuge in natural vegetation was stressed. Attention was called to the important role played by national organizations as well as by IUCN and the World Wildlife Fund. International collaboration again was considered a basic necessity to achieve the aims of preservation and protection.

DETERIORATION OF THE ENVIRONMENT

45. The working paper for the problems of the deterioration of the environment was based on a draft submitted by WHO and prepared by Dr. Abel Wolman (U.S.A.), with specific contributions on air pollution by Professor L. T. Friberg (Sweden) and on soil pollution by Professor H. Shuval (Israel) and with

comments and additions by the Secretariats of Unesco and FAO. It was presented by Dr. A. Wolman.

46. This document recognized that wherever man exists he creates wastes and in so doing interferes with small or large ecosystems. These interferences are not always disastrous, and may actually be beneficial when properly controlled. The use of domestic sewage for agricultural enrichment has been practised for centuries, at times to advantage but sometimes spreading disease.

The resurgence of interest in the quality of the environment is primarily due to rapid growth of urbanization, industrialization and population. All of these in concert have intensified the already familiar problems and have highlighted the necessity for their more rapid solution and abatement. In addition, the great advances in chemical technology have resulted in literally hundreds of new compounds—many of them characterized by non-degradability, unknown toxicity and indiscriminate use.

The technology is available for many correctives. For others, research is required. Although some conditions are better than they were a few decades ago, there are constraints to rapid abatement, namely in law, administrative machinery money, superior priorities in economic development, manpower deficiencies, public understanding and governmental motivation. Success in abatement will require multidisciplinary action, the use of modern tools of analysis, continuity of monitoring and assessment and strengthening of central and local controls. Caution is needed in extrapolation of data very far into the future because technical and societal conditions can change rapidly.

47. The delegates of France, U.S.A., Italy, Madagascar, U.S.S.R., Lebanon, Ireland, Netherlands, Hungary, Argentina, Australia, Federal Republic of Germany, Ukrainian S.S.R., and the representatives of FAO and WHO participated in the discussion or submitted written notes.

48. Basic data and background information on pollution are lacking in many parts of the world. It was pointed out that with increasing population, urbanization and industrialization man is faced with the need to accept purities of air, water and soil which may be less than those considered to be the most desirable or even the most achievable if purity were the sole criterion. It is therefore necessary to choose among alternatives, to make compromises. Such choices are often influenced by what a biologist or an engineer feels is the desirable state of the human environment. These opinions are too often based on theories, or even data, which may not be relevant to man in his present and probable future cultures. It therefore becomes necessary to bring more data from the behavioural sciences, such as psychology and sociology, into the analysis of these problems. And even when the desirable path seems well defined, man's capacity to achieve his goals must be examined and it is necessary to turn to economics, political science, and the social sciences for guidance.

Much discussion was also devoted to the significance of the newer products of modern times, many of which have long lives, e.g., plastics, ionizing radiation. Similarly, synthetic chemicals pose additional hazards of insufficiently known toxicity to plant, animal and human life, where these are widely used as pesticides and therefore disturb ecosystems because they degrade very slowly or not at all.

Certains forms of land utilization result in high amounts of suspended soil particles in the waters, which may be considered a form of pollution. The meteorological conditions under which air pollutants are dispersed and accumulated should be recognized, particularly in urban planning.

Much epidemiological research is required to clarify the relationship between the constituents of air, water and soil and the diseases of man, animals and plants. Green space for urban areas, protection of watersheds, prevention of noise, and prevention of zoonoses by air should be noted.

The desire was expressed that some international agency provide normal cost data for abatement devices, public and industrial, which would be useful guides for governments. Proposals for legislation controlling the use of insecticides were described as being in preparation by joint international bodies.

HUMAN ECOLOGY

49. The working document on man and his ecosystems; the aim of achieving a dynamic balance with the environment, satisfying physical, economic, social and spiritual needs was prepared on the basis of a draft submitted by Professor René Dubos (U.S.A.) with comments and additions by Dr. Marion Clawson (U.S.A.), Dr. F. Fraser Darling (United Kingdom), Professor F. Bourlière (France), and the Secretariats of Unesco, FAO and WHO. It was presented by Professor K. Buchwald (Federal Republic of Germany).

50. This working document stressed that the genetic endowment of *Homo sapiens* has probably not undergone any significant alterations since the late Stone Age and there is no indication that it will change significantly in the near future. It is an illusion that man could enlarge the range of his genetic adaptabilities and thus escape from the bondage of his evolutionary past. Man can function only to the extent that he maintains or creates around himself a microenvironment within the range of his natural tolerance. It is obvious that man's phenotypic manifestations have changed with time and differ from place to place. The wide range of genetic potentialities of man becomes practical reality through the creative effects of the responses that each person makes to environmental stimuli or challenges.

Whether the challenges come from physical or social forces, the diversity of environments is of crucial importance for the evolution of man and his societies because the ultimate result of a stereotyped and equalized environment can be and often is an impoverishment of life, a progressive loss of the qualities that we identify with humanness and a weakening of physical and mental health. Our policy should be to preserve or to create as many diversified environments as possible. Richness and diversity of physical and social environments constitute a crucial aspect of adaptation of functions to needs, whether in the planning of rural and urban areas, the design of dwellings or the management of individual life.

Professor Buchwald then added the following ideas: (a) it is a necessity to develop ecology towards 'landscape-ecology'; (b) the development of the concept of 'human ecology', in the true ecological sense both on the social and biological levels, is urgently needed; (c) more research on the influences of a diversified or stereotyped environment on man is necessary; (d) ultimately, it is necessary to produce a series of plans adapted to the varying conditions and containing the proposals for protecting and developing the landscape on an ecological basis for a modern industrial society, e.g., proposals for a healthy and ecologically rich environment, for a land-use of an optimal and sustained productivity and for preventing damages. Professor Buchwald also pointed out that the evolution of mankind has progressed at a very fast rate in relation to other living organisms because of the phenomenon of cultural evolution, a characteristic unique and exclusive to man.

51. The delegates of Australia, Federal Republic of Germany, Argentina, France, Spain, U.S.S.R., Ukrainian S.S.R., Italy, Israel, Canada and U.S.A. took part in the discussion.

52. It was pointed out that, in the course of human history, there was an epoch of great discoveries which started about 10,000 years ago when domestication of most species of animals and plants used at present took place. What were the origins of these discoveries? Throughout history there have been great changes in the way man uses natural resources. The biology of domestication and its consequences are little known and Unesco was asked to hold a series of symposia on this theme.

Several health aspects were then discussed, particularly genetic effects on the human population through natural selection and possible human manipulation of genes and the largely unknown effects of chronic exposure to low levels of harmful chemicals by workers in various industries. Many points can be summed up by saying that epidemiology should become more ecological. The importance of trace elements in the quality of foods and man's ability to control the proper balance in mineral cycling was illustrated in relation to environmental changes. Much discussion was devoted to the need of developing new policies as a result of the increase of population growth and the technological revolution and these should take into account the socio-cultural factors in order to operate effectively. Emphasis was placed on the need to study the problems of human environment not only in developed industrialized countries, but equally as they already occur and might appear with the rapidly changing traditions in developing countries. The search for 'pleasure of living' and for 'quality of life' were abundantly stressed in the discussion.

RESEARCH PROBLEMS

53. The Commission on Research under the chairmanship of Professor A. R. Clapham (United Kingdom), elected as its vice-president Professor H. Ellenberg (Federal Republic of Germany), and as rapporteur Dr. W. H. Van Dobben (Netherlands).

54. The following Member States participated in the work of the commission: Algeria, Argentina, Australia, Austria, Belgium, Brazil, Byelorussian S.S.R., Cambodia, Canada, Ceylon, Czechoslovakia, Democratic Republic of Congo, Denmark, Finland, France, Gabon, Federal Republic of Germany, Hungary, Indonesia, Iraq, Ireland, Israel, Italy, Ivory Coast, Japan, Lebanon, Madagascar, Mali, Morocco, Nicaragua, New Zealand, Netherlands, Norway, Peru, Poland, Senegal, Spain, Sweden, Switzerland, Thailand, Togo, Ukrainian S.S.R., U.S.S.R., United Kingdom, Upper Volta, United States of America, Venezuela and Viet-Nam, as well as representatives of organizations of the United Nations system:

United Nations, FAO, WMO, WHO, UNDP, of intergovernmental organizations, international and non-governmental organizations including IUCN and IBP.

The conference, after examining the report of the commission, approved the following conclusions and recommendations.

ECOSYSTEM RESEARCH

55. Particular stress was laid on the importance of research on the functional aspects of ecosystems. Knowledge about the functioning of ecosystems is very scanty in spite of the fact that it forms the essential conditions for good management. Such research should be based both on the global and the analytical approach. The global approach would comprise studies on total biomass and its variations with time, energy flow, efficiency of energy conversion (photosynthesis, energy conversion between trophic levels), evaluation of input and output of energy and mass as well as internal transfer processes. Emphasis was laid on nitrogen fixations, biogeochemical cycles, soil biology, biogeochemical activity of living organisms and water-soil-plant interrelationships. The analytical approach will take into account problems of response of single individual plants and other organisms to changes in external and internal factors as well as the establishment of laws governing the exchange of energy and mass between organisms and the environment. It was also stressed that research is needed on the influence of climatic conditions and their variations on ecosystems and particularly on land- and water-use potentialities.

56. The problem of response of the whole ecosystem to external influences (e.g., management) was brought out. Comparative studies should be made on actual and potential production and on the effects of changes of structure on the functioning of the ecosystem. Changes with time in the functioning should not be neglected (seasonal changes, phenology, evolution of the structure and functioning of the ecosystem). A more theoretical aspect was commented on: the reduction of entropy during the evolution of the ecosystem.

57. In order to implement such research, new techniques should be developed and a network of research areas set up. Although IBP at the present time does useful research work on primary and secondary production and energy flow in ecosystems, this could only be considered as a first step towards the full study of the problems concerned. IBP should therefore be followed up by some intergovernmental programme of biosphere research emphasizing the functioning of ecosystems in the broadest sense. Only such research work can give a better understanding of the consequences of interference caused by land development. Semi-natural and agricultural ecosystems should be included in this scheme. Human ecology should be considered as a section of general ecology. There was general agreement that inventory work as well as ecosystems analysis is hampered by a lack of taxonomists.

INVENTORIES OF RESOURCES

58. The existence of many survey schemes, especially those undertaken by United Nations organizations as well as by other international and national organizations, was noted by the conference but further extensions of inventories of natural resources seem urgent. The conference, however, did not stress the

case of a uniform mapping system of several biosphere elements. The scale and composition of a map depends too much upon the purpose for which it is designed. A punch card system was considered a useful implement for the collection of data from which choices can be made for several purposes. Such a system also provides opportunities for operational research. It was thought necessary to make a list of the urgency of elements to be surveyed. The drawing up of inventories has to precede land development.

METHODOLOGY

59. The need for co-ordination of analysis methods of all kinds was strongly felt. Data storage in computerized information centres was recommended as well as the development of models to describe the structure and functioning of ecosystems. The use of remote sensing techniques (satellites, airborne platforms) for the study of the structure and functioning of the biosphere was recommended. The extension of existing networks of recording stations for several parameters was thought important by several delegates.

POLLUTION

60. The opinion was generally expressed that further extension of existing monitoring networks for air contamination and pollution involving both substances and conditions was desirable. Worldwide determination of normal constituents of the air (for example CO_2) as well as pollutants is urgent. The assessment of the critical levels of several pollutants (e.g., radioactive materials) in respect to damaging effects, as well as studies on the persistence and the dispersion into the different constituents of biosphere elements was thought to be important. Great anxiety was expressed in respect to indiscriminate use of pesticides, especially the chlorinated insecticides which persist in living organisms and often prove to be deleterious to animals and man at the top of certain food chains. In some areas waste of fertilizers constitutes a threat to particularly interesting oligotrophic ecosystems. Pollution of water including increasing salt content is also a field in which research work should be stimulated.

DETERIORATION

61. It was acknowledged that much research work has been done and measures taken in the field of soil erosion. It was however felt by some experts that research work on erosion must be extended, especially in mountain and arid zones. In particular, research is needed on soil erosion factors and a synthesis on a world scale on this subject would appear to be necessary. It is necessary to discriminate in this respect, because a moderate level of erosion ought not to be detrimental in some cases. Anxiety was expressed concerning large projects of civil engineering which are sometimes undertaken without considering the destructive effects on vegetation and wildlife. Overgrazing is a problem in large areas in semi-arid regions of the world as well as salinization and the extension of arid land. Research work could be helped by mapping from the air. The loss or depletion of valuable species by deterioration

of the vegetation is also a matter of concern. It was acknowledged that legislation plays a major role in regulating land-use and wildlife management.

CONSERVATION

62. During the discussion it was appreciated that much work has been done on the protection of wild plants and animals. It was pointed out that the preservation of species is guaranteed in the most satisfactory way when the ecosystems and landscapes to which they belong are protected. This conclusion must also be extended to man-made landscapes threatened with disappearance by modern techniques. It was considered of special interest that gene-centres of species are conserved. This is of international interest and thus an object for international aid. The research work required for the management of reserves should be stimulated.

RATIONAL USE OF RESOURCES

63. Research work should be promoted to assess methods of management which avoid deterioration and impoverishment of natural resources. Multipurpose use is thought to be generally better than uni-purpose use. In view of the large parts of the earth suffering from deterioration, studies in rehabilitation of depleted areas is thought urgent. The rational use of water resources, particularly the use of run-off and underground waters, the reduction of irrigation losses, and the reduction of transpiration by chemical methods, should be investigated.

Attention was drawn to the urgent need from the very inception of planning as well as in the implementation of development projects, to make provision for:

(1) Assessment of the ecological impact on the environments of any proposed development, especially flooding, urbanization, engineering developments, which bring about major alterations of the environment.

(2) Determination of the long-term ecological consequences and their implications to the success of the project and on human welfare in general in the area involved.

(3) The necessity, wherever massive alterations are involved, to carry out in advance the appropriate surveys and investigations to determine which resources may be lost such as habitats, populations of terrestrial or aquatic organisms of actual or potential economic importance, as well as the individual species of flora and fauna; to evaluate potential hazards of disease; and to determine what measures may be taken to avoid or minimize these adverse effects.

RECOMMENDATION 1

INTERNATIONAL RESEARCH PROGRAMME ON MAN AND THE BIOSPHERE

64. The Conference,

Recognizing man's role in developing and utilizing the resources of the biosphere for human welfare, through his activities in agriculture, forestry, medicine, and exploitation of aquatic resources, *Noting* that the technological developments of man as shown by his achievements in industry, transport, communications and urbanization, all of which are essential aspects of human welfare, have nevertheless resulted in major problems of pollution: the carbon dioxide balance in the atmosphere is being altered and a variety of pollutants, including radioactive materials and a wide range of toxic chemicals, is being added to the biosphere,

Stressing that improvement of the human condition has been very largely achieved on a pragmatic basis aimed at obtaining immediate benefits, without sufficient consideration or even understanding of the long-term environmental consequences and their implications to human health and well-being, and that these consequences, such as the deterioration of terrestrial and aquatic environments, changes of water balance, loss of plant and animal species, are all results of this immediate success of human activities in exploitation as is the most significant consequence of this success, the tremendous expansion in the human population,

Emphasizing that there are very special problems associated with developing countries where there are urgent and rapidly increasing demands to utilize the natural resources to the fullest extent, to provide an adequate standard of living for all inhabitants, and where, because modern technologies will have to be applied on a major scale, it is important to plan carefully, so as to maximize the benefits and to avoid the deleterious effects that have been produced in the past,

Further *recognizing* that many of the changes produced by man affect the biosphere as a whole and are not confined within regional or national boundaries, and that these problems cannot be solved on a regional, national or local basis, but require attention on a global scale,

Stresses also that these factors have created a situation which is becoming increasingly perilous, and which, if allowed to continue, may produce an extremely critical situation that could seriously harm the present and future welfare of mankind, and become irreversible unless appropriate actions be taken in due time,

Invites the Member States, intergovernmental organizations, particularly the United Nations through its General Assembly, and non-governmental organizations, to take congnizance of this situation and take appropriate action at national, regional, and international levels,

Further *notes* that, although there is much scientific information which can be immediately applied to many of the problems of the biosphere, there is urgent need for an expansion of relevant research on a global scale,

Consequently *recognizing* the multidisciplinary nature of the problems of the biosphere involving not only biological and physical sciences but also social sciences; and that it is therefore necessary to call on the various disciplines of the scientific community to concentrate on environmental problems,

Noting the valuable start and precedent in this direction made by several non-governmental organizations, particularly the International Biological Programme (IBP) initiated by the International Council and Natural Resources (IUCN); but recognizing that while these efforts are world-wide in scope, the capabilities of such non-governmental activities are necessarily limited, and that at the conclusion of the IBP in 1972 many problems of the biological basis of productivity and human welfare will have been defined and partially explored but few will have been studied to conclusion.

Draws the attention of Member States, intergovernmental and non-governmental organizations to the importance of continued and increased support for IBP and IUCN,

Suggests that IBP might usefully be followed by an international programme of expanded and strengthened research, education and implementation on the problems of man and the biosphere, based on intergovernmental and governmental recognition and support, and on the participation of relevant non-governmental international scientific organizations,

Recommends that Unesco, in co-operation with all organizations concerned, should, without delay, set up suitable working groups, including in particular representatives of the appropriate intergovernmental organizations and governmental scientific bodies, to prepare a plan for submission to Member States to implement the above recommendation.

RECOMMENDATION 2

RESEARCH ON ECOSYSTEMS

65. The Conference,

Considering that the renewable organic resources of the biosphere are produced within functional entities, the ecosystems, in which living organisms and physical factors of the environment react upon one another,

Bearing in mind the very great diversity of the ecosystems and the considerable inequality of their production potential,

Recommends that Unesco, in collaboration with other intergovernmental and non-governmental organizations concerned, should prepare a plan for a world programme of ecological, ecophysiological and bioclimatological research on a range of ecosystems, both natural and semi-natural artificial or cultural, on land and in water, selected from both temperate and tropical zones, in wet or arid countries, in order to determine the potentialities of the zones studied and thus obtain an estimate of the renewable organic resources of the biosphere,

Further *recommends* that such a plan takes into account the following aspects:

1. The global and the analytic study should be conducted simultaneously. The global study should reveal the nature of the ecosystem as a functional entity, showing the part played by the different factors involved in the functioning of the global ecosystem complex. It should include an evaluation of the plant and animal biomass, its variation in time and of primary and secondary production. The analytical study should include research on the process of energy conversion within the ecosystem, particularly at the photosynthesis level and at the passage between trophic levels. It should establish the role played by the different organisms in the transfer and transformation of energy and matter. The response of ecosystems to external influences, such as management, should be studied.
2. In all regions of the world, this research should turn upon a minimum programme comprising all or part of the global study.
3. In regions where this is possible, this programme could be extended and regarded as 'advanced' or 'optimal' as soon as it includes the following topics: definition of water cycles and major or minor mineral elements, the

biology of the substratum, the ecophysiology and genetics of the most representative species, research into all the conditions favouring the growth of chlorophyll-containing plants, including the symbiotic fixation of the nitrogen in the air which, with other stimulants, is likely to increase the over-all yield of ecosystems, both terrestrial and aquatic and, therefore, agricultural, pastoral, forestry and fishery productivity.
4. Research into the working of ecosystems call for the training of teams of physicists, physiologists, experimental biologists, taxonomists, soil scientists, microbiologists and micrometeorologists and for the development of methods and models specially adapted to such research.

RECOMMENDATION 3

RESEARCH ON HUMAN ECOLOGY

66. The Conference,

Considering that man is an integral part of most ecosystems, not only influencing but being influenced by his environment; that his physical and mental health, now and in the future, are intimately linked with the dynamic system of natural objects, forces and processes that interact within the biosphere and including also those of man's culture,

Recommends to the Member States and their appropriate institutions, to Unesco, WHO and the international organizations concerned:

1. That research be directed to man's basic ecology and to his social and physical adaptability to the changes of all kinds to which he is being subjected, whether in simple or in more complex societies, including those that are highly technological and urbanized.
2. That continuing and intensified research be undertaken on the ecology of human diseases, with special reference to those associated with environmental change and to the zoonotic diseases arising from interactions between man and animals.
3. That this research be directed at solving increasingly important problems of the establishment of the necessary balance between man and his environment in relation to the maintenance of his health and well-being in their broadest connotations.

RECOMMENDATION 4

INVENTORY AND MONITORING OF RESOURCES

67. The Conference,

Recognizing that planning for rational use and conservation of resources at any level of organization requires precise knowledge of resource quality and availability, and that long-term balanced planning further requires knowledge not only of the present status of and requirements for the resources involved, but of the trends (i.e., whether increasing or decreasing) and in some cases, of the potential, and that such information can be obtained only through well planned programmes of resource inventory and monitoring and associated research designed to provide information for specific and well-defined purposes and requirements, and

Noting that there are a number of international arrangements for describing, evaluating and mapping natural resources, but that methods used are not in all cases standard throughout the world, and problems of comparability of data make regional or international assessments difficult,

Draws attention of Member States, intergovernmental organizations, and non-governmental scientific organizations as appropriate, to the need for attaining an increased uniformity of procedures for data-collection and data-recording, including mapping, particularly among similar ecosystems in different parts of the world, for both scientific and comparative planning purposes;

Suggests that a first step in the development of an intercomparable international system might involve an inventory and evaluation of the existing structures, methodologies and data. Appropriate existing activities could be continued and strengthened and appropriate existing materials could be utilized in the further development of comparable monitoring and evaluation methodology;

Recommends that Unesco, in co-operation with other intergovernmental and non-governmental organizations concerned, take the necessary steps for including the following specific requirements:

1. Definition of the resources to be involved, and establisment of priorities.
2. Determination of the objective and function of the operation for each resource (i.e., what is the purpose of the survey, inventory, or monitoring operation).
3. On the basis of the function and objective of the operation, determination of the most effective methodology both for obtaining data and for recording and disseminating it; agreement upon standardization of the methodology to assure compatibility and comparability; determination of necessary levels of accuracy and consequent sampling intensity.
4. Dissemination of the resultant data in forms usable to scientists and to planners in the development of bases for rational use of resources. This applies both to commodity resources, such as types of timber and food products; and to non-commodity resources, such as natural areas or research reserves to preserve scientifically adequate examples of the world's habitat types and endangered species of flora and fauna.

RECOMMENDATION 5

METHODOLOGY AND CO-ORDINATION OF RESEARCH

68. The Conference,

Recalling that the proposed intensification of research on ecosystems in general, as well as the inventory and monitoring of resources, has to be supported by appropriate development and standardization of methods of study,

Bearing also in mind the need for storage, communication and elaboration of a large amount of information,

Recommends to Member States, intergovernmental organizations and non-governmental organizations concerned that the necessary steps be urgently taken for:

1. Standardizing and intercalibrating of methods of study, where the methods are considered satisfactory and standardization is not otherwise assured.

2. Increasing the number and quality of recording stations, for a number of selected parameters, such as radiation.
3. Developing new methods for surveying and monitoring, including the full use of the possibilities offered by modern technology, such as remote sensing.
4. Creating and supporting on a multi-country basis the appropriate data centres for storage and retrieval of information on representative types of natural, semi-natural and man-made ecosystems.
5. Developing acceptable and standardizable procedures for the typification and classification of complex entities (e.g., soils, ecosystem) in co-operation with and assisted by appropriate scientific agencies and organizations already in existence.
6. Ensuring the involvement of mathematicians, systems analysts and other appropriate specialists in studies of ecosystems, in recognition of the importance of sound mathematical concepts at all stages of research, including design, conduct and analysis; and of developing models for the deeper understanding of the functioning of ecosystems and for predicting the consequences of change.

RECOMMENDATION 6

POLLUTION RESEARCH AND MONITORING

69. The Conference,

Recognizing that pollution of the biosphere, involving products of, or associated with, combustion, other substances and conditions, is becoming an increasingly serious problem, directly or indirectly, affecting the health and well-being of humans as well as other organisms,

Recognizing that certain pollutants may be transported over large distances, particularly in air and water, and produce undesirable effects in places remote from the source of pollution,

Recognizing also that some long-lasting pollutants may persist in the biosphere in time and space, far from their point of origin, gradually accumulating to the point where they reach dangerous levels,

Recognizing further that changes in technology, increasing industrialization and the development and use of new chemicals, particularly pesticides and fertilizers, are constantly introducing new substances into the biosphere or changing their distribution, and that research is needed to determine the physiological, toxic and ecological effects of these introductions,

Recognizing further that the problem of pollutants demands monitoring on a world-wide basis and that emphasis should be placed on the need for increased intergovernmental co-operation of monitoring services,

Recognizing further the desirability of supporting, expanding and co-ordinating the monitoring services for environmental pollution in most European and several other countries and the need to develop such services in those countries where they do not yet exist,

Recommends that Unesco, WHO, FAO, WMO and other intergovernmental or non-governmental organizations concerned, promote a research programme along the following lines:

1. Definition and identification of actually or potentially involved substances

and conditions including those associated with combustion and the breakdown products of these substances and, as appropriate, determination of priorities among them for research and monitoring.

2. Development of uniform terminology and monitoring methods, leading to internationally compatible data and techniques which form the basis of world-wide monitoring in air, soil, water and living organisms. This will include attention to remote sensing, direct sampling, methodology of analysis, standardization of measurements, etc., and should be based upon and make fullest use of the existing monitoring systems and other appropriate structures and activities of international agencies and Member States.
3. Determination of levels of contaminants or pollutants dangerous or critical to other components of the environment in general, and to human welfare in particular, either directly or through long-term accumulation of low-level toxicants; determination of the subsequent formulation of water quality criteria or desirable standards for all uses of water; research and surveillance, directed towards new substances or conditions actually or potentially dangerous.
4. Studies of the movement and degradation of pollutants through the environment, and determination of necessary levels of sampling and consequent numbers and locations of monitoring stations required for different substances and conditions.
5. Research into methods: (a) to prevent, control, or avoid introduction of these substances into the environments; (b) to analyse their dispersion and accumulation; (c) to reduce their level; and (d) to mitigate their deleterious impact.
6. Where possible, prior to introduction of new chemicals or conditions, measurements should be made to establish the values of relevant parameters against which to measure their developing effects and to support control regulations.
7. Development of effectively safe means of transporting potentially toxic substances and pollutants to avoid accidental discharge.
8. Research into the potentially dangerous effects of food additives and means to achieve satisfactory reduction or elimination of those determined to be deleterious in human and animal foods.

Further *recommends*:

1. That scientists and technologists in all Member States be encouraged to co-operate in the measurement of existing levels of physical, biological and chemical parameters in order to make it possible to evaluate changes in the environment, such as levels of concentration and patterns of distribution of pollutants.
2. That the United Nations Specialized Agencies and their appropriate consultative bodies be asked to assist Member States in examining their existing programmes and in re-directing, where feasible within resources, programmes to accomplish this purpose.
3. That Member States and non-governmental organizations encourage research activity, and ensure co-operation amongst scientists in the continuous quantitative measurements outlined in this recommendation.

RECOMMENDATION 7

UTILIZATION AND PRESERVATION OF GENETIC RESOURCES

70. The Conference,

Recognizing that only a very small number of the very numerous plant and animal species are directly utilized by man as a result of cultivation and domestication, and that a limited number of other species attract his attention and interest,

Noting that there is a widespread and growing interest and activity in enriching the genetic resources of organisms useful to man through selection of new forms from wild strains, hybridization and production of mutants derived from chemical and physical action,

Taking into account the accelerating rate of species extinction, and the fact that others are becoming rare and threatened, largely because of the destruction of suitable habitats for them,

Suggests that special efforts must be taken urgently to preserve the rich genetic resources that have evolved over millions of years and are now being irretrievably lost as a result of human actions, and that these efforts must include:

1. Preservation of representative and adequate samples of all significant ecosystems in order to preserve the habitats and ecosystems necessary for the survival of populations of the species.
2. Establishment of special protected areas in regions where long-domesticated species of plants and animals thrive in their original habitat.
3. Strenuous efforts to protect the remnant populations of rare and endangered species of plants and animals and to provide the care and conditions necessary for increase of their numbers, their selection and their improvement.
4. Increase and improvement of actual collections of germinal plant plasm.
5. Establishment and care of numerous species, varieties and strains of long-domesticated kinds of plants, such as cereals, and animals, such as cattle, in living collections so that the rich variety of their genes will not be forever lost because of the present tendencies in agriculture and animal husbandry to concentrate on a limited and highly selected array of strains.

Recommends that Member States, Unesco, FAO and other interested international organizations concern themselves with these facts and take vigorous steps to preserve the heritage of genetic resources which, if lost, can never be recovered.

RECOMMENDATION 8

RATIONAL USE OF NATURAL RESOURCES

71. The Conference,

Stressing the urgent problems posed by the destruction and degradation of natural resources due to ever-increasing pressure of the expanding technology and human population on the environment,

Emphasizing the need to promote rational use of the resources based on scientific research, *Noting* that the development programmes carried out throughout the world often do not sufficiently take into consideration the ecological aspects of the problems, so that they result in significant unintended alterations of the environment,

Recommends that Unesco and the other international and non-governmental organizations concerned, prepare a research programme with the object of acquiring the basic scientific knowledge for rational use of resources and which should include:

1. Analysis and possibility of choice in integrated use of natural resources to ensure the permanence of the biosphere, in connexion with terrestrial and aquatic ecosystems and with regard to:
   (a) Identification of the different resources, with special reference to water and soil, from the point of view of their various values for use (economic, scientific, recreational, aesthetic, educational);
   (b) Evaluation of the possibilities of using these resources, under varying climatic conditions, based on their characteristics and on the social and economic factors involved in their use;
   (c) Multipurpose use.
2. Study of the rational use of resources, particularly water and soil, with special reference:
   as regards water: to its use in agricultural ecosystems, to the use of saline water in ecosystems to which it can be applied, to the control of evapotranspiration both from soils and from open water surfaces and to its role of essential component of the habitat of aquatic species;
   and, as regards soil: to the influence of soil characteristics on the choice of use, to the possibilities of improving fertility and productivity, to the problems raised by the transition from shifting to intensive cultivation, mainly in tropical zones, to the restoration of degraded and saline soils; and lastly, to the deterioration due to fire and accelerated erosion, particularly in the tropical zone and in mountain areas.
3. Study of the rational use of plant and animal resources both terrestrial and aquatic, with regard to the increase of primary production (optimization of environmental conditions, reduction of losses, introduction of exotic species), the increase of secondary production including utilization of non-domesticated species, domestication, improvement of the quality of production, and the restoration and enhancement of the quality of the environment, and the management required to achieve the above objectives.

EDUCATION PROBLEMS

72. The Education Commission under the chairmanship of Dr. Jan Cerovsky (Czechoslovakia), elected as vice-president Dr. Sanga Sabhasri (Thailand) and, as rapporteur, Professor O. Boelcke (Argentina).

73. The following Member States participated in the work of the commission: Algeria, Argentina, Australia, Belgium, Brazil, Cambodia, Canada, Democratic Republic of Congo, Czechoslovakia, Finland, France, Federal Republic of Germany, Ireland, Israel, Italy, Japan, Madagascar, Mali, Netherlands, Norway, Romania, Spain, Sweden, Switzerland, Thailand, U.S.S.R., United Kingdom,

United States of America, as well as representatives of FAO, WHO, IBP, IUCN, Inter-American Institute of Agricultural Sciences, International Youth Organization for the Study and Conservation of Nature and the International Federation of Landscape Architects.

The conference, after examining the report of the commission, approved the following conclusions and recommendations.

74. A declaration of principles to clarify the opinions of the conference on matters of education was considered an essential starting point (see recommendation 9 below). There are gaps in education which have to be filled as soon as possible. The global approach on nature and its problems should induce people to think ecologically, maintaining a realistic approach towards nature. Man should be considered as being in partnership with nature, the ethical value of which was stressed. It should be borne in mind that the scarcity of people capable of carrying out this educational programme in many of the developing countries will greatly hinder the realization of over-all educational programmes unless strenuous efforts are made to overcome the deficiency.

75. Careful consideration was given to pre-school education, as it is very easy to influence children at this formative age. Much of this education will have to come through the parents—which often implies that they must be educated first—but on the other hand the role of the kindergarten is becoming increasingly important in most developed countries. Action will have to be taken to train teachers properly for this level.

76. As to the introduction of environmental education in primary and secondary schools, there is in many countries a shortage of trained science teachers with adequate ecological understanding. On the other hand, in many cases there is too little time allocated for the teaching of biology and very often the teaching material available is totally inadequate or inappropriate for a particular country or region. It was also pointed out that it is difficult to teach this subject in the great cities where children lack the direct relationship with nature. Maximum use of environmental education should be made of vacation time at rural summer camps. In developing countries with large rural populations, particular attention should be given to improve rural education. Adequate radio and television programmes dealing with environmental education may be great allies in getting ideas across to children as well as to adults. Science centres should provide useful instruments for the training of teachers for different levels of education.

77. Properly trained specialists will have to form the hard core upon which education at all other levels will depend. The training of these specialists will primarily be the responsibility of universities, as well as the introduction of the teaching of ecology into the curricula of different disciplines, primordially those connected with planning man's activities in relation with his environment, but also dealing with others that do not directly treat land management, such as human health. This can often best be done through the 'infiltration of ecological thinking', particurlaly when existing structures may be already overloaded or the material resources not available. The necessity was recognized to strengthen and develop as soon as possible appropriate interdisciplinary national and regional centres that will deal with environmental education and research for

professional ecologists. Planning and management of landscapes on ecological bases were also recognized as important related fields to be developed.

78. The importance of out-of-school youth education was stressed, particularly in consideration to the impressive percentage of younger people of the world population. Special youth organizations show great promise for developing effective programmes dealing with environmental education. Also the possibility was pointed out that nature conservation could be taught during military service.

79. As to adult training, many suggestions were made to improve the mass media of instruction, developing and using for that purpose existing facilities such as national parks and urban parks, as well as programmes with active participation, such as tree-planting, landscape beautification and development of recreational facilities. The importance of the best use of press, radio and television was emphasized.

80. The necessity of setting up an international body to help in developing all teaching activities in the different countries was specially stressed.

81. The clarification of concepts involved in environmental education led to the following views of the conference.

CONCEPT OF ENVIRONMENTAL EDUCATION

(1) The critical problems of the biosphere urgently require the development of environmental education to form an attitude of man and his society towards the biosphere in the sense of wise rational use and conservation of the natural resources and the unity of the landscape.

(2) The basic principles of environmental education, interpreted according to possible levels and purposes, should be:

To maintain and wherever possible to enhance the economic and social capital of the biosphere;

To provide an integrated scientific approach to the planning, management and development of the environment as a unit in space and time;

To seek man's personal fulfilment in partnership with nature through and with natural forces;

To develop a policy of trusteeship for posterity.

(3) Environmental education is required in different depths, according to the level of education being provided and the objectives being pursued, and should reach:

Specialists in different occupations dealing with both biosphere management and education in order to fulfil effectively the principles set out above;

Adults in order to guide children and young people, to develop criteria by which they can judge policies and practices affecting their environment and, generally, to enrich their lives;

Children and young people, as part of a scientific and liberal education, to enable them to enjoy the environment and use it wisely.

(4) All available media should be employed in an integrated as well as continuous and sustained programme of education and information about the environment. Each country should have a council, centre or similar institution for environmental education and these activities should be co-ordinated also on an international scale.

RECOMMENDATION 9
TRAINING AT THE PRIMARY- AND SECONDARY-SCHOOL LEVEL

82. The Conference,

Considering that there is insufficient provision for ecology in the curricula for biology and related sciences, and that there is a lack of knowledge of ecology among primary—and secondary—school teachers, and that ecological thinking is a necessary ingredient in instruction,

Recognizing the special importance and need for sound environmental education at these levels, both in terms of providing general student awareness and as a basis for eventual specialist training.

Being aware of the pressing need for appropriate educational materials and curricula at these levels,

Recommends to Member States that their national authorities and educational organizations engage in:

1. The revision of curricula so that environmental education be introduced, improved or extended in biology and also incorporated into the teaching of other subjects.
2. The training of a core of teachers in ecology which would provide leaders in this field.
3. The organization of workshops or seminars or other training activities for teachers who are responsible for environmental education.
4. The posting of experts from Unesco and other United Nations and international organizations concerned, to assist projects to help the training of teachers in developing countries, by working with local counterpart staff and to provide funds to support such projects.

Recommends that Member States make every effort in setting up or improving environmental education at the primary and secondary school levels, by collecting, producing and disseminating a comprehensive range of suitable educational aids (including textbooks, regional ecological studies, filmstrips, teachers' guides and similar materials); and

Recommends that Unesco and other United Nations and international organizations concerned should assist these activities by helping to provide materials, information, advice and expert assistance, and by keeping Member States informed of national and regional developments in this field.

RECOMMENDATION 10
TEACHING OF ECOLOGY AT UNIVERSITY LEVEL

83. The Conference,

Considering that there is an urgent need for ecologically oriented specialists,

Recommends to Member States and their institutions of higher education:

1. The introduction or extension of an ecological approach into the university courses, at all levels, including post-graduate, short-term and any other special courses, in the training of professionals such as teachers, biologists, agriculturalists, foresters, health workers, engineers, architects, economists, sociologists and all specialists who play any part in the use and conservation of the resources of the biosphere.
2. The training of professional environmental scientists and technologists through

the establishment of university chairs and institutes for environmental studies and conservation.
3. The review and, where necessary, the improvement of all existing and proposed measures for the collection, retrieval and dissemination of information to environmental education.

Recommends that Unesco, in co-operation with FAO and other United Nations organizations, international organizations and non-governmental organizations as well as regional organizations concerned, assist in these activities with experts and funds.

RECOMMENDATION 11

CENTRES FOR TRAINING AND RESEARCH IN RATIONAL USE AND CONSERVATION OF THE RESOURCES OF THE BIOSPHERE

84. The Conference,

Considering
1. That the training of leaders in rational use and conservation of the resources of the biosphere, capable of intervening in the policy and decision making of their country, is of greatest urgency;
2. That such training must preferably be done at centres adequately staffed and equipped and located in areas that duplicate as much as possible the ecological, cultural (including linguistic) and economic conditions of the country of origin of the trainees;
3. That such training is costly and that these centres should be used as efficiently as possible by combining training with research, documentation and other related activities;

Recommends to Member States, to United Nations organizations and to regional organizations:
1. That existing interdisciplinary national and international training and research centres which at present deal with the broad field of rational use and conservation of the resources of the biosphere, be strengthened in staff, facilities and fellowships to make possible a strong programme of training and research in ecology and related environmental aspects.
2. That new centres be established within appropriate regions, where they do not exist already.
3. That co-ordination of these centres with counterparts from other Member States or regions of the world be established so as to allow the maximum of free flow of staff and information and the minimum of wasteful duplication.

RECOMMENDATION 12

OUT-OF-SCHOOL ENVIRONMENTAL EDUCATION OF YOUTH AND ADULTS

85. The Conference,

Recognizing
1. The urgent need to help all sections of the community to understand the broad ecological principles involved in man's use of natural resources and the interactions that exist between man and his physical and biological environments, and

2. The desirability of increasing public awareness concerning the biological and historical perspectives of mankind's position in relation to the biosphere and the concept of the partnership of man with other living beings,

Recommends that Member States should fully engage the resources of mass media and also use and develop information centres, parks, museums, zoological and botanical gardens, field stations and nature reserves, in order to educate children, adolescents and adults in environmental biology and make them aware of their environmental heritage;

Recommends further that Unesco and United Nations organizations, as well as international organizations concerned, should be prepared to assist Member States by helping provide the advice, equipment and expert staff which may be needed in the operation of these programmes of community education.

Such programmes of community education, bearing in mind the special requirements of communities of differing educational standards, traditions, language, cultural backgrounds, should:

1. Include the preparation and distribution of publications and visual aids;
2. Make provision for special incentives (e.g., honours, prizes and public recognition) for those members or sections of the community who achieve distinction in either the production of popular educational material (by scientific writing, journalism, film-making, travelling exhibits and related activities), or the survey, care and development of environmental projects;
3. Encourage the special participation in environmental projects of existing youth and social groups and associations;
4. Encourage the participation of youth in out-of-school environmental education programmes;
5. Integrate formal school environmental education with out-of-school youth programmes.

RECOMMENDATION 13

INTER-AGENCY CO-ORDINATION ON ENVIRONMENTAL EDUCATION

86. The Conference,

Recommends that Unesco explore urgently, in consultation with the United Nations, FAO, WHO, WMO, ILO, IUCN and ICSU, the means of serving, on a continuing basis, the following needs in environmental education:

1. Extending existing liaison arrangements.
2. Reviewing existing programmes and proposals.
3. Identifying the changing needs in education and specialist training, and establishing priorities for action.
4. Recommending the division of responsibilities among the organizations concerned with regard to programme activity.
5. Recommending areas of action and specific projects which should be the subject of joint action by two or more of the relevant organizations. These projects might include the provision of common services in the preparation and distribution of educational materials through the various channels already available to the organizations.

Further *recommends* that attention be given to appropriate administrative arrangements for such purposes, including possibly the constitution of a permanent inter-agency working group.

POLICIES AND STRUCTURES

87. The Commission on Scientific Policies and Structures met under the chairmanship of Mr. C. S. Christian (Australia). Dr. E. Balcells (Spain) and Mr. Baba Dioum (Senegal) were elected vice-chairman and rapporteur respectively.

88. The following Member States took part in the work of the commission: Argentina, Australia, Belgium, Brazil, Byelorussian Soviet Socialist Republic, Canada, Democratic Republic of the Congo, Czechoslovakia, Finland, France, Federal Republic of Germany, Hungary, India, Iraq, Ireland, Israel, Italy, Kenya, Lebanon, Madagascar, Mali, Morocco, Netherlands, Norway, Peru, Senegal, Somalia, Spain, Sweden, Switzerland, Thailand, Turkey, U.S.S.R., United Kingdom, United States of America, Uruguay and Viet-Nam, as well as representatives of the United Nations, FAO, WHO, IUCN, IBP, the League of Arab States, the Organization for Economic Co-operation and Development, and the International Relief Union.

The conference, after examining the report of the commission, approved the following conclusions and recommendations.

NATIONAL STRUCTURES

National organizations for the rational use of the resources of the biosphere

(i) Science and resource use policy

89. The conference discussed in detail the problem of the national structures needed to reach the objectives set by the conference. It agreed on the impossibility of recommending a single formula to meet the conditions pertaining to each country, particularly in view of the different stages of development reached by them and of already existing institutions. Several delegations quoted examples of national structures which were proving satisfactory (National Council of Natural Resources, Regional Planning Service, Interministerial Commissions, etc.). The conference examined the problem of the level—national, provincial, local—at which decisions should be taken, and which depend on certain political options.

(ii) National parks and reserves

90. The discussion on this question emphasized that national parks and nature reserves are of great economic and scientific importance. The creation of such parks and reserves often implies a choice between conflicting national interests, and this choice should be preceded by widespread consultation that can only be held at a national level. It was agreed that wherever there is as yet no national organization to select, establish and manage a network of national parks and nature reserves as part of an integrated plan, such an organization should be set up in the near future. This organization, whether already in existence or yet to be created, should work out or further elaborate a national programme for national parks and nature reserves, endeavouring as far as possible to conform to the selection criteria and standard nomenclature set up in accordance with resolution 713 (XXVII) of Ecosoc and in accordance with the principles laid down by the Secretary-General of the United Nations; these are the criteria

and standards which IUCN recently used for the publication of the second edition of *United Nations List of National Parks and Equivalent Reserves.*

(iii) National legislation

91. The conference stressed the need for national legislation to be based on scientific data, and invited the developed countries to make their laws available for purposes of information, to developing countries. The problem of the difficulty of applying effectively the existing laws was, of course, discussed. The need to strengthen the responsible administrations and to inform the communities was emphasized. Attention was again drawn to the importance of laws providing exemption from taxation for measures such as reafforestation which are designed to restore soils.

Structures in education

92. The conference stressed the importance of the education of individuals and groups in the framing and implementation of a policy of conservation and rational use of resources of the biosphere.

93. The conference emphasized the usefulness of the mass media (television, radio, cartoons, etc.) in the education of the public, and also the need to obtain the co-operation of tourist and travel agencies in such education. It recommended that an issue of the *Unesco Courier* should be devoted to the conference, to the functioning of the biosphere and to the work of organizations with responsibilities in this field.

94. It also recommended the expansion of the Unesco bulletin entitled *Nature and Resources*, which might be used to report on the experiences of the different countries.

95. Turning to the training of experts, the conference stressed the need to develop biological programmes at all levels to facilitate the training of ecologists. It also urged the necessity of providing post-graduate courses to train specialists in the integrated approach, such courses to be adaptable to the new developments of science. Likewise it stressed the need for a diploma course in ecological engineering which would have a practical value in the conservation of natural resources and the management of the land. The conference also underlined the importance of the training of educators and the contribution which international seminars and scholarship awards might make to this training.

Research structures

96. The conference emphasized the importance to be attached at the national level to institutional structures and the organization of research in regard to natural resources of the biosphere, particularly agricultural, forestry, pastoral, fishery and wildlife research. The complex problems involved by research on ecology and agronomy directed towards practical aims of development plans demand an integrated multidisciplinary approach and taking into account all the imperatives of science, technology, economy and the socio-political aspects of development.

97. At the national level, research agencies must be centralized in multidisciplinary institutions to include all scientific disciplines and the formation of interdisciplinary teams of research workers, among which an important place must be found for specialists in the human sciences in the broadest sense.

98. National structures and the organization of research must provide direct links between the authorities responsible for scientific policy and the planning of research and development, and those carrying out the research and implementing results.

99. The conference also recognized that it was absolutely indispensable for close working relations to be established between research, education, the training of technological staff, popularization and the supporting services as a whole. By this means, the lessons of research will be passed on; and, through the efforts of all appropriate social, economic and political structures, the results of research will be given practical and effective application in the many units of production in the agricultural sector.

Specialized associations

100. The conference recognized that specialized semi-governmental or non-governmental associations could contribute towards advising governments on particular subjects (town planning, health, etc.), when larger or more permanent organizations were neither justified nor necessary. It recommended governments to give material and financial aid to such associations and to call on them whenever possible to complement research or educational work.

REGIONAL AND INTERNATIONAL STRUCTURES

Regional structures

(i) Specialized Agencies of the United Nations

101. The conference thought that the United Nations Specialized Agencies should pay more attention to their regional activities in the field of the conservation and rational use of the resources of the biosphere, the region being considered here essentially as a natural area.

(ii) Organization of research at the regional level

102. The problems of natural resources, their conservation and rational use, and biological and agronomical problems as a whole, extend beyond political and administrative frontiers. They are closely linked to biogeographical areas, river basins and are to be found in the context of large natural entities or ecological zones.

103. Given our limited human and financial resources, it is important to regionalize efforts where possible, in order to avoid any overlapping of activities which is not justified scientifically and to prevent duplication and, as far as possible, wasteful competition. The aim of science is to solve problems focused on practical objectives, starting from concerted working hypotheses. The best way to achieve this is to establish priorities and find effective means of strengthening intergovernmental co-operation. All countries situated in the same ecological zone have common problems by virtue of their similar environmental conditions, and therefore have similar topics for research.

104. For this reason FAO, in co-operation with the other United Nations Specialized Agencies, governments, bilateral and international institutions and private foundations, wishes to hold conferences with a view to drawing up agro-

nomical research programmes on an ecological basis aimed at promoting exchanges of information and international co-operation in the scientific, technical, social and economic fields of agricultural research and development. The main purpose of such conferences will be to identify regional priority topics for agronomic research, to lay down the broad lines of action and the measures to be taken for the implementation of these projects by existing national research bodies, and to disseminate their results. In addition they should lead to the preparation of a better over-all use of the assistance provided for research by taking maximum advantage of available resources in a framework of multidisciplinary and complementary activities.

105. The biogeographical framework of the large ecological zones represents an excellent scientific basis for the regionalization of research and for strengthening intergovernmental and international co-operation in the field of both agricultural research and development, and the conservation and rational use of natural resources.

International structures

(i) Co-ordination of research

106. With regard to research of international interest, the conference emphasized the need for effective co-ordination, while recognizing that, at the present stage, in connexion with co-ordination—in the strict sense of the term—difficulties existed and that it would be more fitting to speak of exchanges of information. Effective co-ordination will only become possible once there has been general acceptance of standard methods. The conference noted the role which might be played by information centres in developing research, but it considered that, apart from well-established specialized information centres, the primary requirement was to develop regional information centres.

(ii) International legislation

107. With regard to international legislation concerning the rational use of the biosphere, the conference took note of the current activities of the Legislation Branch of FAO, and of the Commission on Legislation of the International Union for the Conservation of Nature and Natural Resources (IUCN). The Conference also noted that the IUCN Commission on Legislation has prepared a preliminary draft convention on the import, export and transit of certain species which has been distributed to interested governments, to facilitate improved national legislation.

108. The need to conclude international agreements for the conservation and rational exploitation of common natural resources, or even purely national resources such as endemic species, was mentioned.

109. The Conference considered that Unesco should be invited, in co-operation with the other appropriate Specialized Agencies and non-governmental organizations, to make a thorough examination of all the problems concerning international agreements as a whole. This examination might be carried out by a group of specialists convened for the purpose.

110. The Conference emphasized that any future international agreements which might be concluded should have a sound scientific basis and should also have the support of a well-informed public opinion.

111. The representative of IUCN drew the Conference's attention to Article 25 of the Universal Declaration of Human Rights, the beginning of which reads as follows:

> 'Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services. . .'

It was recognized that man's health and well-being depend also on the quality of the environment, that man has the right to a healthy environment, and that man's activities and the use which he makes of natural resources must maintain and enhance the quality of the environment. It was suggested that Unesco, FAO and WHO explore the possibility of proposing to the United Nations General Assembly that it recognize that health and well-being within the meaning of Article 25 of the Universal Declaration of Human Rights include these basic principles.

RECOMMENDATION 14

SCIENCE AND RESOURCE POLICY

112. The Conference,

Considering that rapid developments occurring in all countries threaten destruction of certain resources of the biosphere and that development of one resource frequently has deleterious effects on other resources, effects which are not recognized when plans are formulated and policies established;

Further *considering* that maintenance of the total environment is often neglected in connexion with land use, development of water resources and waste disposal procedures, and that in other situations the complex interactions are not readily evident to those who establish policy,

Recommends that Member States and governing bodies of all United Nations organizations develop comprehensive and integrated policies for management of the environment, and that international efforts and problems be considered in the formulation of such policies. Such policies should include:

1. An inventory of natural resources as a basis for the determination of priorities, taking into account the existence of areas particularly endangered and provision for periodic review of priorities for exploitation depending upon technological and economic changes.
2. Management and utilization of natural resources in the most economical manner, taking into account the repercussions of utilization of a particular resource on other resources and on the environment as a whole. Such ecological concepts should be applied in the planning at national and local levels.
3. Optimal productivity consistent with continued utilization of the biosphere on a long-term basis.
4. Recognition of the possible multiple use of resources.
5. A comprehensive and integrated research programme covering all the aspects of the management of water, soil and biotic resources, including research on socio-economic factors.
6. The application of science and technology to the management of the environment.

7. Provision of an appropriate mechanism that will assure that the best possible advice from specialists of biological, physical and social sciences, technology and economics is available on a regular basis to the authorities at all levels responsible for decision-making concerning all aspects of environmental management and utilization.
8. The establishment of an appropriate structure and mechanism to assure periodic and comprehensive review of policy and with authority, responsibility and resources to readjust guidelines and goals and to make deletions, revisions and realignments in action programmes, based upon empirical experience, scientific and technological advance, and changes in national or world conditions.
9. A programme of education and information for the general public covering the principles and importance of environmental management while avoiding completely theoretical statements and emotional appeals in contacts with the public.

RECOMMENDATION 15

PRESERVATION OF NATURAL AREAS AND ENDANGERED SPECIES

113. The Conference,

Noting that increasing human populations and development activities make the selection and preservation of representative examples of biotic communities and endangered species imperative, and that throughout the world increasing numbers of plant and animal species are in grave danger of extinction as a consequence of direct actions against them and of indirect destructive influences on their indispensable habitats;

Realizing that the extinction of species and the total destruction of certain communities represent an irreparable loss, considering their economic, scientific, educational and aesthetic values for man;

Recognizing that the International Union for the Conservation of Nature, the International Biological Programme, and other organizations and agencies, both national and international, are working on these problems;

Recommends that all such bodies, public and private, make strenuous efforts to establish natural areas for the preservation of species, their habitats and representative samples of ecosystems; and

Recommends that Member States accelerate the establishment and protection of national parks and wildlife sanctuaries, that they encourage their local administrations and private citizens to take appropriate local action, and that they themselves undertake and encourage scientific research and education in support of these important activities;

Further *recommends* that the developing countries receive, in this respect, appropriate assistance.

RECOMMENDATION 16

MULTIDISCIPLINARY RESEARCH AND TRAINING CENTRES FOR RESOURCE INVENTORY AND EVALUATION

114. The Conference,

Drawing the attention of Member States to the importance of multidisciplinary centres for research and training on the environment and its resources at both the national and local levels, if the complex problems of the management of resources of the biosphere are to be satisfactorily studied;

Considering that such institutions could of course be established in a number of different ways according to the existing institutional structures of countries, to the particular ecological conditions, to the actual needs for inventory, evaluation and management of resources and to the particular situation as regards qualified personnel;

Further considering that the need for expanded interdisciplinary activities appears desirable to all countries;

Urges Member States to give attention to this need in the development of their scientific structures, especially in relation to planning the development of the resources of their territories;

Recommends that the United Nations organizations concerned assist in the planning and establishment of such institutions in the many countries, especially developing ones, where the scientific structures are not yet sufficiently strong to meet these needs.

DEVELOPMENT OF INTERNATIONAL ACTIVITIES

UNITED NATIONS CONFERENCE ON HUMAN ENVIRONMENT

115. The conference noted and discussed the resolution concerning man and his environment adopted by Ecosoc at its 45th session (1346 XLV) following a proposal by Sweden that the question of convening a United Nations conference on this subject be examined at the next session of the General Assembly.

116. A number of delegations remarked that the present conference had shown that much remained to be done before answers could be found to all the problems involved in the rational use and conservation of the environment, but that at the same time a great deal of what was already known had not been properly applied. They emphasized that to arrive at the rational use, conservation and improvement of the human environment, it would be advisable to settle not only scientific problems, but much wider economic, social and political matters outside the scope of the present conference. These delegations consequently welcomed the idea of an international conference such as the one referred to in the Ecosoc resolution, it being understood that the outcome of such a conference would encourage joint action by all organizations of the United Nations system.

117. Other delegations, however, pointed out that the decision to convene such a conference lay exclusively with the United Nations General Assembly. Reservations were expressed in regard to the complexity and cost of such a

conference. Several delegations particularly insisted on the necessity to ensure first that financial and other resources were available for the practical application of the recommendations which the proposed conference might adopt.

118. The idea of preparing a Universal Declaration on the Protection and Betterment of the Human Environment was referred to in the course of the debate. The general opinion was expressed that, if a United Nations conference were to be convened, the adoption of such a declaration could be one of its objectives.

119. At the conclusion of the debate, the conference adopted the following recommendation.

RECOMMENDATION 17

UNITED NATIONS CONFERENCE ON HUMAN ENVIRONMENT

120. The Conference,

Being informed that the Economic and Social Council of the United Nations (Ecosoc) at its 45th session approved a resolution on the question of convening an international conference on the problems of human environment, on which the United Nations General Assembly is going to decide

Recommends that, in its deliberations, the United Nations General Assembly might:

1. Take into consideration the recommendations of the conference on the biosphere.
2. Consider the advisability of a Universal Declaration on the Protection and Betterment of the Human Environment.

TECHNICAL ASSISTANCE FOR BASIC AND APPLIED STUDIES ON THE RESOURCES OF THE BIOSPHERE

121. As regards the experts provided by international organizations to assist developing countries in the integration of their national activities, to carry out appropriate research programmes and to implement training programmes, the conference noted that the specialists concerned should fall into two different categories: (a) short-term high-level advisers whose task would be to advise governments on the broad lines and planning of their programmes; (b) highly experienced long-term experts who would be responsible for assisting scientists and technicians in the execution of these projects.

In this respect the need was emphasized to train local counterpart staff who would be able to continue activities under way and launch new projects, once international aid had come to an end.

122. It was further pointed out that in many cases the most qualified specialists are not able to accept long-term assignments either because their governments do not agree to second them or because they are not sure of finding employment in their country of origin when their assignments come to an end.

RECOMMENDATION 18

TECHNICAL ASSISTANCE FOR BASIC AND APPLIED STUDIES ON THE RESOURCES OF THE BIOSPHERE

123. The Conference,

Considering that the resources of the biosphere are imperfectly known, especially in developing countries, and that this lack of knowledge also applies to the rapid changes that are taking place in the biosphere as a result of man's activities;

Recommends that all Member States, with the assistance of the United Nations organizations, and other national, regional or international organizations, give immediate consideration to ways and means for applying more effort to increase basic and applied knowledge of the resources of the biosphere, particularly in the developing countries, in the interest of mankind as a whole, so that the rational use and conservation of the biosphere may be everywhere founded on a sound scientific basis;

Further *recommends* that better mechanisms be devised to increase the effectiveness of bilateral and multilateral assistance to enable the temporary release of experienced scientists from developed to developing countries and that developed countries be urged to improve their procedures towards this goal.

RECOMMENDATION 19

RATIONAL USE AND CONSERVATION IN ASSISTANCE PROJECTS FOR DEVELOPING COUNTRIES

124. The Conference,

Considering that developing countries cannot promote their socio-economic development without making rational use of their natural renewable and non-renewable resources;

Noting that agricultural, live-stock, fishery and forest production which form the basis of the economic growth of these countries should increase at the high rate demanded by the demographic expansion and by the necessity to improve the living standard of the population;

Considering also the great hopes raised in many of these countries by regional associations for the common use of resources or river basins where the integrated management through dam constructions should develop irrigated agriculture, assure the needs of navigation and supply energy to industrial complexes;

Fearing, on the other hand, that intensive exploitation of the natural resources of these countries, and the necessary developments of industrialization could cause irreversible perturbations in an environment which is still little disturbed and whose balance is fragile;

Taking into account the shortage of human, material and financial means faced by these countries, to successfully manage their environment and harmonize the goals of their development with the needs of conservation, in accordance with scientific basis;

The Conference recommends:

1. That pre-investment projects of governments of developing countries carried out by United Nations Specialized Agencies with financial help from UNDP should take adequate account of all the recommendations made by the conference concerning the nature of projects, the choosing of experts, the awarding of fellowships, and the supplying of equipment, and that this also applies to investments financed by loans through the World Bank.
2. That ecological interactions should duly be taken into account in all large-scale development projects.
3. That international organizations, especially UNDP and the World Bank should not hesitate to draw the attention of governments to these long-term concerns when elaborating their requests for assistance.
4. That these same organizations should take the necessary steps so that regional projects involving several countries receive particular attention and that the mechanisms for their implementation be simplified as much as possible.
5. That, in relation to development programmes, these same organizations should dedicate all the necessary consideration to problems of research, education and creation of institutions.

INTERDISCIPLINARY PROGRAMME

125. Following the deliberations of its three commissions, the conference discussed the means of applying a future programme for implementing its recommendations. The discussion showed that thorough preparation was necessary before any final decision could be taken on the matter. It noted the proposals in Unesco's Programme and Budget for 1969-70 concerning action to be taken following its deliberations. It considered that these proposals, in particular those concerning the meeting of appropriate working groups, would make it possible to start on the establishment of a long-term programme.

126. The means of directing such a programme were discussed. The mechanism of a co-ordinating council like that of the International Hydrological Decade was quoted by way of example, but in the opinion of the conference, it was premature to come to any decision at this stage. It was further stressed that action should be taken to ensure the satisfactory co-ordination of existing and future international programmes and activities in the vast field of environmental studies.

127. At the conclusion of the debate, the conference adopted the following recommendation.

RECOMMENDATION 20

PREPARATION OF AN INTERGOVERNMENTAL INTERDISCIPLINARY PROGRAMME

128. The Conference,

Conscious of the importance and urgency of the environmental problems existing in both the developed and in the developing countries;

Recognizing that a considerable amount of knowledge already exists which, if used judiciously, would enable a big advance to be made towards the solution of many problems;

Recognizing, too, that new knowledge is essential on a world-wide scale, as is also an enormous effort to promote education and to establish national structures and institutions in all countries;

Recognizing that in the biological sciences several non-governmental organizations, and particularly IBP and IUCN, have established networks of scientists who are now studying certain aspects of rational utilization and conservation of biological resources;

Recognizing likewise that these networks of scientists have developed widely and cannot make further progress without governmental and intergovernmental support;

Recommends that a plan for an international and interdisciplinary programme on the rational utilization and conservation of the resources of the biosphere be prepared for the good of mankind—a programme which should be carried out on an intergovernmental basis, with the participation of the non-governmental organizations required;

Recommends that this programme concentrate on the scientific, technical and educational aspects of the problems in the rational utilization and conservation of the resources of the biosphere and in the improvement of the human environment;

Recommends that Unesco, in consultation with the other organizations of the United Nations system and the non-governmental organizations concerned, initiate the necessary measures during the 1969-70 biennium to review the existing situation and to make proposals to Member States with a view to the launching of a long-term programme in 1971-72, thereby making provision for a follow-up and adequate extension of the International Biological Programme and for additional work on the part of the various United Nations institutions and non-governmental organizations;

Recommends that proposals be worked out with a view to setting up adequate co-ordination machinery for this programme, which will allow for concerted action by Member States, United Nations organizations and non-governmental organizations.

GENERAL CONCLUSION

129. In dealing with both the use and conservation of the resources of the biosphere, the conference has sought resolution of what at first glance appears to be a contradiction between consumption and preservation of resources of the environment. A resolution seems to have been found in the scientific basis for decisions leading to rational action and in the fact that conservation, while including preservation, has come generally to mean the wise use of resources. It is believed essential to compare the views of all those scientists and technologists who are engaged in the exploitation of the resources of the natural environment with the views of those who are concerned with their preservation in parks and natural reserves. Such comparisons are one of the most important characteristics of the Biosphere Conference. While the facts derived from biological and physical sciences are indispensable, as are the technologies

based upon them, they are by themselves insufficient for wisdom. The social sciences must be considered also because of the roles played by economics, politics, administration, law, sociology and psychology, for man is the key component of the biosphere.

In order to approach the challenging question placed before the conference, it was recognized that the biosphere is that thin shell at the interface of the atmosphere, hydrosphere and lithosphere where life and its products exist; that living organisms manifest their characteristics by constant interrelations with the environment; and that in doing so the interactions themselves create a degree of systematic order. It is thus that the biosphere is seen to occur as an array of ecosystems or levels of organization of life and environment according to various patterns of occurrence of kinds of organisms and sets of physical-chemical conditions of the environment.

Inasmuch as the environment of any one organism includes other organisms and their products as well as physical-chemical conditions, it can be said that the environment for man consists of all things, conditions, and processes to which he is sensitive and capable of reacting. And in that context, resources are any thing, condition and process that man has the capacity to use, actually or potentially, including the societal features of his own culture.

The extreme complexity of the biosphere, its changes in space and time, and the variety of human needs and purposes in relation to it, of which many are in conflict, make it certain that there are no simple answers to the problems of an environment of quality and of human life within it. Clearly, our efforts cannot succeed if they are based upon doctrinaire principles, upon some inflexible assumption or thesis, or upon the intuitive quest for a single panacea. As a consequence, the conference concluded that the historic independent and uncoordinated use of resources must be replaced by well-planned, integrated, multidisciplinary activities. In the place of single-purpose actions in disregard of their associated consequences, both public and private, there is need to substitute planned programmes for the management of resources if past degradation of the environment and deterioration of ecosystems are to be corrected, if the biosphere's productivity is to be maintained and even enhanced, and if aesthetic appreciation is given opportunity to flower. The approach to these goals has an essential political ingredient. It is clear, however, that solutions are possible under the several political, economic and social systems.

The contributions of Member States to the Biosphere Conference make it quite clear that the deterioration of the environment has been occurring at an accelerating rate, especially in recent decades, because of the very rapid growth of the human population and its aggregation in large urban concentrations and because of the explosive industrialization that is spreading to the developing countries and is likewise being concentrated in and around the cities. Parallel to this urban and industrial concentration a massive rural exodus leading to under-occupation of rural areas and other adverse physical and social consequences, has sometimes been witnessed. Disappearance of traditions and customary rights, as well as changes in the mode of life, bring about very important disturbances in developing countries. Thus, unprecedented pressures have lent a sense of urgency to the deliberations of the conference as human needs multiply and resource productions to meet them seem more difficult to accomplish in developed as well as developing countries.

These changes are having many effects: pollution of air, water and soil by human and industrial wastes; rapid destruction of natural ecosystems and widespread mismanagement of them; danger of local famines and malnutrition; threats to physical and mental health; decrease in quality of life; and a general lack of planning to separate conflicting and incompatible land uses.

Until this point in history the nations of the world have lacked considered, comprehensive policies for managing the environment. It is now abundantly clear that national policies are mandatory if environmental quality is to be restored and preserved and land-use planning is to have a sound base. Although many of these changes have been taking place for a long time, they seem to have reached a threshold recently that has made the public aware of them. This awareness is leading to concern, to the recognition that to a large degree, man now has the capability and responsibility to determine and guide the future course of his environment, and to the beginnings of national and international corrective actions. Solutions are to be found in regional planning. For industrialized countries this implies diversification within socio-economic units of the national territory. Political decisions should take into account ecological as well as economic considerations.

The understandings, conclusions and recommendations of the conference, based largely on the work of the commissions, are some but only some of the steps that can be taken if man is to be better able to manage his ecological relations with nature. It has become clear, however, that earnest and bold departures from the past will have to be taken nationally and internationally if significant progress is to be made. No man, no people, can travel this road alone. This recognition of the necessity of co-operative action has given the conference a spirit of optimism in the face of unprecedented challenges to man's wisdom and his good will.

Opening addresses

Address by Mr. Malcolm S. Adiseshiah
Acting Director-General of the United Nations
Educational, Scientific and Cultural Organization

Ladies and Gentlemen,

It is a great honour for me today to welcome to this house, which belongs to all scientists, the eminent experts who have come to take part in the Intergovernmental Conference on the Scientific Basis for Rational Use and Conservation of the Resources of the Biosphere.

The importance of a conference of this nature is particularly obvious when we consider that in recent years there has been, throughout the world, an increasing awareness of the threat to the very future of our species constituted by the combined effects of an unprecedented increase in population and the often irreparable damage inflicted by man on natural resources and on his environment. The problems you will be studying are ones engaging the most earnest attention not only of governments, but also of the great international organizations, which are devoting much of their effort to development. In 1964, the United Nations Economic and Social Council requested the Food and Agriculture Organization (FAO) and Unesco to prepare a report on the conservation and rational use of the environment, and commissioned the World Health Organization (WHO) to draw up a report on pollution. The joint FAO/Unesco report, which should assist you in your discussions, has been distributed to you with the other working papers for this meeting. It is to be noted too, that at the 45th session of the Economic and Social Council, held at Geneva last July, Sweden proposed that a United Nations Conference on 'Man and his environment' should be organized; and the council recommended that the General Assembly of the United Nations include this question in the agenda of its 23rd session, which will open on 24 September. The council's resolution also recommends that full account should be taken of the results of your meeting, when and if the United Nations takes a decision concerning the conference.

Unesco, for its part, has naturally always been concerned with the problem of securing an harmonious balance between man and nature—as is witnessed in the programmes it has carried out with regard to research on the arid zone and the humid tropics, or the activities it has undertaken, in co-operation with its Member States, in the context of the International Hydrological Decade, which it inaugurated in January 1965. But it has found it necessary, as its Advisory Committee on Natural Resources Research urged as early as September 1965, to take steps, with the assistance of the other international organizations concerned, and with the help of various branches of modern science, to define rational methods of using natural resources—that is, ways of using them while at the same time ensuring their conservation.

This idea was taken up again a year later by the General Conference of Unesco, which, at its fourteenth session, in November 1966, adopted a resolution authorizing the Director-General 'to continue to stimulate research and training relating to the natural environment and resources of the land areas and their conservation, by encouraging synthesis of knowledge, exchange and dissemination of information and research of international significance' and to convene in 1968 an intergovernmental meeting of experts in ecological studies and the conservation of natural resources.

It is in pursuance of this resolution that the present conference is being held. It has been organized and convened by Unesco, with the participation of the appropriate institutions within the United Nations family—the United Nations itself, FAO and WHO—and with the co-operation of the International Union for the Conservation of Nature and Natural Resources and the International Biological Programme.

All these organizations have been closely associated with the preparations for this meeting, in particular, with the drafting of the provisional agenda, and I am anxious here and now to tell their distinguished representatives how grateful I am for the invaluable assistance they have given Unesco by affording it the benefit of their advice. In this fruitful partnership, I see, with the deepest satisfaction, an outstanding example of that co-ordination and co-operation among international organizations, without which no enterprise of world-wide scope could hope to be crowned with success.

Ladies and Gentlemen, To the extent that the purpose of your proceeding is to show wherein modern science can facilitate the choice and elaboration of rational methods for using natural resources, while at the same time ensuring their preservation, their aim is to create, among scientists, political leaders and within the general public a current of 'ecological thinking', calculated to promote a better understanding of the relations between man and nature as part of the broader question of the relation between man and his environment. For the scientists, this will imply rising above the traditional frontiers between disciplines, for the political leaders, it will mean a conceptual and financial effort for the lauching of programmes of ecological conservation and research; for the public, it will mean a realization of man's power over nature and a rediscovery and reaffirmation of his responsibility to his environment.

In the light of the reports presented by Member States and of the deliberations of your commissions—which will deal respectively with research, with education and with scientific policies and structures—it will be for you to define the broad lines of the action which might be taken at national and international level, and in this connexion I have no doubt that you will draw up specific recommendations to Member States and the international organizations concerned. As far as Unesco is concerned, I can assure you that these recommendations will receive the Director-General's fullest attention, and that they will be submitted to the General Conference, the supreme organ of Unesco, at its forthcoming session which opens on 15 October.

It is my most sincere hope that your proceedings, which respond to the expectations of mankind today and the call of the future, may be crowned with a success commensurate with our learning and our hopes.

MAN'S HEALTH IN RELATION TO THE BIOSPHERE AND ITS RESOURCES

Address by Dr. M. G. Candau,
Director-General of the World Health Organization

Mr. Chairman, Ladies and Gentlemen,

The ecologist conceives the term 'conservation' as the wise management and utilization of natural resources for the greatest good of the largest number. One may debate the position of man in such a universe, but only as to what level of hierarchy he may allocate himself. That he exists and affects his own kind and all else in that world is not debatable. It is conceivable that a 'Garden of Eden' might exist without man, but it would bear no resemblance to the biosphere to which this conference is dedicated.

My comments rest upon the fundamental realization that man is not only dependent upon the resources of this earth, but that he himself is one of its most valuable resources. As such, man's history justifies the claim that he, like most other animal and plant life, is 'an endangered species'.The record of human disease makes amply clear that this danger is neither new nor predicted only for the future. Man, in his struggle for survival, poses as many true ecological challenges as the more familiar lion, rhinoceros or whooping crane. The environment truly may be his friend or enemy.

Of course, it is equally true that man and his acts may be the friend or enemy of the environment. One cannot think of the resources of the biosphere without recognizing that they have been profoundly altered—both for good and for ill—by human societies and their increasingly extensive technological manipulation. And it is clear that these man-caused changes in the biosphere must also affect the levels of health. Those of us whose responsibilities lie in the study and promotion of human health must, therefore, be interested in studies of the ecology of the biosphere and in its rational use.

It is my purpose to speak of man as the beneficiary, the violator and the manipulator of the environment. What are the nature and origin of his diseases? What are the geographic variations and implications? How do the biological, chemical and physical features of his internal and external environment make their impact? The worker in health learned centuries ago some of the lessons, in the observation of human health, which are now so diligently and so advisedly stressed by the conservationist. Rational development as against exploitation of human resources presents great opportunities for the application of 'ideal' conservation principles. It is in such a setting that I should like to particularize as to human health and the problems to which the World Health Organization has devoted its energies for two decades since its creation. As in all human endeavour, it cannot go about its task alone, but must collaborate with those national and international agencies, whose purpose and responsibilities impinge upon those of WHO.

One has reason to be pleased with the progress in human health during the past ten years, even though 'areas of darkness and light' are evident in the health picture.

Decreases in general and infant mortality and increases in the expectation of life at birth characterize a good part of the world. Communicable diseases, largely preventable, have been reduced, but by no means eliminated. In the so-called developed countries, reduction of births has balanced decreased mortality so as to result on the whole in a moderate population growth. In the great majority of developing countries, such a balancing effect has not yet occurred.

The prevalence of disease continues to change, and these changes are not always favourable. The communicable diseases, such as malaria, yaws and poliomyelitis, are on the decrease. But even here vigilance is a prime necessity, as witness the tremendous recrudescence in 1967 and 1968 of malaria in Ceylon, which had been relatively free of this affliction for more than a decade. This invasion of a disease thought largely to be eradicated is a dramatic example of nature's alertness to weakness in man's armour of disease protection.

It may be strange to report to an audience in 1968 that diseases, for which the means of control was discovered over one hundred years ago still challenge the biologist, physician and engineer.

Smallpox still ranges through much of the world, and cholera in a new form is spreading from its historic foci in Asia and has reached the portals of Europe.

Malaria, schistosomiasis, the enteric diseases, tuberculosis, leprosy, measles and cerebro-spinal meningitis are still well-established causes of morbidity and mortality. Other less well-known diseases like viral hepatitis and haemorrhagic fevers are arousing increasing concern.

In many regions the health scene is dominated by the presence of malnutrition, kwashiorkor, nutritional marasmus, and other forms of protein-calorie deficiencies which affect millions of children.

In the impoverished, developing countries, the infant mortality rate, a very sensitive indicator of the state of public health, fluctuates between 200 and 300 per thousand births. In this less favoured world, mandies early of the communicable diseases, and his life expectancy is less than 45 years. He is the easy victim of his debilitated internal and external environment. By contrast in the developed world, man suffers least from the communicable diseases and has an expectation of life at birth of some 70 years with an infant mortality rate of 20 per 1,000 or even less. With some exceptions, he is well fed, lives long and hence encounters the penalties of the ageing process, particularly cancer and cardio-vascular diseases.

Man's health is influenced by environmental forces. Many of his physical and mental disabilities are in large part the result of his failure to understand and to manage these often hostile forces.

Yet much research still needs to be done in the areas of the ecology and natural history of disease. For example, we need to know much more than we do about the role of disease in the dynamic equilibrium of nature. How are human disease patterns altered by man's changing of the biosphere—not only the dramatic changes such as the stripping of a forest by lumbering and the flooding of a valley floor by a man-made lake, but also the changes brought about by the building of a new road or the expansion of suburban areas into the countryside. We need, of course, much more knowledge of the ecology of specific diseases and their fluctuations. Finally, we need to know more precisely how to measure the variables comprising the environment.

Any real change for the better in human health for the 'third world' is contingent upon economic development in agriculture and industry, upon the creation of skilled manpower and organization of health activity and upon the provision of such environmental necessities as safe water and sanitation services. Each of these prerequisites to progress in preventing disease, reducing mortality and promoting positive health invokes issues of ecologic import, and forces us to make choices in the manipulation of resources.

Thus modern public health knowledge has given new emphasis to the need for resource management. One such influence, of course, stems from the increasing impact of economic thought on development in all countries. For most of the billions of people in the underdeveloped areas, poverty, hunger, and ill health are inseparably intertwined. To attack one without a simultaneous struggle against the others would be fruitless. Economic, social and technological advances are prerequisites to the full consummation of the great aspirations of the WHO charter—to attain 'complete physical, mental and social well-being' for all people. True health reform has always involved, in fact, a broad socioeconomic advance, to which the preventive medicine team has contributed valuable assistance.

May I briefly refer to some major ecological problems affecting human health?

The few examples which I will cite are all man-made. Sometimes they were intentionally but ill-advisedly created, on occasion they were the unanticipated consequences of social action, at other times apparent necessity brought forth evil consequences.

For millenniums, man has been both an urban and a rural animal, but it is only in this century that a major transformation has occurred, from a traditional, rural to a highly urbanized way of life. Industry has now become the source of livelihood for increasingly large numbers of people. Throughout the world and particularly in developing countries, a steadily growing stream of people migrate from the country to the city, especially to the great metropolitan areas.

The physical and social consequences are too familiar: general deterioration characterized by physical congestion, bad housing, poor community services, choked-up traffic, absence of even elementary sanitation, squalor and disease. Taken together they justify a frequently quoted conclusion, namely that 'the metropolitan problem is perhaps the greatest single problem facing man in the second half of the twentieth century'. In many countries, in the meantime, the difficulties of rural complexes have hardly been touched.

It is not my purpose to comment here upon the enormous resources in money, manpower and technology required to make even a minor impression upon these conditions. However, some of the consequences of urbanization for health and disease should be noted. Many of these stem from the failure to provide adequate sanitation, particularly in the settlements of new and poor migrants.

For example, one preventable disease which increasingly affects city dwellers throughout South-East Asia is filariasis, transmitted by *Culex fatigans*. In India in 1953, 25 million persons were estimated to be living in areas where filariasis transmission occurred. In 1960 this figure had risen to 64 million persons. Increases both in the density of mosquitoes brought about by poor sanitation and in the incidence of Bancroftian filariasis have been reported from many countries in Asia, Africa and Latin America.

A large proportion of the people of the world must carry water from long distances or from poorly-spaced standpipes in the street. Even where piped supplies are available in such areas, quantity may be scarce, delivery infrequent and quality unsafe. As a result, the enteric diseases are common and hospital beds are occupied by cases which were preventable. In rural areas, the opportunity for mass transfer of disease is usually self-limiting in the case of waterborne infections. However, in densely populated urban centres, badly controlled community water supplies may carry a special risk.

Progress is slow in providing well-controlled community water service in the rapidly expanding metropolitan areas. Lack of money, of trained people and of organization are the continuing obstacles confronting public health authorities.

One must also note the public health implications inherent in the failure to collect and properly dispose of the solid wastes of urban populations. The problem is not limited to sewage. The waste products of man's food and industry are ever present and never cease piling up. It has been said that the simplest index of the level of civilization of a community is how well it collects and disposes of its garbage.

The discarded food dump is a happy hunting ground for rodents and flies. In areas of relative abundance, man has been able more or less to curb the ravages of the rodent. Where poverty reigns, the hazard of rodent infestation is great. Its cost is measured in diseases which are transmitted by rodents and their ectoparasites. It is even more manifest in an appalling loss of food-stuffs and other goods through pilferage by rats.

But the ecological problems of cities and of other human settlements are hardly confined to the animal and insect vectors whose-life-opportunities are enhanced by human crowding, filth and lack of planning. Equally important are the radical changes which urban, industrialized societies imply for both the quality of man's life and for the natural environment. These changes can offer both exciting new and often alternative possibilities, of freedom and unforeseen constraints, of great affluence and seemingly intractable poverty. Some of the larger implications of urban society can be usefully considered under three headings: *scale*, *change* and *organization*.

Urban societies are *large-scale* societies. They involve not only the crowding of millions of persons into metropolitan areas but the pervasive spreading of urban ways into the countryside. Urban man daily sees not only the familiar faces of kinsmen and neighbours, but the thousand faces of strangers from everywhere who rush past him on crowded streets. His world is not centred upon the parochial concerns of his village nor bounded by the radius of a day's walk. His food may come from thousands of miles away, and his work may affect the lives of men on other continents. Indeed, the transformations which are so radically altering the biosphere—be they scientific industrial farming, mining and other means of natural resources exploitation, or the uses of nuclear energy—are organized by and contribute to the needs of an *urban* society. Already, we have changed the environment so much that natural ecological areas become increasingly rare—with unknown consequences for mental health, or for the spread of disease. For this reason, better knowledge about and education concerning the rational use of the biosphere is of paramount importance.

But the effects of modern urban civilization are not limited to the vastness of its scale and of its scope. They are to be seen also in the size of the problems it can generate—in the world-wide pollution which can stem from the fallout from a nuclear device, the potentially massive effects of urban air pollution not only on human health but even on the climate of regions, or the accelerating pace at which the demands of an urban civilization threaten the depletion of natural resources.

Modern urban society is also a society of incessant *change*. Cities are places of endless movement. Urban people are mobile people, and change is the order of the day among human activities and organizations; the very dynamic of modern science and technology alone assures this. It has increased man's capacity for affecting the biosphere tremendously in recent decades, and this capacity is likely to go on increasing.

Many of the consequences of scientific research and technological innovations are unanticipated or unplanned. Thus, for example, the problems which arose because the very pesticides which promised great advantages for man's health and prosperity created resistances in mosquitoes came as an unpleasant surprise to everyone.

Again, the effects of a fast-changing urban civilization must be understood in terms of its impact upon people. The restricted but psychologically comforting traditional world of the village is fast being destroyed by the onslaughts of modernity. The migrants from villages to cities the world over may often be the special victims of change; cut off from familiar ways and from the protective network of kinsmen and neighbours, they must learn to adjust to the impersonal environment of city life. Often ill-prepared to find and keep a job in a competitive technological milieu, and poorly equipped to cope with urban conditions, they may be forced to live under the city's harshest circumstances. No wonder that the adjustment of migrants to urban living involves the risk of both physical and mental ill health!

The challenge of helping individuals cope with rapid changes such as these is a major task in the effort to secure man's optimal physical, mental and social well-being. It is also a prerequisite to assuring their rational use of the resources of the biosphere.

Finally, modern urban society is marked by the pervasiveness of *organization.* The very success of modern organizational and management methods—in the gigantic enterprises of our cities, in the transformation of farms into 'agricultural factories' and above all in the all-embracing organizational environment of the modern State, has made possible the realization of technological progress. But it is a characteristic of modern organization that it deals more effectively with specific tasks than with long-range or ultimate goals. The objective, both in perfecting the physical environment and in achieving health for man, is to learn how to plan and to use the organizational, scientific and technological tools available. And to do this in such a way as to secure not only the 'greatest good for the greatest number', but a niche with freedom, security and opportunity for every individual. Nowhere is this challenge more evident than in the need to make the great cities of our world fulfil the promise which continues to draw multitudes to their gates.

The correction of the results of 'run-away' urbanization will require money, manpower and management skills—all in grievously short supply. No success is likely to be obtained without real co-operation in the basic planning process between planners, physicians, engineers, economists and administrators. The problems of an urban society are easier to describe than to solve—another illustration of the truth that diagnosis can be simpler than therapy! What is clear is that all such efforts will require an ecological approach.

One cannot close this discussion of man's environment and health without some reflections upon the charge made by some, that, simply by reducing disease, society is subjected to even more violent hazards because of great population 'increases' and resultant shorter and shorter supplies of food. The argument is commonly linked with population predictions of some 6,000 million people in the year 2000—and of 'standing room only'.

One might choose the fatalistic road laid out many years ago by Malthus and take refuge in despair. We have not disposed of the problem, however, by choosing that debilitating route, because it leaves unsettled what we shall do with the millions of people already alive. The marriage between sociology, economics and public health, so long overdue, is unlikely to produce immediate solutions. Many countries are turning to health planning as a method of organizing the distribution and utilization of limited resources. This has particular relevance to health services in the face of current changes in population dynamics, including changes in population growth rates, in the age composition of populations, and in migration patterns.

Better health is correlated with changes from wasteful patterns of high mortality and high natality to more productive patterns of low mortality, with natality regulated as desired—whether this involves an increase or decrease over previous levels. Family planning is being considered as an important feature of medical practice in the care of mothers and children and in the promotion of family health, in addition to whatever role it may play in relation to possible demographic problems.

At any rate, people, both the living and those yet to be born, will have to be fed and sheltered. Regardless of rationalizations, economic, social, technological, it can never be accepted that people can be left to die. The tempter of the world in which we live does not permit of such a solution. Circumstance, and not emotion, requires that our choice be clear and humanitarian. The challenge lies in mobilizing our vaunted science and technology so as to guarantee a reasonable probability of success.

At the same time, rational approaches to human health and to the full use of the resources of the biosphere alike demand that each be considered in terms of the other. Human well-being depends on the conservation of the resources of our world—and this, in turn, depends upon maintaining a proper balance between our species, *Homo sapiens* and the other inhabitants and resources of our globe. Certainly, we need more knowledge about the relations between human populations and their potentials and those of the natural environment. The development of a comprehensive ecological knowledge is a necessary ingredient for planning a better world.

The need of our times, then, would seem to be a concerted attack on the problems of men and of their biosphere. Within its abilities, the World Health Organization stands ready to play its part in meeting this challenge.

FOOD REQUIREMENTS AND PRODUCTION POSSIBILITIES

Address by Mr. A. H. Boerma
Director-General of the Food and Agriculture Organization of the United Nations

Mr. Chairman,

I feel most privileged to be here today and to have an opportunity of addressing you on behalf of the Food and Agriculture Organization of the United Nations. This is a conference whose importance derives not merely from its scope, but also from its timeliness. For it comes on the crest of a mounting wave of concern about the state of natural resources on which human life depends, but which man himself has all too often in the past treated in primitive or profligate fashion.

Agriculture, forestry and fisheries—the three sectors with which FAO is concerned—represent a potent force not only for the improvement of man's welfare, but also for the destruction of his natural environment. The history of modern agriculture is, in part at least, the story of an unceasing drive to achieve precisely that rational use of resources which is the ultimate objective of this conference. The conservation of soils, of water, of forests, is an integral part of our work. For us the ideal of rational use and conservation of resources is therefore not a new one. What *is* new, and what gives this conference its interest, is the scientific approach to the total resources of the biosphere, whatever the use to which they may be put. We in FAO welcome this development, and I am grateful to the Director-General of Unesco for inviting us to participate in the convening and organizing of the conference.

My task today is to take a long look forward at the perspectives for the world's food requirements and production possibilities. I hope thus to give you something of a framework for your discussions. Without venturing too far into the specific subject matter of the conference. I should like to offer you a few points of reference, which I believe should be taken into account when you come to work out your recommendations.

In this, as in so many other subjects, we must make a basic distinction between the prospects of the developed and those of the developing countries.

In the richer areas, the combination of an advanced technology with abundant capital has raised the productivity of agriculture to a point where, for many countries, the most serious danger in coming decades will almost certainly be that of overproduction. The current butter crisis in the European Common Market is a striking example of how the involuntary creation of surpluses can lead to serious economic and social difficulties. The future objective of most developed countries will be to improve the efficiency of their agriculture without at the same time unnecessarily increasing production.

The lines of approach will probably differ somewhat from one region to another. In parts of Western Europe, for instance, I believe that an increase in the size of the average farm, permitting the creation of more efficient production units, will be an important factor. In Eastern Europe, on the other hand, emphasis will almost certainly be placed on the progressive improvement of managerial standards on many of the State and co-operative farms. In all developed regions increasing efficiency will result in the continuing release of manpower for non-agricultural sectors of the economy.

By and large, the developed countries already have more land available for agriculture than they really need. Between the late 1950s and the mid-1960s, the area under cultivation in the developed regions as a whole changed very little. In the United States, however, a significant amount of farmland has been deliberately taken out of production. This may well be the start of a wide trend, since advances in efficiency will continue to diminish the amount of land required for agriculture. There are a few straws in the wind that suggest the possibility of rather considerable reductions, and even of producing some food without the use of land at all.

Agriculture depends basically on photosynthesis, the process by which the energy of sunlight is transmuted and stored up in food. Land is essential, not only because of the nutrients contained in soils but also because it acts as a collector of sunlight. In recent years, however, a start has been made on using other sources of energy for the manufacture of food. By far the best known is the production of single-cell protein with the energy contained in hydrocarbons. The first large-scale industrial plant using this process is to come on stream in the near future. The protein thus manufactured will probably in the initial stages be fed to animals and thus converted to human food. Subsequently we may expect that it will be made palatable for direct human consumption. Until the economies of the operation become a little clearer, we cannot foresee what sort of future lies ahead for this radical new process. But this could well be considerable.

If we are thinking ahead to the end of the century, we must also take account of a possible breakthrough in the search for a method of taming the forces of nuclear fusion, a search in which the major nuclear powers have been engaged for some years. Such a breakthrough, we are told, would mean the advent of almost unlimited quantities of low-cost energy. Its impact on agriculture might well be remarkable, for instance in making it economically feasible to use desalinated water for large-scale irrigation; whether, or to what extent, it would permit the industrial production of food on an economic basis is impossible to foresee at present.

Mr. Chairman, I have advanced perhaps unduly far into the dangerous realm of speculation in order to make one point quite clear. The technological revolution in agriculture is far from over. Many intriguing possibilities are under discussion, and doubtless others will emerge. Although the exact form that future changes will take is difficult to divine, I believe that they will have one feature in common: they will all tend to reduce the area of land needed for agriculture. The developed countries should thus, on a gradually increasing scale, be able to make 'surplus' agricultural land available for non-agricultural uses.

This process has, in a sense, already been going on for a very long time: we all know how farm land has been extensively taken over by the builders. But I suspect that, in coming years, the reduced land needs of the farmers may well raise even more urgently than hitherto the problem of conserving one of the most precious of all our natural resources: the countryside. In the ever-richer societies of the future, for instance, continuing policy decisions on a national scale will surely be needed to ensure that the populations of our cities are provided with adequate recreational areas for weekend and holiday use. The importance of such a feature for a highly mechanized urban society is underlined by what our statisticians politely call 'the decreasing trend of energy expenditure relative to food intake'. In simpler terms, we are taking less and less physical exercise but continuing to eat just as much as before. Available evidence suggests that during the past two decades energy expenditure relative to intake has decreased at the rate of 10-15 calories per annum, resulting—as I have learned to my cost—in a gain in weight with advancing years. Unless food consumption declines, the solution must be to increase physical activity during leisure and recreation in order to compensate for the decrease in energy expenditure during working hours. This line of approach will, of course, require the continued development of recreational areas for urban populations.

So far I have spoken exclusively of the outlook for the advanced nations. The situation in the developing areas is profoundly different. It is here, indeed, that we find the food problem with which FAO—and informed opinion everywhere—is so greatly concerned.

Let us look first at the requirements side of the food equation. We find that the demand for food is rising, and will probably continue to rise, at a historically unprecedented pace. Precise forecasts are difficult in view of the many variables involved. The most we can say with reasonable certainty, on the basis of present knowledge, is that the increase in the food requirements of the developing regions will amount to something between 3 and 4 per cent per annum for the foreseeable future. At least two-thirds of this is likely to come from the population factor, the increase in the number of mouths to be fed.

I should like to state firmly that FAO has no statistical evidence suggesting that the world is proving incapable of feeding a rising population. For the developing areas as a whole, food production has just about kept up with population increases in recent years, except for the very serious setback in 1965 and 1966 due to extensive droughts in India, Pakistan and parts of Africa. The situation remains precarious, but there are no symptoms of a long-term decline in *per capita* food production. At present, therefore, I see no justification for neo-Malthusian predictions of disaster. We shall certainly continue to experience catastrophes from droughts or floods, from diseases and pests. But this is quite a different matter from the widespread famine that would result from population outstripping food supply. Of such an occurrence, I find no warning in our graphs.

However, the outlook becomes a great deal more uncertain when we go beyond population growth and take into account the further increases in food demand resulting from rising incomes as well as from urbanizations. The most compelling reason for meeting this additional demand is that it offers the only real solution to the problem of nutritional deficiencies. We have doubtless all read about the chronically inadequate diets of millions of people, especially of children, in the poorer countries, and particularly their serious lack of protein. The most effective remedy is to make people better off through general economic progress, and at the same time to ensure that food is available for them to buy with the extra money that comes into the family. Only if we can satisfy the additional demand for food associated with rising incomes, particularly those of the poorer strata of society, can we hope in the long run to achieve a world that is free from hunger and malnutrition.

In recent years, the farmers of the developing countries have *not* succeeded in meeting this additional demand. Food aid has covered part of the gap. Scarce foreign exchange has also had to be diverted to food imports. And in many cases rising food prices have created hardship for the poorest sections of the population. Unless this performance can be dramatically improved upon, the world food problem will continue to give major cause for concern. What are the chances? Can the developing countries actually achieve an increase in food production over an extended period at the rate of 3 to 4 per cent per annum?

I must say immediately that a straight, unqualified answer is impossible at the present stage. The issues involved are being examined in great detail by FAO in the preparation of our Indicative World Plan for Agricultural Development. Production possibilities as well as food requirements are being analysed initially on a regional basis. Our regional studies are well advanced and will be circulated for comment this year, while the world study is to be published in the course of 1969. The plan will go beyond a mere analysis of issues, and will suggest both realistic targets for 1975 and 1985 and the policies which governments should consider adopting if these targets are to be attained. When this work is finished, I shall be in a position to make a more detailed and authoritative statement on the long-term outlook. I should prefer, today, to limit myself to a few general considerations.

Until quite recently, the developing countries were able to increase their agricultural production mainly by extending the area under cultivation. This approach still remains open in many parts of Africa and Latin America. However, in most countries of Asia—the region where the population is largest and the food problem most acute—there now remains very little leeway for bringing new land under the plough. Our statistics show the trend rather clearly. Over a period covering most of the 1960s, the developing regions as a whole increased the area under twelve major crops by 21 per cent. Between the late 1950s and the mid-1960s, however, the increase was only 11 per cent. We expect the slowdown to continue as land grows increasingly scarce in the most populous countries.

We can therefore say, quite firmly, that a solution of the food problem *must* come mainly from an increase in the annual output per unit of cultivated land. I am sure we all know that the advanced countries have been highly successful in increasing agricultural yields, particularly in the course of this century. It has been estimated, for instance, that in the United Kingdom wheat yields doubled between 1950 and 1960, and have doubled again since them. What about the developing countries? Where do they stand on the ladder of progress?

The answer is that they have, in recent years, been achieving a modest but significant growth in productivity, and the signs are that the rate of growth is itself gradually accelerating. The process is, however, still in its earliest stages. One or two figures will put the matter in perspective.

In the period around 1910, the wheat yield in the Indian subcontinent was estimated at 8.1 quintals per hectare. By coincidence, the figure was exactly the same in Greece. Currently, the yield in Greece has risen to 17.2 quintals per hectare or more than double—a result that is typical of the wheat-growing countries in the temperate zone. In India and Pakistan, however, the figures are virtually the same as they were almost sixty years ago, even if they are now moving upwards from still lower levels. During the same sixty years period, rice yields in India, Pakistan and Burma have actually fallen slightly, although in Japan they have increased by about 70 per cent, in the Soviet Union they have more than doubled, and in the United States they have almost trebled.

The physical sciences disclose no intrinsic reason why yields in the majority of developing countries should not grow at the same rate as those in the advanced areas. It is often loosely believed that the temperate zones have an overwhelming advantage because of their climate. From some points of view this is quite misleading, and if anything the reverse of the truth. Cold winters in the temperate zone severely restrict the possibilities of growing more than one crop a year. In tropical and sub-tropical areas, however, variations in temperature are much less, and multiple cropping is often feasible where water can be made available in the dry season. I would therefore not agree that climate is a decisive factor. In the matter of soils, nature has of course been kinder to some countries than to others. But if we compare the developed and the developing regions as a whole, we find that she has been reasonably impartial in the distribution of her riches. Man, and man alone, holds the key to agricultural plenty. The answer to the world food problem lies 'not in our stars, but in ourselves'.

It is for this reason that I confess myself an optimist regarding the future. The developing countries *have* the potential, and I am convinced that they will succeed in making good use of it. The three basic ingredients required are capital, technology and organization. They are becoming available in increasing measure, and I believe that the agriculture of the developing countries is now reaching the point of 'take-off'. Certain current developments lend force to this assessment.

New high-yielding varieties of wheat and rice suitable for the tropical and sub-tropical areas have recently been developed in Mexico and the Philippines respectively. They have been widely and successfully adopted and adapted by many developing countries, so far particularly in Asia. Where adequate quantities of water, fertilizer and pesticides are available, yields can be increased several fold. This is the first time that the developing regions have benefited from a technological breakthrough comparable with those experienced by the richer countries. The results will soon be showing up in our productivity figures, and provided that the necessary measures are taken I am confident that they can mark the beginning of a sustained trend. The realization of these hopes will require tremendous efforts by the developing countries themselves, as well as by the international agencies and by donor nations. We in FAO have rather precise ideas concerning the action required in coming years.

In the first place, much more needs to be done to draw maximum benefit from the high-yielding cereal varieties I have just mentioned. Increasing the area on which they can be grown will call for massive investments in irrigation works as well as in fertilizer and pesticide plants. Intensive breeding of further varieties is needed in order to meet the wide diversity of ecological conditions in different areas, to ensure resistance to plant diseases and to extend the breakthrough to other types of crop. Facilities for both transportation and storage will need to be increased in line with rising production, and a whole series of measures will be required to deal with the institutional and economic problems that may be expected to arise.

Secondly, I believe that an all-out drive needs to be made to overcome the protein deficiency in the developing countries—the so-called protein gap. This affects mainly the children in the poorer income strata. Available evidence points to the rich eating enough and more than enough protein to meet their physiological needs, while the poor and particularly their children have to live on diets seriously deficient in protein. Unlike the situation with respect to calories, our most recent calculations have produced no statistical evidence of an over-all gap between protein supplies available and estimated minimum needs, except possibly in a few countries of Africa which have predominantly starchy diets. Indeed, in most of the developing countries protein supply per caput exceeds theoretical requirements. The protein shortages actually observed are caused by the uneven distribution of buying power within populations, and the fact that protein can be taken by the well-off in excess of their needs without causing harm. In the future, demand for high-protein foods is expected to rise a good deal faster than demand for cereals. Here, however, we cannot yet report any signs of a technological breakthrough which would put adequate protein within the reach of the poor. More efficient animal and fishery production will of course be sought. But if we are to bring about a real improvement in the diet of the neediest, we must also aim at a greater intake of vegetable protein, for instance through increasing the protein content of staple foods. At the same time non-conventional sources of protein must be explored and, where economically feasible, exploited.

Our third action programme will be aimed at the prevention of waste. Direct food losses between harvesting and consumption cannot be precisely estimated, but probably amount to billions of dollars a year in the developing regions as a whole. In some circumstances, resources can be more effectively deployed in preventing waste than in increasing production. This programme is particularly close to the aims of your conference, since it will extend to indirect losses from the misuse of land and water resources, as well as to the rational utilization of fishery resources and prevention of losses of forestry products.

Our fourth area, covering measures to help the developing countries to earn or save foreign exchange, is perhaps less relevant to your debates. However, our fith and last programme, for the mobilization of human resources for rural development, deserves a special mention. The concept of integrated rural development is by no means a new one. FAO and other agencies, particularly ILO, have been preaching and practising it for some years. But the pressure of circumstances, rising populations, the flight from the land to already swollen towns, the need for continuously more sophisticated rural structures in the modernization of agriculture—the pressure of all these trends is now so great that I believe programmes for rural development must rank amongst our very highest priorities.

Such programmes will, by definition, have many facets and will involve the closet collaboration between FAO and our sister agencies. I would particularly mention the importance of rural education and training—an area in which we shall be working together with both Unesco and ILO—as well as agrarian reform, the establishment of co-operatives and improved extension services. All these are well-known approaches, and will find their place in what I hope will be a dynamic attempt to improve the quality of rural life.

I must admit, however, to considerable doubts whether we can achieve a real success in this endeavour without a radical change in the demographic outlook. While I am convinced that the developing countries *can* achieve an agricultural growth rate exceeding the rate of population increase, I do *not* expect this agricultural growth to be accompanied by corresponding increases in employment. Furthermore, success in solving the food problem can probably be attained only at the cost of diverting investment capital and human resources from other areas, that is to say by some sacrifice of progress in the non-agricultural sectors of the economy. Rural as well as urban unemployment and underemployment are already at alarming levels, and no relief is in sight. Current demographic trends seem destined to lead to the inexorable growth of what Dr. Prebisch, in a terrifying phrase, has called 'marginal population'. I believe that this is the gravest problem facing the world of today and tomorrow.

Mr. Chairman, I have tried to convey to you some of my thoughts on the very different prospects facing the affluent and the needy nations. It is my hope that, while giving due attention to both, your conference will bear in mind that the true challenge comes from the developing regions. Your debates will cover a subject of vital interest to FAO, and I shall wait with the greatest interest to learn of your conclusions.

QUALITATIVE AND QUANTITATIVE LIVING SPACE REQUIREMENTS

Address by Mr. Guy Gresford
Director for Science and Technology
of the United Nations Department for Economic
and Social Affairs

The conference for which we are assembled here today brings us face to face with a complex of problems which are of the utmost importance and urgency to all mankind—whatever our individual or national political ideologies, our religious beliefs, or our stage of economic and social development. The planet Earth has by the ingenuity, brains and skills of *Homo Sapiens* become one small world and although man can now reach out into space he must come to terms with the fact that his life span must be lived out in this planet's biosphere for some considerable time to come.

In the past, man's relationship with the biosphere has involved the establishment and maintenance of a harmonious balance and he can only ensure his continued existence, and achieve a measure of happiness, if he acknowledges this need and shapes his desires and actions accordingly. Today, the equilibrium between man and nature is being increasingly disturbed, so much so that we now sense the onset of a crisis, acute, intricate, and on a scale seldom experienced by mankind before. Because of its multiple aspects and extremely diverse forms of expression, its exact nature is difficult to define with precision. The rapid pace of change in world conditions and relations has brought about many disproportions, and grave anxieties are current about the threatening imbalance between population and resources, the growing gap between technologically more developed and less developed areas, the widening rifts between strata of society—the urban and the rural, the old and the young, the better educated and those less educated, the high moral aspirations and the continuing injustice and cruelty of man to man. There is increasing concern over the deterioration of the environment and the improvident uses made of our common patrimony, our only habitable planet.

Man is a creature of nature, and yet distinct. Most major philosophies agree that man's principal concern on Earth is his relationship with other men. Devotion to human welfare is therefore a human imperative. Belief in the humanistic objective of our endeavours must never be lost, or else we cannot endure in the possession of the accumulated cultural attainments of past millennia. On this matter, all present societies of men agree. The family of the United Nations owes its existence to the embodiment of this wider humanistic consensus.

In recent centuries, however, the world has been increasingly dominated by a dualistic world-view in which the distinction between man and his environment has been particularly stressed. This view accepts as a virtual axiom that man's foremost task consists in the progressive establishment of complete mastery over all of non-human nature. But, in recent times, man has tended to become so dominant on Earth that he is now approaching a position where he constitutes one of the principal aspects of his own environment and in which environmental mastery would require the subjugation even of human nature by man. The resolution of this situation is a philosophical problem, which requires a restatement of the humanist objectives in new terms on which we can agree or acquiesce. In the meantime, and in the absence of an agreed philosophy, we must address ourselves to the urgent practical problems which have arisen and to the practical means available for solving them.

The basic concern of this conference is the use by man of his living space on Earth—the achievement of a dynamic balance with the environment. In speaking of human living space, we are confronted with a phenomenon involving a number of interrelated aspects not always easy to define. Physically we move and have our being in a living space of soil, water and air filled, in varying abundance, with animal and plant life and inorganic resources. Within this layer we create another space of human habitation and movement which involves social groupings, political entities, and organizations designed to ensure food, health, learning, meaningful activities and human rights and dignities. In our own minds, these outer spaces give rise to inner living spaces entracing the world of ideas, symbols, arts, communications, traditions and beliefs. Disorder in any one of these spaces can produce disorder in another, making the harmonious management of the total human living space a very complicated affair. Because of this interdependence, our combined living space is in a sense indivisible, but it is so vast that order cannot easily be ensured throughout it at any one time unless there is simultaneous attention given to the more detailed circumstances within each constituent portion of the larger space.

Man lives in a world of national sovereignties, often strenuously engaged in preserving portions of the biosphere from unwarranted external interference. Since only one or another fragment of the earth can serve each man as his more intimate home it has always seemed normal that this should be so, but it is clear that now restraint must be observed in the exercise of sovereignties, in order to prevent unwarranted interferences elsewhere, this requirement is given added urgency by the increasing momentum of population growth.

It is hardly possible to approach the general theme of this meeting, and in particular the 'qualitative and quantitative aspects of human living space' without touching on the problem of population balance. There are very great difficulties in dealing with this matter in dispassionate terms because of the emotions which are normally enough linked with the intensely personal concept of procreation. Because of these emotions there is, at times, a tendency to isolate the problem from its historical and sociological context. There are widely held fears, which in the present state of our knowledge it is impossible fully to substantiate or refute that a slowdown in the gathering avalanche of human beings may not come soon enough to avoid a disaster. More recently however there has been a tendency to view the matter no less seriously but in less simple and drastic terms than those of the classical Malthusian dilemma based on the food-population equation. Many governments particularly involved with the problem tend rather to be seriously concerned with the impoverishment of the sum of their national resources in relation to unremitting population growth. Moreover, it is becoming more and more widely felt that the disproportionate accumulation of human beings, even if success can be achieved in providing the technical and economic means for their physical sustenance, will deprive human life of much of its human meaning. It may be that in some regions of the world such a state of affairs has already come to pass, and it is for this reason that governments and international organizations are now engaged in devising and implementing policies designed to facilitate a reduction in the frequency of childbirth by those who desire it. In any event it has now become impossible to ignore the increasing number of clearly unwanted pregnancies and of the very grave human, social and health problems which are thereby created.

Medical and sanitary improvements which have been largely responsible for extending the probabilities of individual survival will not, of course, be undone, and in fact they must be perfected still further. But continuing progress will create a more dangerous situation unless some parallel progress is made by mankind in the self-conscious regulation of his own numbers. No one should underestimate the difficulties of such a process, involving a matter of highly confidential communications seeking to elicit a motivated response at the humblest level. There is always a risk of inflicting much psychological harm and in dealing with this problem particular attention must be paid to social psychology. Perhaps quite different venues and approaches may have to be found in different cultural settings. Because of their great importance ot the respective governments such facets will have to be investigated with the greatest possible patience. At a critical juncture finding the correct approach can be even more important than an insistence on immediate quantitative success. Meanwhile, we can find some encouragement in the knowledge of what has already taken place in overcoming many of the difficulties in a number of economically developed countries under the combined influence of increased education, urbanization, diversified economic activities (including those of women), social mobility and reduced infant mortality. Paradoxically, the present accelerated population growth in many regions is a serious impediment to such achievements, without which a large reduction in birth rates has so far not been shown to occur.

The human living space is indeed changing enormously under the combined influence of population growth and increasing urbanization. With change so rapid it is small wonder that institutions and modes of organization now lag behind the greatly altered needs. A few tentative estimates and forecasts, though they merely touch the surface of the problem, may make this clear. The figures refer to the years 1920 and 2000, an interval of eighty years, the order of the life-span of a man.

It can be estimated that in 1920 the world's combined urban population totalled 360 million and that it may surpass 3,000 million by the year 2000 —an eightfold increase. The world's rural population totalled 1,500 million in 1920 and may also come to surpass 3,000 million by the century's end—that is, it would double within that interval of time.

However, as we know, there is now a wide differentiation between the population growth of the world's more developed regions and the less developed regions.

For the more developed regions it can be estimated that the urban population totalled 260 million in 1920 and that it may rise to 1,160 million in the year 2000, a quadrupling within eighty years. The rural population in the more developed regions may have totalled 415 million in 1920 and may diminish to 280 million by the century's end—a net decrease of one-third. Thus, in the more developed regions about two-fifths of the population was urban in 1920 and by the end of the century the proportion may have risen to four-fifths.

For the less developed regions the combined urban population in the year 1920 can be estimated as 100 million, and a nearly twentyfold increase can bring this total to 1,930 million by the year 2000. Also in the less developed regions, the rural population may have totalled 1,085 million in 1920, and this total may rise to 2,740 million in 2000, a stupendous growth despite the immensely rapid rise of an initially small urban population. Less than one-tenth of the population of less developed regions was urban in 1920. As tentatively calculated, the population of less developed regions will be two-fifths urban by the century's end. Their average urbanization level would then be as high as was that of the more developed regions eighty years previously. But with the greatly increased size and density of the population, the future circumstances in the less developed regions can hardly become comparable with earlier circumstances in the more developed regions.

An increasing proportion of the urban population, both in more and less developed regions, is that of the big cities. For some time past, big cities in more developed regions have grown into 'conurbations', 'metropolitan areas', and eventually entire 'urbanized regions'. More recently, some of the big cities of the less developed regions, even those with recurrent food deficits, have begun to show the same tendencies.

With big cities growing into regional conglomerations, the whole concept of 'urban' and 'rural' areas undergoes a vast change. No longer are cities mere points, like oases, in a rural desert. Entire regions are altered as they fall under an urban dominance. Outlooks and modes of living are transformed.

Demographic, economic, social and cultural conditions differ enormously between more developed and less developed regions, and between their urban sectors no less than between their rural sectors. It is becoming questionable whether urbanization in less developed regions can bring comparable prosperity and welfare as it has brought in the past to what are now the more developed regions. The economic and social overhead costs of urbanization are exceedingly high in relation to scant resources.

In the meantime, urban and rural environments differ from each other to an increasing extent, making the latter more and more remote from the former. The relative stagnation of small towns makes them appear as the weakest links in an increasingly distorted settlement structure. The social transitions that are to be made by rural-urban migrants exceed more and more their psychological capacities for personal achievement within their own lifetimes. New approaches to organizational forms in which the slum and shanty-town dwellers of the poorer countries can be effectively engaged and absorbed are urgently needed.

Nor can it be said that urbanization problems have been dealt with satisfactorily in the more developed countries. The dominance of narrowly technical and economic criteria has too often produced environments which are unsatisfying from the point of view of the human being as a naturally pedestrian, sociable and meaning-seeking creature. Disenchantement and alienation are widespread in the poorer quarters of even the wealthiest cities, as the sense of participation in a combined social endeavour is being lost. The link between the citizen and his mostly inorganic neighbourhood becomes disrupted and motivating attachments are severed. Man's feeling for a place, his sense of belonging, have too often been violated by the abstract monotony of an uninspiring architecture which can provide shelter without creating a home. Nor do the suburban residences of the better-off citizens provide the wished-for relief. Even there, living tends to become artificially segmented into a set of uncoordinated separate functions. As if caught in a trap, the urbanities suffer from an erosion of attainable aesthetic objectives, and the goals of a competitive society, with all its strenuous work, are less and less well understood.

Many other aspects of the qualitative deterioration of man's living space will be the concern of this meeting. In the face of man's rapaciousness the conservation of natural resources has long been a losing battle. Soils are being eroded and their fertility depleted, often beyond the possibility of regeneration. Water resources are becoming scarce. Many forms of wildlife are disappearing. National scenery continues to suffer from the merciless inroads made by highway construction or the disposal of industrial wastes. More recently, there has been an intensification of concern with the wholesale pollution of air and water associated with extensive urban and industrial developments, and the primacy of the internal combustion engine. The congestion of traffic and unwanted noise are other forms of pollution which produce wastelands in the spaces of human movement and thought. In attacking these problems enormous tasks lie before us to safeguard the patrimony of our living space for the use and enjoyment of future generations—and indeed for our own.

But in the light of our review of the increasingly depersonalized and dehumanized living spaces in which man has to make his home, it is necessary to assert that conservation is not enough. It is not enough to prevent additional abuses, to slow down the unwarranted inroads into the biospheric surroundings which still occur at a rapid pace. It is necessary to create conditions for allying the concept of conservation with the rational use of the resources of the biosphere. It is necessary first to re-create, to reconstruct, before we reach a point of no return.

We are all keenly aware of the extent to which men are fashioned by their environments. In aesthetic surroundings where their appreciation is cultivated men feel more at peace with the world than they can where their eyes and ears are met with constant offence. Men willing to engage in the work of clearing the debris, of refashioning their living space so as to make it more germane to truly human needs, can overcome their difficulties more readily than those deprived of personal participation in the building of fit environments. The work must be done everywhere, in rich countries and poor, in villages and cities, at the levels of international, regional and national organizations.

Fortunately, man is now in possession of scientific and technological means which can be used for this task of reconstruction. One of the tasks of this conference will, in effect, be to provide an inventory of the tools made available by science and technology and to sketch out the main lines of action whereby they can be used for securing the more rational use and conservation of the resources of the biosphere at national and international levels. The evil side-effects which have, in the past, often followed the uncritical applications of science and technology must be avoided. In using the scientific knowledge available to assist in the restructuring of the living space, it must be employed for achieving improvement of the quality of human life. Much planning in the past has been done with reference to truncated models of man. Some have thought of him principally as a political creature and have hoped that welfare could be ensurely by devising satisfactory forms of government. Others have believed that human happiness can be achieved by economic growth alone. Specialists in many fields have naturally been tempted to over-emphasize man's primary concern with health, or education, or leisure, or some other enjoyment. But the concept of the biosphere, the human environment—man's qualitative and quantitative living space—can only be considered as a totality and we have seen the growing urgency of the problems caused by the disturbance of the delicately adjusted equilibria between its various facets.

The aims and work of the members of the United Nations family range over all aspects of the biospheric environment and this conference will serve as an important international catalyst in stimulating concern at the problems and drawing up plans for attacking them. The members of the United Nations family, national governments, non-governmental organizations, the scientific community in developed and developing countries, planners and administrators, must all be involved.

Many of these institutions are already actively concerned. In the United Nations, the Advisory Committee for the Application of Science and Technology to Development is basically concerned with ensuring that science and technology are applied in the interests of economic development which will enrich the quality of human life in the developing countries witout having undesirable side-effects such as have occurred in the past. The second Development Decade must have the same ends in mind. The work of the members of the United Nations family, each in its own field, also has the same objectives.

But as a perusal of some of the papers to be presented to this conference makes abundantly clear, the problems which mankind faces in this area cannot be tackled piecemeal. The biosphere and man's place in it must be envisaged as a whole. The initiative which has been taken by Unesco in arranging this meeting is a significant first step in this direction. An important proposal has also been made at the most recent session of the Economic and Social Council by the Swedish Government. This has drawn attention to the problems we are facing at this conference and the urgent necessity for gearing the achievements of science and technology to the improvement of the quality of human life. The Swedish proposal envisages the eventual calling of a major international conference which would serve the purpose of encouraging an intensification of existing efforts in the field and giving them a common outlook and direction. This proposal has now been the subject of a resolution of the Economic and Social Council which recommends to the General Assembly that it should, in the light of the achievements of the present Biosphere Conference, consider ways and means of providing a framework for a comprehensive consideration within the United Nations of the problems of the human environment in order to focus the attention of governments and public opinion on the importance of the question and to identify those aspects of it which can only, or best, be solved through international co-operation and agreement. The present meeting must be regarded as the first step towards the provision of such a framework within which it must be possible for mankind to conserve and use quantitatively and qualitatively the living space which is available to them.

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