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INTERNATIONAL POSTGRADUATE COURSE IN ECOLOGICAL APPROACHES TO RESSOURCES DEVELOPMENT, LAND MANAGEMENT AND IMPACT ASSESSMENT IN DEVELOPING COUNTRIES (EMA)

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Centre for Protection and Improvement of Environment (Berlin) of the Ministry of Environmental Protection and Water Management of the German Democratic Republic in cooperation with the Technical University Dresden

Subject II: Ecological fundametals of production systems

STUDY MATERIAL

elaborated by a team of authors under W. Bassus

Volume One

II.1. Biological fundamentals of production

- -Basic problems of the ecology of terrestrial ecosystems
- -Basic problems of the ecology of aquatic ecosystems
- -Fundamentals of primary production
- -Production of useable biomass and strategies for its utilization
- -Influencing the productivity of ecosystems

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- -Economie, social and hygienic influences
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VOLUME FOUR

Volume Four

II. 4. Stability and protection of ecosystems

II. 4.1. Economic, social and hygienic influences

Human populations are components of ecosystems. Man is exploiting ecosystems and is changing them in a desired but very often also in an undesired, unfavourable manner for purposes which are called development. So human populations like all other living beings are governed by the ecological and biological laws of nature but man as a social being is also depending on socio-economic and psychological aspects. In man's relations to his environment four main aspects can be distinguished:

- the flows of energy, nutrients and water
- the movements of pollutants and other toxic agents and the appearance of undesired side effects like radiation, waste, heat, noise etc.
- the transfer of disease-producing agents
- a communication and perceptual relationship involving response to a variety of environmental stimuli.

The understanding of man's interrelationship with his environment requires first of all an accurate characterisation of the essential structural and functional properties of human populations and an analysis of the processes within them and caused by them. The main characteristics of a population, according to WEINER, 1974, are:

1. Population size, population composition, population dynamics and demographic constitution
2. Nutritional status of the population
3. Developmental and anthropometric status
4. Physiological fitness and functional efficiency
5. Medical and hygienic status
6. Psycho-social status
7. Genetic constitution

The dynamics of the human community within tropical eco-systems and the system formed by it are illustrated in figure II. 4-1 in a simplified manner.

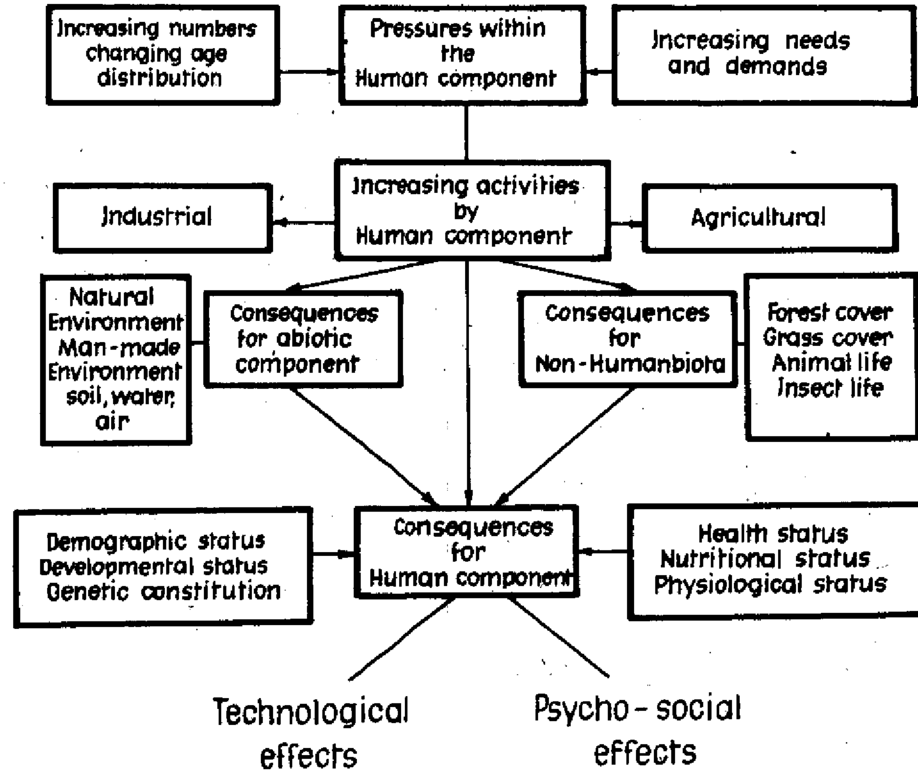


Figure II. 4-1 Dynamic relationships of the human community in tropical ecosystems (From WEINER, 1974)

The key element in this system is the pressure within the human component, that means the human population itself and its permanent increase. So the human population problem has to be considered as the most important and most serious of all the problems confronting man.

It begins as a biological problem, but quickly becomes connected with economic questions, social issues and moral and religious aspects.

Human population growth and its pressure on the environment give rise to certain hazards, the most important of which are:
- food shortage
- environmental degradation and pollution
- shortage in resources
- psychological stress

<u>The world population</u>

Evolution of man was a long process of millions of years which set man as a biotic being apart from the animals. About 3 or 4 million years ago, in the savanna-regions <u>Australopithecus</u> emerged, a tool-using pre-man whose population numbered perhaps 100,000 - 200,000 individuals.

Man's evolution was accompanied by a cultural evolution which led about 200,000 years ago to the appearance of modern man, <u>Homo sapiens</u>. Cultural advances caused a slight decline in the average death rate resulting at the end of the Old Stone Age (20,000 - 10,000 B. C.) in a human population of 2 - 3 million with an annual increase rate of about 0.002 per cent.

Between 9,000 - 7,000 B. C. an <u>agricultural revolution</u> began, allowing man to shift from gathering and hunting to farming which made him more independent from nature.

Life expectancy increased and larger settlements were established which again led to a population growth with a rate of increase of about 0.012 per cent per year which brought the world population to about 200 million in the year one. With advancing human civilization the <u>industrial-scientific revolution</u> began between 1650 - 1750 resulting in a population of 500 - 800 million; although this rise in population was quite irregular. Due to an increased standard of living the rate of increase was about 0.3 per cent between 1650 and 1750, reaching 0.5 per cent between 1750 and 1850 and 0.8 per cent after 1850; mainly due to the fact that the death rate continued to decline.

Later on the growth rate of population reached values of 1 - 2 per cent resulting in a geometric growth pattern of human population - a unique exception in the biological world where the normal growth pattern is a logistic one.

Due to limited resources and space, the geometric growth cannot continue for a very long time because world population is doubling now in less than 35 years.

Therefore the control of human population growth and the stabilization of the population are the most pressing needs.

In the second half of the nineteenth century the so-called <u>"demographic transition"</u> started in the industrialized countries, characterized by the decline of birth rates, and resulting in a stabilization of the population growth on a low level. Thus, two principal demographic trends in the industrialized world could be distinguished. The first was a decline in death rates and the second was a decline in the birth rate following industrialization.

In the developing countries, the first mentioned trend is still the dominating pattern of population growth which soared drastically after the end of World War II.
(Figure II. 4-2)

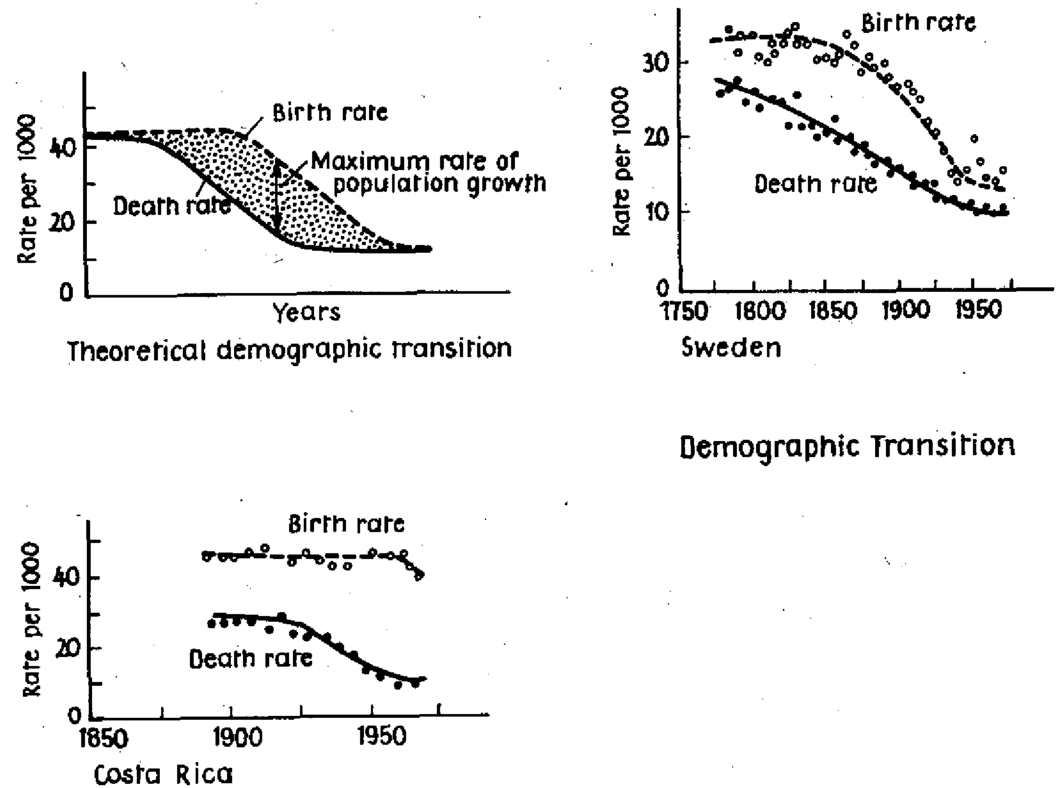


Figure II. 4-2 Demographic transition (From KREBS, 1972)

What determines the death and birth rates in human populations?

Modern medicine and public health are very often considered to be the important factors but they seem to be only one factor of a complex process as can be seen from the Sri Lanka example where the drop of death rates from 1944 to 1954 was explained by malaria control operations in some areas. But similar drops in death rates occured in non-malaria areas of Sri Lanka too, where DDT was not used.

So the general economic progress in a society including improved nutrition, housing, sanitation, public health measures, medical care and education acting in a complex manner are the reasons for the drop of death rates.

Why does the birth rate fall?

In ancient times the birth rate was always high and the reproductive potential of man had been used completely. Ten and more children was the normal family size and due to the environmental resistance 8 to 10 births per woman had been necessary to ensure the survival of the species man and the survival of the family.

The population growth was regulated by some limiting environmental factors. Today "industrial man" is more or less freed from such limits, and the population increases so that other mechanisms of regulation are necessary. Though some undeveloped primitive tribes have developed mechanisms of self-stabilization, spontaneous stabilization did not occur in modern societies. But now, in developed countries with an increasing standard of living birth rates drop. There are mainly social and psychological factors which dominate this process, and relations between limited family size and standard of living, prosperity, costs for education, available recreation time and other factors are of essential importance so that many children will be a financial burden to the parents. In other regions with developing countries regulations by society are necessary to achieve demographic transition and to stabilise population growth. Family planning and birth control are the main strategies to realize this concept. Peoples have to be motivated to keep family size in the limits required for demographic transition, because due to poor economic conditions in these regions a large number of children is vital for the existence and survival of all members of the family. Children contributed to the labour force of the family and they were the only source of old age security.

It is only economic development which could mitigate this situation, and which will allow families to reduce the number of children.

Distribution patterns of human populations

World population cannot be analyzed as one unit, so that separate subpopulations have to be analyzed according to their increase rate and density (Table II. 4-1).

	Total population (millions)			Annual growth rate (per cent)	
	1970	1985	2000	1980 - 85	1995 - 20
World	3632	4933	6494	2.0	1.7
Developed regions	1090	1275	1454	1.1	0.8
Developing regions	2542	3658	5040	2.4	2.0
Southern Asia	1126	1693	2354	2.6	2.0
Africa	344	530	818	3.0	2.8
Latin America	283	435	652	2.8	2.6

Table II. 4-1: Distribution of the world population and annual growth rates in the various regions (A. C. LEE, 1972)

If people were distributed evenly throughout the world, the density would be little over 19 inhabitants per km^2 but due to different ecological conditions density-distribution is very heterogeneous (Table II. 4-2).

Country	Density / km^2
Brazil	12
United Kingdom	222
Japan	222
Puerto Rico	250
Belgium	285
Indonesia	420

Table II. 4-2: Population densities of selected countries

In the hunting and food-gathering period of human evolution about 5.2 km^2 of fertile land was required to support one individual, and 50 km^2 of hunting area for one family. Now, agriculture and technology permit much greater human populat- ion densities and the development of permanent human settle- ments with all the well-known negative consequences to the environment.

The establishment of cities provided the basis for some of the world's oldest civilizations but only with the rapid growth of cities after the industrial revolution urbanization became the dominating demographic trend with a steadily in- creasing migration of people from rural to urban areas in search of a better life. The urbanization process in the developing countries is more rapid than it used to be in in- dustrialized countries; though the hopes for better life are rarely fulfilled. If the urbanization trend continues at the same rate up to the year 2020, nearly everyone would then live in urban areas and about 50 per cent of the world pop- ulation would dwell in cities of over one million inhabitants. Infrastructure, town planning, housing programmes, health and hygienic conditions face pressing problems. The consequences of the artificial environment in urban regions on human evolution cannot be assessed yet.

Ecological consequences of urbanization on the rural hinter- land

The food supply of a city of 100,000 in humid Asia requires an area of 750 km^2. A city of the same size in arid Africa needs a hinterland area of about 2,850 km^2. The energy de- mand in fuel wood equivalents is 1.76 for urban dwellers in comparison to 1.0 for rural people. In the vicinity of large cities the desertification process is very much accelerated due to deforestation. The impact of urban people on forests by clear-cutting to satisfy their wood-based energy demand is 9 times that of rural people. So, in the surroundings of Khartoum, there is an annual clear-cutting for fuel wood of 3,300 km^2. Eighty per cent of wood are used to satisfy urban demands (WHITNEY, J. B. R., 1981).

Demand for food is depending on similar factors, as table II. 4-3 shows.

Table II. 4-3: Per capita consumption of selected foodstuff in kg by rural and urban dwellers in Sudan (WHITNEY, 1981)

	Urban	Rural
Sorghum	141	111
Millet	6	49
Wheat	9	6
Mutton	13	5
Beef	16	8
Butter	3	0.75

In cities meat demand is two times higher than in rural regions. Each urban dweller needs more agricultural products for his support than a rural inhabitant, therefore additional production has to be achieved entailing serious environmental consequences.

Woodland clearing for cultivation is increasing, more and less suitable grassland comes under grazing pressure and herds have to migrate over greater distances to satisfy their demand. All these factors have a deteriorating effect on the rural hinterland. Price and market problems have to be considered as well. The increasing water demand which for urban dwellers is at least 20 to 100 times higher can cause many problems too (overexploitation of water resources, inappropriate waste water disposal etc.).

Increasing food and energy demands and some ecological, social and economic consequences

Due to the increasing population with an average growth rate of 2.0 - 2.5 per cent in developing countries an increase of at least 4 per cent in food production is required to fulfil the growing demands, and the same accounts also for energy supply (See Figure II. 4-3). In most developing countries the production of these commodities is mainly a "soil-based" process in which producing ecosystems are involved. As discussed later it is not the extension of arable land which can be used as the main strategy to fulfil the demands, it is a great improvement in the efficiency and productivity of agriculture in most of the tropical developing countries which is necessary to provide their increasing population with adequate food, employment and a better standard of living.

Nearly 70 per cent of the people of these countries currently depend for a living on agriculture which, with few exceptions, accounts, on an average, for almost one-third to two thirds of the gross domestic product and for even more than half the total value of exports. Hence, agricultural development is not only needed to produce more food for domestic consumption and raw materials for local manufacture but also to provide exports to earn foreign exchange for the purchase of resources which must be imported for industrial development. So for most tropical developing countries agriculture in combination with forestry can be considered to be the "back-bone" of national economy.

Current agriculture is influenced by social, economic and political circumstances, as well as by the environmental, ecological and technical factors, and some of them should be briefly discussed here.

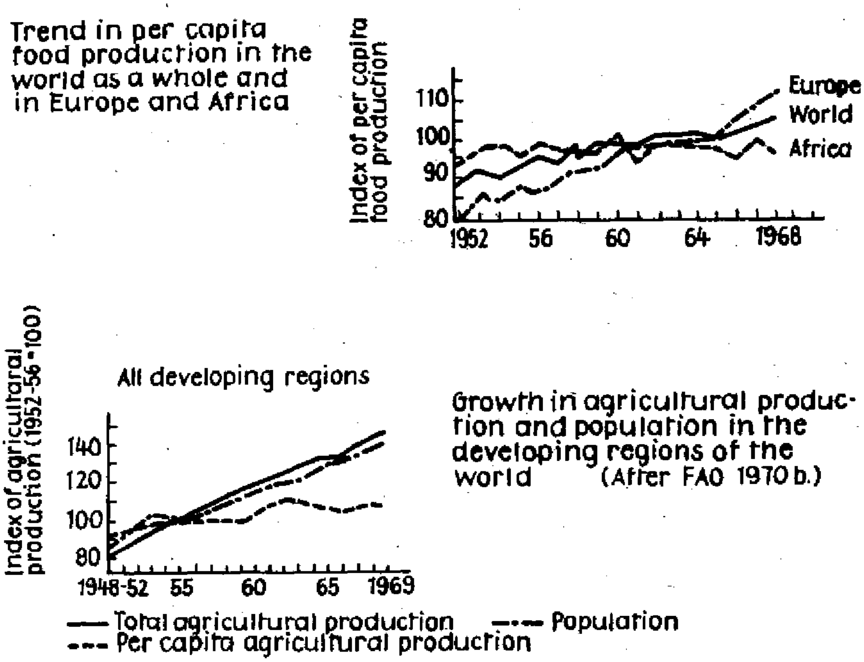


Figure II. 4-3 Trends in food production and in human population increase (From KREBS, 1972)

Social structures and customs

In most parts of the tropics farming is mainly undertaken by smallholders who practice it with traditional methods and low productivity mainly for subsistence. This kind of farming formerly was an intrinsic part of culture and tradition of the people.

Religious beliefs also can have an obvious influence as can be seen from the cattle sacred to Hindus which cannot be killed so that they exert a profound influence on agriculture in India where much of the land is burdened with inproductive cattle.

Other customs may also have an important effect on the land use patterns. Some African pastoral tribes keep as many animals as possible only as a matter of prestige and they completely disregard the carrying capacity of the land and the quality of the stock. This commonly results in overstocking with severe consequences of environmental deterioration. Also, the influence of group or tribal life with traditional strictly cultivation pattern affected agriculture very much, and considerable efforts are necessary to persuade people to change their traditional attitudes like shifting cultivation, extensive pastoralism etc. with their undesired side effects on the environment.

Land tenure and inheritance

Land tenure systems associated with customs regarding inheritance have an important bearing on the way of agricultural development. Communal tenure is the most common system but often individuals have user rights in cultivated land, usually including that lying fallow. Generally this custom places difficulties to the improvement of land use, particularly if soil fertility is concerned, and tree growing may be affected too. Forms of individual tenure as freehold, leasehold and various kinds of feudal tenure characterized by wasteful land use also may have some disadvantages but the main problems result from unsatisfactory landlord-tenant relationships. Wasteful exploitation of the available land will dominate over the careful maintenance of ecosystem productivity because sometimes one third to a half of the crop has to be used to pay the rent for the land. Given unfavourable conditions, farmers become continuously indebted to their landlords, and this prevents investments for the improvement of the land (WEBSTER and WILSON, 1980).

Fragmentation of the land is very common and makes it difficult to use all the distributed plots efficiently and to care for soil fertility and soil conservation.

All these factors place obstacles on the improvement of agricultural productivity, accelerate environmental deterioration, and give rise to social problems. Changes in such a way to form cooperations or to grow perennial cash crops are first attempts to overcome the disadvantages but the first need for governments is to carry out a <u>land tenure reform</u> and to deal with fragmentation by redistribution of land and consolidation of holdings.

Population pressure

Population pressure has already caused a decline in the productivity of much of the land farmed by indigenous methods.

In Africa, traditional <u>shifting cultivation</u> was formerly capable of providing indefinitely for the subsistence of a sparse population. In many places, however, increased population pressure has rendered restorative fallows impracticable, or too short to be effective, with the result that soil fertility an crop yields have greatly declined and the land is no longer capable of adequately supporting the people. Similarly, in pastoral areas the growing human and stock numbers have commonly accentuated the ill effects of poor farming, with following disastrous erosion and pasture deterioration. This happened mainly in Africa, not in Asia, where more intensive farming systems have been evolved, capable of maintaining soil fertility at least at a moderate level and of sustaining the people but only on a low standard of living.

Increasing population density leads to a decrease in farm size and thus to under-employment and lower productivity. To meet increasing demands requires larger farms with higher productivity, for that reason some people have to leave the land. This again requires alternative employment for those who leave the land, but this cannot be easily provided.

Farm equipment and requisites which are essential preconditions to increase productivity are commonly limited in numbers and primitive in nature. Modern equipment and technologies are compulsory for the improvement of productivity but due to the large increases in their costs most farmers, owing to their poor economic conditions, are not able to buy enough of them unless government support and finance is provided. In addition the whole strategy requires much support from the government regarding legislation, administration and finance public utilities and services. This includes the complete land use planning, infrastructure, marketing and export system, storage and processing facilities, research, training and education and much more developmental aspects (See also Chapter III and VII).

Energy problems

Though not more than 8 to 10 per cent of the world oil production is consumed in developing countries to meet their energy demands these countries have to spent more than 50 per cent of their export gains to pay for the oil. Currently fossil fuel is the main energy source but most tropical developing countries dispose of these substances only in very limited amounts.

Therefore the growing energy demand has to be met by other sources, for instance mainly using renewable resources in form of biomass which is grown or produced in different ecosystems. In addition to fuel wood crop and plant residues could be used, and energy-crops like sugar cane, cassava, fast growing trees etc. can be directly converted into energy in form of alcohol. Production of biogas from agricultural and human wastes is also one of the available strategies. In tropical developing countries more than 2,000 million people are depending on wood, dung and agricultural residues as energy source, accounting for 4 - 5 per cent of the world's total energy consumption only (FOLEY, 1981). Wood directly used or indirectly in form of charcoal plays the most important role in an ecological sense because its utilization results in deforestation with all environmental consequences.

Currently nearly 100 million rural people suffer from acute fuel wood scarcity, and more than 800 million use their fuel wood more quickly than it is being replenished. By the turn of the century this last figure is expected to rise to 2,225 million. In developing countries fuel wood accounts for about 20 per cent of total energy needs, and 80 per cent of it is used for cooking and heating in households. About 25 - 30 per cent of the family budget is required to purchase fuel wood, and more than 10 hours per household and week is the average collection time. This illustrates the pressure exerted on human populations by the fuel wood demand. Concerning total consumption of wood the share of fuel wood is about 60 per cent in Africa, 93 per cent in rural regions of India and 20 per cent in Latin America.

The influences on the forests and on the environment can easily be recognized from the Kenyan example. This country uses more than 30 million m^3 of wood annually, and the forest area is declining permanently, exposing the land to erosion and desertification.

The whole ecological connexion of fuel wood demand - deforestation - soil impoverishment - climate affection - food shortage illustrates clearly the environmental consequences which may be caused by human activities only to meet their basic needs, if total annual consumption of more than 1,000 million cubicmetres of wood has to be considered in developing countries.

It has been calculated that in 1994 a deficit of more than 650 million m^3 of fuel wood has to be expected worldwide due to overexploitation and increasing demands, and by the year 2020 nearly all of the accessible forests will have been cut. The deficit of 650 million m^3 of wood can be compensated by the use of dung and crop residues for fuel purposes which then, however, will be missing for the maintenance of soil fertility with all its adverse consequences.

Another alternative is the cultivation of <u>energy crops</u> and the establishment of <u>energy plantations</u> (fast growing tree species) but this will cause conflicts to agriculture for food. Decision makers so have to consider carefully the ecological and economic constraints of this <u>food-feed-fuel conflict</u>.

<u>Food and nutrition</u>

Except for the present shortage of food man is able to overcome all other limiting factors in his development. Adequate food production is one of the most important problems which man is facing now.

What means an adequate food supply?

The simplest way to describe and compare diets is to measure the energy they provide per day.

According to FAO-standards a world average of 9,850 kJ (= 2,345 kcal) per capita per day is required. 5,880 to 6,720 kJ per day are required for the maintenance of the basal metabolism. Hard physical labour requires 14,700 to 21,000 kJ per day. For a short limited time survival is possible with 2,940 to 3,360 kJ.

FAO estimated that an average of 10,160 kJ (2,420 calories) per capita per day in food was available worldwide at the market in the mid-1960s. However, differences in the distribution of food between and within countries must be taken into account. The gap between needed calories and available calories is increasing.

In developed countries, diets contain about 12,600 kJ per day; the figure for developing countries ranges from 7,560 to 8,400 and more, provided that people can afford adequate nutrition.

Although world production in calories is sufficient to meet all demands, a high percentage of world population is suffering from inadequate energy supply. More than one thousand million people cannot get the minimum of food they require, even people in developed countries and particularly the rural population of developing countries.

Energy demand and input alone is not enough to assess the value of a diet. Another way to measure the diet is the <u>protein intake</u> and here the situation is still worse than in case of energy. According to FAO recommendations the daily protein requirements are in a range of 0.8 to 1.0 g per kg body weight. More than 500 million people do not get this daily amount. This leads to different forms and degrees of <u>malnutrition</u> like Kwashiorkor and Marasmus. Child and infant mortality is 40 - 50 times higher than in case of adequate protein supply.

More than 30 to 40 million people die annually from starvation or malnutrition.

Other deficiency diseases shall only be mentioned here, like scurvy, beriberi, pellagra etc.

So, protein deficiency is the most serious problem in human nutrition.

World population consumes about 85 million tons of protein annually; two thirds of it coming from plants, mostly cereals and legumes. Animal protein which accounts for only one third of the consumption is better digestible than plant protein and its content in essential amino-acids is higher. So the effective transformation of primary plant biomass into secondary animal biomass is an important aim in developing food strategies. Besides this, emphasis should be put on increased yields of high-protein crops.

In 1980, a deficiency of 10 million tons of animal protein was calculated, and in 2000 an annual deficiency of 22 million tons of animal protein will be expected.

The total primary production of the biosphere (including water areas) amounts to some $42 \cdot 10^{17}$ kJ annually. In 1970 man harvested about $22.26 \cdot 10^{15}$ kJ of food, that is about 0.5 per cent of the gross primary production; or 1 per cent of the NPP. 99 per cent of the food energy came from land areas. If an annual demand of 4.2 million kJ per capita (= 11,760 kJ daily) is considered, then the above mentioned harvest is sufficient to feed more than 4 billion people adequately, using only 0.5 per cent of the gross primary production.

So it seems that man is not yet making full use of the photosynthetic capacity of the earth.

However, the possibilities to feed man should not be overestimated, and some of the limiting factors should be briefly discussed here.

A total of 43.6 per cent of the gross primary production are produced by oceans, and presently only food from marine animals can be conveniently harvested while only limited areas can support intensive fisheries.

Domestic animals are utilizing about 12 per cent of the net primary production of the land area, but the efficiency of energy transfer is in the range of 10 per cent only; that means that a tenfold number of people can be supported from a given area by plant food in comparison to feeding animals first and then eating the meat. However, due to the high nutritional value of meat man is interested to transfer a certain amount of plant energy into animal biomass. So in some countries 50 to 70 per cent of the agricultural production is used to feed animals.

About 12 per cent of the land area most suitable for agriculture is already under cultivation. Another 12 per cent is arable, but to bring it under cultivation would require much more funds than the intensification of agriculture on good lands (See Table II. 4-4).

Table II. 4-4
Forms of land use on the total land surface (FREYE, 1978)

Total: 14.9 thousand million hectares	of land surface
1.4 thousand million hectares	arable land under plough
2.6 thousand million hectares	pastures and grassland
4.0 thousand million hectares	forests
0.4 thousand million hectares	unused (barren)
3.3 thousand million hectares	deserts and semideserts
1.3 thousand million hectares	Antarctis
0.5 thousand million hectares	tundra
0.2 thousand million hectares	ice-covered
1.2 thousand million hectares	built-up area (housing, traffic and other human purposes).

In the course of human history more than 2 thousand million hectares of biologically productive land were lost and today more than 7 million hectares are lost annually by erosion and other factors like mining, construction purposes, salinization, desertification etc. So the chances to increase food production by bringing a large amount of new arable land under cultivation are small.

About 70 per cent of the arable land is located in tropical and subtropical regions. To double food yields will require a tenfold increase in fuel, fertilizers, pesticides etc. and the respective funds. This will also result in a dangerous increase of environmental pollution.

Therefore, intensification of already existing agriculture is the only strategy to meet the increasing human food demand. This requires:

- use of high yield plants and animals
- multiple cropping of the land
- irrigation by controlled water supply or drainage
- increased and controlled application of fertilizers and pesticides
- use of modern technology and increased energy input.

Compared to 1962 with a fertilizer-input equivalent-index 100 the application of fertilizers in 1985 will reach a value of 1,210. This is necessary to achieve an increase in cereal yields of about 3 per cent per year.

The socio-economic consequences of the intensification affecting employment, land tenure, cultural attitudes, family planning etc. should not be underestimated.

To overcome the protein deficiency an increase of livestock production of at least 3.8 per cent per year is required compared with the actual growth of about 1.8 per cent. The strategy is to rely on pig and poultry production because of their shorter life cycle and higher efficiency in converting plant food into animal meat.

Various regional dietary patterns which are mainly depending on the protein sources and the available staple food can be distinguished. Climatic conditions of the region, economic capacity, religions, customs, taboos, tastes and habits of the people account for the various patterns and require different strategies to provide the necessary food (See also Chapters I, III and IV).

Environment-related diseases and their hygienic influences

Man's interaction with other organisms has many forms. As a member of a biotic community man has also to fight various disease-causing organisms to preserve his health. These organisms are more or less linked with ecosystem structures and functions which may be changed in an undesired manner by human development activities. Human activities favour disease vectors and intermediate hosts resulting in an increase of some environment-related diseases which might be called "man-made" diseases. In many cases human development projects are closely linked with environment-related diseases like schistosomiasis and malaria, but even sleeping-sickness or yellow fever and various other diseases are affected by human environmental activities. For medical aspects see Chapter II. 3.6.

Schistosomiasis

The so-called snail fever is one of the most complex, environmental related health problems, where ecological, social economical aspects are involved.

It is mainly the result of improperly planned irrigation projects and inadequate extension services.

The pathogens, four different species of flukes, are completing their developmental cycle via three larval stages in some species of freshwater snails as an intermediate host.

The ecology of the snails is the most important factor in the epidemiological complex. The ecological requirements comprise water temperatures above 20°C, stagnant waters, or water with a current velocity of less than 30 - 35 cm/sec. and sun exposure of the water to encourage growth of food plants.

Most of the irrigation schemes established now provide such conditions so that snail populations increase. This results in an increased occurrence of schistosomiasis too, when no hygienic precautions are taken. However, not only irrigation schemes are responsible for the increase of the disease. Eutrophication of water bodies by waste water and fertilizers, pH-rise by water contamination, increased sun exposure of water bodies by deforestation and even the killing of snail-eating birds are reasons for the increase of the snail populations.

The reforestation of the respective areas shades the water plants and suppresses the snail population, so schistosomiasis decreases correspondingly.

The ecological interrelations are clearly visible when we compare the frequency of the disease among people living in forests with those living in open areas. In forests where ecological conditions of water bodies due to shade and clean water are less favourable for snails the disease is considerably less frequent than in open areas.

Controlling the disease requires an integrated approach considering the human and the environment components. Medical treatment and hygienic precautions (human excreta disposal, clean water supply, exclusion of man from infested water etc.) are main tasks in relation to human populations.

The eradication of the disease presupposes the control and suppression of the snail population as the intermediate host. Without profound knowledge of the ecology of snails this aim cannot be achieved. The control operation comprises a chemical, a biological and an environmental component. Some molluscicides are available for chemical control, but they are toxic to non-target organisms too. The use of herbicides and the clearance of weeds as an indirect means to remove the food of the snails can be considered. The use of competitors and natural enemies (water birds, snail cracker fish) could supplement these activities.

Destruction of snail habitants is the most important environmental related control operation. Rendering water unsuitable for snail breeding by increasing its current velocity, enclosure of water bodies, periodical drying out, and shading of water plants are some of the possible options in this respect.

Environmentally beneficial water projects and adequate sanitation, however, are the most important prerequisites to avoid further spreading of the disease.

Malaria

After certain successes in controlling malaria in the mid 1970s the disease again has increased seriously. This is due to two facts: The pathogen, a protozoon of the genus Plasmodium, has developed strains that are resistant to medical drugs in some parts of the world, and the vectors - mosquitos of the genus Anopheles - have become more and more resistant to insecticides. And it is mainly human activity that encourages Anopheles-populations by providing more breeding places.

The transmission of the disease depends on the presence of an efficient vector in sufficient density. Not more than 60 out of some 400 known species and strains of Anopheles are efficient hosts for the pathogen Plasmodium, and about 30 of them play an important role. Concerning various regions of the earth only few species are really important. Life-span of the vectors, their ecological prerequisites and their behaviour are factors affecting malaria-transmission considerably. Human developmental acitivities have influenced the density of vectors substantially which resulted in a malaria increase. Sometimes it is very difficult to recognize the reasons for such a development.

In Trinidad, after forest clearing and cocoa-plantation establishment malaria made itself felt in very severe forms. It took a long time to find out that the shade trees which cocoa trees need were colonized by epiphytic bromeliads, and that the small amount of water accumulated in the leaf axiles of the bromeliads had become a breeding place for Anopheles. All open water accumulations, even the smallest ones (empty cans, open water tanks on the roofs, open wells, waste water trenches, irrigation canals etc.) are breeding places for Anopheles. Temporarily flooding leaving small amounts of water in soil depressions, and even brackish water in coastal regions can become a breeding place because larval development does not require more than 8 - 10 days.

The flight radius of Anopheles is about 2 km, and human settlements always are surrounded by suitable breeding places. Large-scale deforestation operations bringing the land under cultivation have led to an increase of malaria diseases in all parts of the world. After forest clearing in Malaysia and Cambodia for rubber plantations, in India for rice cultivation, in Thailand after mangrove clearing, and in Vietnam after chemical hillside deforestation or mangrove destruction by chemical warfare a considerable increase of malaria could be observed, mainly by providing new breeding places (paddy-fields!), and by changing the physiography of the landscape.

The exposure of existing water bodies to sun provides more food for Anopheles larval and the warming up of the water renders it into a very suitable breeding ground so causing epidemic malaria outbreaks among workers and settlers.

In intact forests where less vectors occur and where there is a lack of sun-exposed waters malaria is less frequent than in cleared and open areas. Normally in forests primate malaria exists in a mosquito-monkey-cycle, prevailing in the canopy. If man destroys the forests the monkey population is reduced and so the vectors cannot find their hosts. The vectors come to the ground and bite man, transmitting primate malaria to man or establishing a new cycle of human malaria maintained by vectors which changed from a zoophilic to an anthrophilic state as known from Thailand (DESOWITZ, 1978).

Control of the vectors is mainly an environment-related activity. Eradication of the breeding places and proper treatment of any water accumulation is the focus activity (sanitation and regulation of stagnant or flowing water bodies, removal of weeds, covering of wells and water tanks etc.). Use of larval-eating fish like Gambusia is an ecological means but not completely satisfying. Insecticide application against the larvae stages is possible but dangerous to fish.

The control of the adult mosquitos requires at least a four year insecticide spraying programme, mainly in houses. In order to avoid the development of insecticide resistance it is necessary to develop new chemicals but also taking into account possible environmental contamination. When the treated area is free from malaria for three years after the control operation the programme can be considered succesful.

In case of any development project which might change the environment in such a way that Anopheles populations are encouraged the necessary extension services should be organized.

Besides the above mentioned two main "man-made" diseases some other diseases are spread by animals, and environmental and ecological aspects have to be considered. In case of trypanosomiasis diseases various Trypanosoma species as pathogens and some insects as vectors are involved in the epidemiological complex.

Sleeping-sickness caused by Trypanosoma gambiense and T. rhodesiense, and transmitted by vectors belonging to the genus Glossina (tsetse fly) as well as some other Trypanosoma diseases in livestock are of major importance for the entire tsetse belt of Africa. This is an area of about four million sq. m., equivalent to the area of the United States. About thirty countries are affected by Trypanosoma diseases. The crucial ecological requirements of the vector (Glossina spp.) is vegetation providing some shade and the existence of wild animals (mainly Bovidae) as natural reservoirs containing Trypanosoma.

Programmes to eradicate tsetse flies by mass killing of wild animals were not successful because the main blood donors could not be reduced in sufficient numbers. Nevertheless it is worthwile to think about creating an isolation belt completely free of wild animals because the flight radius of tsetse flies does not exceed 8 to 10 miles.

Clearing or destruction of vegetation in tsetse-infested areas has to be carried out very carefully because an increased erosion can be one of the side effects. Activities like this should be done only in the vicinity of villages, roads, cattle routes etc. to minimize contacts between tsetse flies and their hosts. Control by insecticide spraying should be limited to concentration areas of tsetse flies like riverine forests or breeding and pupation grounds. Spraying to form a buffer belt could be one alternative but all ecological consequences have to be considered.

In future a long-term eradication programme by biological means encompassing the introduction of natural enemies, sterilization of the male flies etc. should be given more priority.

The American Trypanosomiasis, the Chagas-disease, is transmitted by bugs. More than forty species of animals like bats, rodents, marsupials etc. are known to be reservoirs. The disease occurs normally only in a sylvatic cycle.

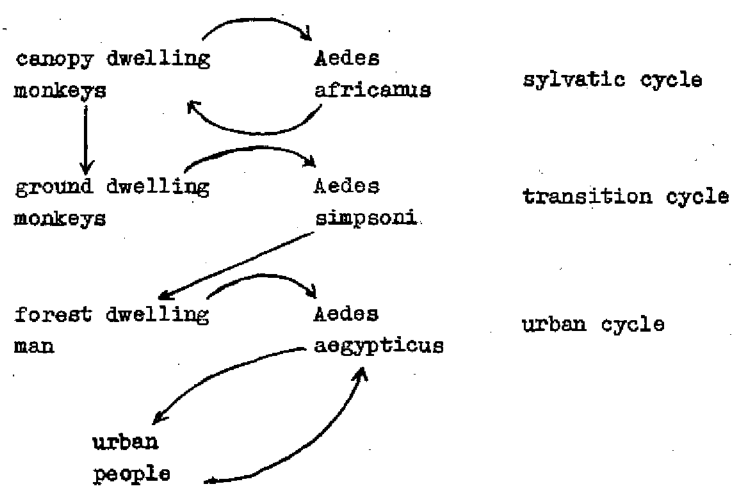
Similar ecological interrelations are to be considered in case of the various Leishmania-diseases. Their vectors, mainly flies belonging to the genus Phlebotomus, are also encouraged by human activities. In case of Filariasis and Onchocerciasis, diseases which are caused by roundworms, some insects (mosquitos of the genus Culex, Mansonia etc., flies of the genus Chrysops and simuliids) are involved as vectors, so again causing close ecological interrelationships with man's environment. Culex, which breeds in smallest water accumulations extends its area more and more. This process is accelerated by the development of insecticide-resistance and by Anopheles-control-programmes which have excluded the latter genus as a competitor of Culex in the small water bodies used for breeding. In some cases due to primate reservoirs and inaccessibilita of the breeding sites it is very difficult to control the vectors. Onchocerciasis, which may cause river-blindness occurs mainly in West and Central Africa. Its vector, simuliid flies, depend on rapid flowing water courses as breeding sites, and because of the small flight radius of the flies the disease is more or less restricted to the vicinity of the water courses. These are the areas with the fertile land which normally could be used for intensive agriculture. Local inhabitants, however, afraid of the serious disease, leave these areas and move to regions free from simuliids. These areas are less fertile and sometimes already densely populated. So the migrants increase the population density of the already marginal land there and increase the pressure on the environment, causing soil erosion and degradation. The vector density increases in such areas where the original forest has been transformed into cultivated land or savanna forests (GARMS, 1973). This fact should be considered in development projects.

The control of the vector can be achieved by insecticide-spraying of the breeding sites where the larvae are fixed to the ground of the water courses.

Besides the above mentioned diseases in which animals are involved directly as pathogens and as vectors or intermediate hosts another group of environment-related diseases has to be considered. These are the so-called <u>arboviruses</u>, where the microbial pathogen (or a virus) is transmitted by arthropods; mainly bloodsucking insects and ticks.

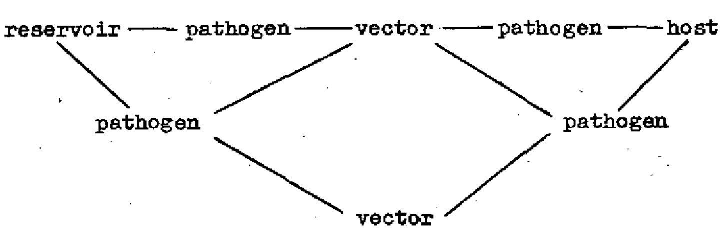
<u>Yellow fever</u> is one of the most important diseases in this context. It is primarily a sylvatically cycled infection of primates; the transmission of the virus is accomplished by mosquitos belonging to the genus Aedes and Haemagogus.

These mosquitos breed in small water accumulations in tree holes, buttres roots, leaf axiles etc. up to a height of 15 m, and normally a monkey-mosquito-cycle is maintained in the canopy. The link to man are monkeys which are not restricted to forests and which come down to the ground in close vicinity to man. This process is frequently combined with deforestation. On the ground now another mosquito species becomes infected with the virus which may then be transmitted to man. Within the human population a third vector is involved which is maintaining ultimately the urban cycle (DESOWITZ, R. S., 1978).



The above given cycles illustrate clearly the complex ecological interrelationships in environment-related diseases where several types of organisms are involved. The key element in the system is always the animal vector or intermediate host. Its environmental and ecological consequences are more susceptible to human activities than the pathogen itself. The strategy of completely suppressing the vectors by means of chemical control operations is not justifiend due to the rapid development of resistance against them. Presently there exist about 400 species and strains of economically important insects and mites which have developed insecticide resistance. Resistance selection is a very quick process which requires not more than 10 - 20 generations and the permanent use of the same pesticide. Due to the short generation intervalls under tropical conditions resistance may be stablished within a period of not mor than 4 to 5 years. The side effect of environment contamination with all its consequences to the ecosystem should not be underestimated.

The only alternative is the strict consideration of the sophisticated and complex ecological system always involved which can be expressed by the following interrelations



and to understand that any interferences in this fragile system could cause disturbances to health conditions in human populations.

II. 4.2. Conditions for the regeneration and stability of ecosystems

The structure and performance of ecosystems depend on their relative stability and continuity. Considering the structural components of ecosystems abiotic and biotic components have to be distinguished which are acting together in a mutual manner forming characteristic patterns. The abiotic component, the biotrop, is formed by climate, topography, soil etc. and is more or less a given natural fact.

The biotop provides the conditions for the biotic components, the communities of organisms living in this particular biotop, and it determines the types of communities called biocoenosis in general. Primarily it is the vegetation type which is determined by the abiotic environment and which characterizes the resulting ecosystems. The main performance of the plant communities is the primary production of biomass.

Furthermore, a simple intact ecosystem is characterized by the balance between primary production and its consumption and decomposition, so maintaining a more or less stable level of biomass production adequate to the abiotic site conditions.

In more complex ecosystems some more trophic levels may be found where various consumers utilize the primary biomass producing secondary and even tertiary biomass which is decomposed by natural processes too. The decomposition process is maintained by the microbial and animal components of the ecosystems. The higher trophic levels are formed by animals which consume plant biomass and transform it into animal biomass without overexploiting the plants. These processes of primary and secondary production and of decomposition are characterized by flows of energy and cycling of matter.

Any disturbance in this balanced dynamic system of production-transformation-decomposition may affect the ecosystem itself.

If ecological disturbances occur there, the consequences will be the more serious the higher the trophic levels of the communities involved.

Normally the abiotic component of the ecosystems is the most stable component over a very long period, and it can be changed only by very slow natural processes like weathering, erosion etc. These processes, however, can be accelerated considerably by human activities, directly by changing the abiotic components and indirectly by changing the biotic communities through removal of the protecting vegetation cover and so exposing the non-living environment to unfavourable influences.

Sometimes natural disasters like flooding, storm, earthquakes, volcanic eruptions etc. may affect the abiotic (and biotic) components of the ecosystems, so changing or even destroying it in a very short time.

These disturbances affecting the abiotic components of the ecosystems should not be dealt with here in detail because proper management, protective construction, global surveillance etc. could be used to reduce the expected damage. In this chapter emphasis will be given to the disturbances and alterations of the biotic components which affect energy flow and cycling of matter resulting mainly in a reduced productivity, and stability of ecosystems.

The productivity of ecosystems is of crucial importance to man because it provides the necessary food and energy supply for his existence.

Highest possible and permanent productivity can only be obtained in relatively stable ecosystems, and so productivity and stability have to be treated as an ecological unit and cannot be separated. Any disturbances in the stability of ecosystems will result in a decline of productivity as well as in losses of basic products for human existence.

What does stability mean?

In a general sense stability is the capacity of a particular ecosystem to maintain its structure and functioning under the influence of disturbing factors within a certain equilibrium range. Other capabilities include:

- to tolerate fluctuations within upper and lower limits without destructing the basic structure of the ecosystem, and
- to return, through regeneration of the damaged components, to the original medium equilibrium level.

If the disturbances exceed the capacity of stability of an ecosystem, then

- productivity will decline
- species may become extinct
- the entire system might collapse with complete destruction of the communities or even the abiotic components.

Natural and seminatural ecosystems are open, self-regulating systems of relative stability, the biotic communities being the dynamic elements. In the long run these communities undergo natural changes in their composition resulting in different stages of development. This process is called succession and leads ultimately to a final stage of natural ecosystems called climax stage. These climax stages which are naturally determined by edaphic and climatic conditions normally reveal the highest level of stability.

Permanent human influences (annual fires) or biotic influences (tree destruction by elephants, browsing by game) may change the direction of the succession leading to anthropogenous or biological climax stages as can be seen in some of the savanna regions.

The duration of the various successional stages which are characterized by considerable biological alterations requires in forests periods of between a few decades and 400 to 600 years, and, by the formation of typical communities, they seem to be relatively stable for a certain time. The stability of the climax stages of the natural ecosystems originates from intrinsic factors of the ecosystems but, apart from natural changes and fluctuations, they are also vulnerable to disturbances which cannot always be compensated by stability.

Due to the increasing demands of human society natural ecosystems had been transformed increasingly in man-made ecosystems (agroecosystems, forest plantations etc.) which made them more productive but reduced their stability. The maintenance of their stability requires an additional high energy input in form of fertilizers, pesticides, weed control etc.; the values of them sometimes are equivalent to or exceed even the value of the desired productivity increase.

Tropical agroecosystems are particularly susceptible to disturbances and reveal a high degree of instability and fragility (JANZEN, 1973); for that reason optimization of yields instead of their maximization should be the strategy of management. Soil exhaustion and soil deterioration, increased pest populations, increasing pesticide resistance and some other side effects are the consequences of improperly managed and only export-oriented agricultural practices. A similar situation applies to the monocultures of forest plantations having the same age.

Therefore, man-made ecosystems should be given particular emphasis in order to maintain their stability and to ensure their production. Agroecosystems which are not used for perennial crops and which have a very short life span cannot evolve sufficient stability because this requires a more or less longer period of coevolution and coexistence between the various communities. So particular attention and support has to be given to them to obtain an equilibrium and biotic balance which has to be maintained by man.

Factors affecting stability

Mechanical and biological factors as well as human influences affect stability. Wind and storm, temperature extremes, drought, fire, flooding, unfavourable site conditions and several other influences are important mechanical factors. They may affect a single member of the sommunities within the ecosystems, or damage or destroy an entire system. Very often the physical structure of the ecosystems which was created or at least improperly managed by man is of crucial importance. A contemporaneous forest plantation, for example, which is improperly tended and thinned may be much more vulnerable to storms than a well-treated one. Unpreper logging may damage remaining trees in the stands or expose them to extreme sun, so killing them. The selective timber logging of tropical forests sometimes causes mechanical damage to more than 40 to 50 per cent of the remaining trees and destroys the natural regeneration.

In case of human influences all activities disturbing the balanced system of primary production-consumption-decomposition and the nutrient cycle and energy flow involved will change stability in an undesired manner. If man harvests for a longer period more biomass or energy from an ecosystem as it can sustain by natural conditions of production then the stability of the system will decrease. If man establishes a new plantation under unfavourable site conditions he creates simultaneously disturbances in the stability of the forthcoming ecosystem from the very beginning.

The above mentioned factors are more or less influences affecting a given ecosystem form outside, so that they have to be considered as extrinsic, stability-affecting factors, and a stability component should be contrasted with extrinsic factors. Much more important are the stability-affecting factors acting inside the ecosystems. Here the interactions and interrelations between different communities and populations which are components of the ecosystems may have an essential influence on their structure and performances which could at least change productivity drastically. Hence, as a second component of stability - the intrinsic factors - have to be considered. These intrinsic stability factors are acting in a very complex pattern, and their understanding requires a profound ecological knowledge, so that this complex should be discussed more detailed.

All factors and activities which maintain or support the natural flow of energy and cycling of matter in ecosystems may increase their stability. Under tropical conditions solar energy and temperature are always available in such a manner that plants can make full use of their photosynthetic potential and produce a maximum of primary biomass. Water and nutrients are the only limiting factors. Their availability is responsible for the actual production pattern which can be influenced by human activities, for instance irrigation, fertilization etc.

Soil organisms

Apart from production of primary biomass and respiration the dynamic processes are of particular importance for the maintenance of stability, and here it is mainly the decomposition of primary and secondary biomass which provides nutrients to the plants, which are available only in limited amounts.

The communities of soil microbes and soil fauna are the main elements responsible for this decomposition process. Organisms of upper layers may be involved to a certain degree, so releasing the nutrients from the plant materials, and providing new nutrients to the next plant generation. It is not only the nutrient content of the soil which is affected. It is also the condition of the soil itself (crumbling structure, aeration, water penetration, water and nutrient retention capacity etc.) which is improved by the activity of soil organisms, in this way providing better growing conditions for the plants and increasing productivity of the ecosystems.

<u>The main groups of soil organisms are:</u>

- bacteria
- fungi
- actinomycetes
- protozoa
- nematoda
- oligochaeta earthworms
- molluscs
- acarina (mites)
- myriapoda (millipedes)
- collembola (springtails)
- isopoda (termites)
- other insects and their larvae.

According to the site conditions may their population density reach very high values.

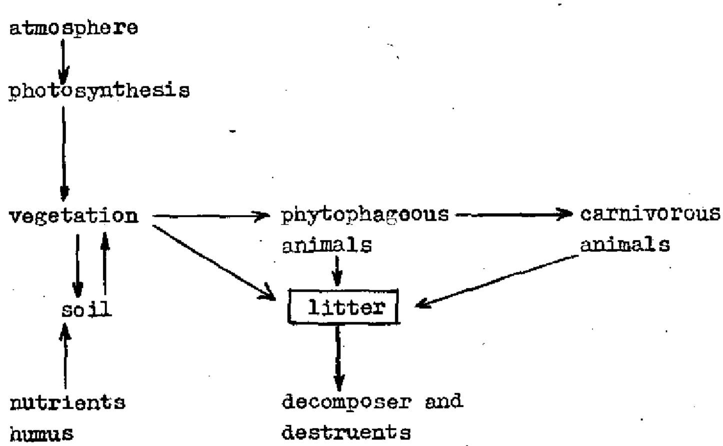
The number of protozoa in 1 g of forest soil varies between several thousand and one million.

In the upper 5 cm, nematodes may number between 5 and 30 million per 1 m^2.

Microarthropodes (acarina, collembola) in tropical forest soils may number between 2,000 and 70,000 per m^2. Numbers of earthworms, millipedes, and molluscs may be no more than 10 to several hundred per m^2, but this is compensated by their high biomass and the activities carried out in decomposition. Taking into consideration their metabolic activity, their secondary biomass production, the breakdown and decomposition of plant material and the production of excrements which are of high nutritive value to plants, the role of soil organisms in the maintenance of basic ecological processes can be easily estimated.

The secondary biomass in soil and litter is 5 to 6 times higher than the above ground biomass and values of 250 kg to 600 kg per ha. can be observed in different tropical soils.

The production of wormcasts with their high nutritive values accounts for 2 to 100 tons/acre/year. They contribute to the improvement of soil fertility just like manure. An average of 50 to 60 per cent of the annual litter fall, which may reach up to 20 t/ha./year, is eaten and decomposed by soil animals regularly, and it can be said that, if there were no soil animals at all available for decomposition, this process would take 2 to 5 times longer, so affecting considerably the nutrient cycle, productivity and stability. The role of soil organisms in the basic ecological process of matter and nutrient cycling can be seen from the following interrelations:



Soil organisms can be encouraged by proper management (correct ploughing, fallow periods, drainage, green and organic manuring, crop rotation etc.). But they can be affected in a negative manner by burning, litter removal, insecticidal treatment etc. so reducing this important factor of ecosystem stability and soil fertility.

According to their importance in basic ecological processes the communities of soil organisms form a balanced and well-buffered system with high resilience to external influences. Even if certain groups are negatively affected the remaining groups are able to maintain the processes of decomposition and matter cycling at least in a limited manner until the affected and disturbed groups have recovered, which normally occurs very quickly. During the course of ecosystem evolution with its structures and performances this crusial community of soil organisms established itself in such a complex manner that complete destructive normally cannot be expected. On the other hand, the ecological importance of this subsystem is underlined by the above mentioned relative stability of the community.

Pest organisms

A second important component responsible for the stability of ecosystems is the equilibrium between production and consumption.

In all relatively stable ecosystems a certain proportion of primary production is permanently consumed by phytophageous species, used for the formation of secondary biomass and rapidly recycled in the same system, without disturbing the producing system. In tropical rainforests, for example, 25 to 30 per cent of the leaves as primary production are constantly eaten by phytophageous animals without causing any damage to the forest. The existing equilibrium in these systems is maintained by the relative stability of the populations of phytophageous species, and so the main question arises which factors are governing the population dynamics of species in natural communities.

In such cases when the fluctuations of populations of phytophageous species exceed the equilibrium limits or when man is removing (harvesting) more biomass from the system than it can be tolerated or when man is disturbing the ecosystem by other interferences, then the balanced cycle will be interrupted, stability will be reduced and phytophageous species will turn from harmless species to pests causing damage to the system and considerable economic losses to man. If pest populations reach epidemic levels then even the entire ecosystem might be completely destroyed as it happens, for example, to mature conifer-ecosystems after bark beetle outbreaks.

In all ecosystems (natural, agroecosystems, forest plantations etc.), where the mechanisms regulating and controlling the population dynamics are disturbed naturally or by human activities, pests can become dominating components of ecosystems and severe damage and losses will be the consequences.

Pests contend with man for basic needs, and the necessary control measures will cause undesired side effects on the environment.

It has been calculated that average losses of 30 to 35 per cent of the world's yield in agriculture and forestry have to be expected annually, and there are even estimates that due to the permanent ecological changes in the environment by the year 2000 about 50 per cent of the yields will be lost. The actual losses account for a value of at least $ 150 - 160 Billion. There are regional differences and differences in the vulnerability of the crops which should be considered.

Within the estimated losses of 35 per cent animals account for 14 per cent, diseases for 12 per cent, and weeds for 9 per cent.

The following groups of organisms are mainly involved in this context:

- diseases: bacteria, fungi
- pests: insects, rodents, nematodes, birds, mites

Mainly pests react and respond via fluctuations to changing environmental conditions so that the understanding of the ecological processes involved is of crucial importance. There is a lot of controversy concerning the question how natural populations function and how they are controlled. It is obrious that all populations are governed by more than one and that very complex mechanisms in 10,000 to 20,000 important pest species have to be considered.

The basic principle which has to be accepted is the reproductive potential of a species and which proportion of this potential is realized under the actual environmental conditions. The interaction of reproductive capacity, expressed in natality and mainly governed by endogenous factors, with environmental resistance, accounting for mortality and mainly governed by exogenous factors, is the main mechanism which causes fluctuations in the population density of a given species.

Fecundity, sex ratio and number of generations per year are the main parameters of the reproductive potential. The environmental resistance is expressed by the sum of all environmental factors which reduce the rate of reproduction, so keeping the population in balance. Physical factors (climate, weather), nutritional influences and biotic factors (predators, parasitoides, diseases, competition etc.) are of essential importance. Figure II. 4-4 shows how complex all the environmental components are which affect the population density of a pest species.

It can be recognized from these complex interrelations that human activities might easily change or disturb one of the controlling factors, hence disturbing the biological balance and pushing a pest fluctuation to outbreak levels.

Improper management, monocultures, unsuitable site conditions etc. are such human influences which normally are not recognized in their importance for disturbances of the above

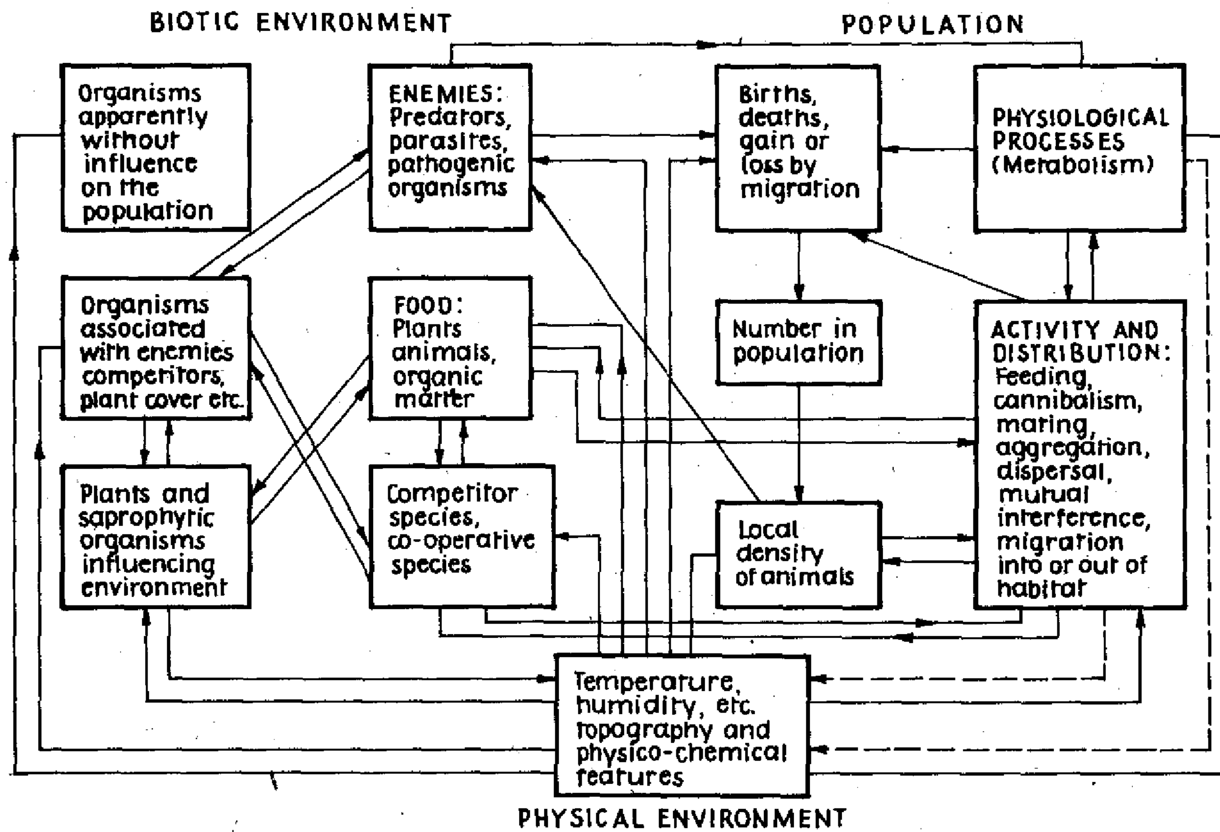


Figure II. 4-4 Factors affecting the dynamics of a population
(From SOLOMON, 1976)

mentioned system. Considering the natural control of pest fluctuations density-independent factors like weather or soil conditions and density-dependent factors like competition, parasitism, predation etc. affect the populations, either stabilizing or unstabilizing them. It is generally accepted now that the density-dependent factors including intraspecific competition are the main regulating and stabilizing mechanisms. Normal population growth is directed toward instability. Some populations are ultimately subject to limits of the environmental resources to support them and follow a logistic curve of increase which is stabilized according to the carrying capacity of a given ecosystem. Many populations, however, are relatively unstable, growing until they exceed their carrying capacity and then crashing to much lower densities.

According to this complex mechanisms different types of fluctuations and outbreak patterns have to be distinguished which require different ecological approaches to cope with and to reduce damages and losses. So this component of stability which is mainly maintained by the compensating effects of environmental resistance plays an important role in the proper management of ecosystems.

If plant diseases are considered the situation is different from animal pests. Diseases cause abnormalities in growth, structure and performances, keeping plants unhealthy in a broadest sense. There are many factors which cause plant diseases, so, for instance, mechanical forces, non-parasitic diseases or disorders brought about by adverse environmental conditions or by internal physiological disturbances and pathogens. Parasitic diseases caused by pathogens like viruses, bacteria and fungi are of major importance because they are infectious and can spread rapidly between plants and give rise to considerable losses in yield or in the quality of crops. Their ecological interrelations with the components of ecosystems differ drastically from those of animal pests. Their development is strongly influenced by weather, soil and other environmental factors which mainly affect the processes whereby the pathogens infect the host plant, but they also influence the susceptibility of a plant to a disease. Under tropical conditions humidity and rain are very important for the development of plant diseases, because the dispersal of certain development stages of the pathogens depends upon rainwater. Temperature is always favourable. Apart from environmental factors man additionally influences the relationship between pathogen and host plant by monocropping, improper cultivation practices, dispersal of diseased plants, fertilization, irrigation etc., and in such a way may cause desired or undesired effects with respect to the epidemics of the pathogen. Development of a disease is not so clearly connected with stability factors within the ecosystem and its epidemic is not regulated and controlled by biotic factors belonging to other populations or communities. Infection, spread and progress of the disease may be affected by ecosystem components (soil conditions, crop debris, previous crops and weeds, alternate hosts, vectors like insects or nematodes) too, thus requiring specific attention, when human activities aim to manipulate ecosystems.

<u>Weeds</u> are important limiting factors in the production of tropical ecosystems. During the rainy season they grow very rapidly and luxuriantly competing strongly with the crop for water, nutrient, light and space. Weeds may affect in particular the first successional stages of agroecosystems with perennial crops or forest plantations and always the annual crops. It is not the stability of the ecosystem as a whole which might be disturbed, but mainly the development direction which the succession of the plant community takes, a direction, which does not allow the community to realize the full productivity of the crop species grown there. Sometimes the crop might be completely suppressed by the weed communities but more frequently a certain equilibrium of weeds and crops will be achieved resulting in a

very low productivity. This process is ecologically governed mainly by interspecific competition during the various stages of successions. The maintenance of a fully producing agroecosystem requires, according to economic strategies, an intensive and effective weed control. This is more essential than in case of pests because then intensive chemical control operations can be replaced by an ecologically oriented pest management as can be seen from Chapter II. 4.3. and III.

Regeneration of ecosystems

If the question of regeneration of ecosystems arises it has to be decided which type of ecosystem is concerned. Is it "back to nature" with the aim to re-establish, for example, a natural plant community which covered once a certain area, or is it to repair a given, intensively managed ecosystem which seems to be disturbed or overexploited or even exhausted and the productivity of which has declined drastically?

The strategy to be applied depends on the objective which has clearly to be defined.

The regeneration of natural or sminatural ecosystems for natural conservation purposes requires, for example, one main concept: leave the ecosystem alone, let the mechanisms of succession operate and give the system time to recover.

That necessitates the identification, exclusion and avoidance of all disturbing factors, aminly human activities. If some components of the ecosystems are already damaged irreversibly (e. g. plant species extinguished) then they have to be replaced by re-introduction (replanting). Those components which have been changed in an undesired manner (e. g. pollution of water bodies) have to be restored into the stage of the original conditions.

This process of natural regeneration and recovery necessitates, depending on the ecosystems involved, a shorter or longer period of time, and sometimes failures cannot be avoided. A tropical rainforest, for example, which was completely cut down is not able to regenerate and only secondary forest formations can be expected. Thus the success of this strategy depends to a high degree on the remaining rest of the original ecosystem.

In case of the regeneration of an ecosystem which is managed for economical purposes (e. G. to produce food, fibres or timber), and the productivity or stability of which has declined considerably, the exclusion of all unfavourable human activities is required and additional efforts are necessary. This includes changes of the cropping pattern, longer fallow periods, returning of substances to the ecosystem which had been removed in an exhaustive manner, measures to improve site conditions and various other factors which are mentioned in Chapter III.

II. 4.3. Measures for the maintenance of stability

Stability is mainly affected by disturbances in ecosystems which cause changes in the density of populations, mainly of those consisting of species which consume primary biomass. So the knowledge of the fluctuations of populations and of the ecological laws governing them is of major importance in order to maintain stability. But there are many controversies in the understanding how natural populations function and how they are controlled.

For a long period the dominating idea was that stability results from a large number of species (species diversity) that act on one another in density-dependent ways. Stability was considered to be a product of the number of species and the complexity of interactions in communities. This concept at least cannot be generalized because some experiments indicate that adding another predator species to a set of interacting prey and predator (or parasitoid) species can either increase or decrease stability.

Mathematical modelling of communities (MAY, R. M., 1973) did not show that increasing the number of species and complexity of interactions increased community stability. Sometimes even an increased number of species and complexity of interactions produced increasing instability and vulnerability of the community models to perturbation. Relative stability in communities apparently results from the population function of individual species and small sets of interacting species, not from richness in species of the whole community. Environments that are stable may permit many species to survive in interaction with one another in a complex community. Individual species may then have relatively stable populations because of density-dependent relationships but the complex community may be fragile if its environment is disturbed. So it can be concluded that community complexity does not produce community stability but that environmental stability permits the evolution of community complexity (WHITTAKER, R. H., 1975). The relative stability of natural populations through evolutionary time results from the accumulation in communities of species affected by a buffering mechanism and density-dependent relationships.

This concept now is supplemented by various other ideas. According to MURDOCH (1975) it is the disturbed coevolution and not a poor species diversity which is responsible for reduced stability. MURDOCH claim that physical complexity of the biotop may increase the stability of populations.

According to WATT (1965) the number of competing species the main factor to increase the stability of ecosystems, and SMITH (1975) considers the food web structure and the non-linear relationships between their components as essential factors to increase stability of ecosystems. According to SAUNDERS and BAZIN (1975) the increase of the number of species and their connection is a factor that reduces the stability of ecosystems, their buffering capacity and the damping rate of fluctuations. The less the linear connections between components of large and complex ecosystems the higher their damping rate and stability. According to VLANOWICZ the redundance of energy flows and the self-regulation and self-organization capacity of ecosystems are the main factors to stabilize ecosystems.

This demonstrates that controversies and even conflicting concepts of ecosystem stability have to be considered and any generalization should be avoided. The actual ecosystem and the communities and populations involved should always be carefully evaluated and determined before conclusions on stability can be drawn.

Tropical rainforests with a high complexity and species diversity are very vulnerable to perturbing forces from outside, while, due to the heterogenity, the regulation of population fluctuations inside is easily achieved.

In contrast ecosystems poor in species diversity such as temperate broadleaved forests or tropical savanna woodlands consisting only of few dominating tree species (e. g. Dipterocarpus spp. in Southeast Asia, Acacia spp. and Balanites aegyptica in East Africa) are rather stable against internal or external perturbing influences.

Thus it can be generalized at least that during the course of succession the respective climax stages as mature ecosystems reach the highest degree of complexity and stability.

To meet his basic needs for food, fibres and timber man establishes ecosystems of high productivity which are similar in their ecology to early successional stages. That means they consist of populations which follow the "r-strategy". With a high reproductive potential they very rapidly colonize suitable sites which are not yet occupied by other competing communities. This very rapid process does not permit the establishment of a satisfying degree of stability between the different populations of the community so that considerable losses have to be expected. Therefore, man has to ensure and maintain stability through artificial measures by additional input of energy in form of pesticides, fertilizers and proper cultivation methods. However, environmental and economic constraints (pollution, funds etc.) are limiting factors. The suppression of fluctuating pest populations by applying pesticides is the most important measure thought it is effective for a limited span of time only.

Ecological aspects of pesticide application

About 200,000 to 300,000 tons of insecticides, at least containing 200 to 300 chemical ingredients, are applied worldwide annually which results in a considerable reduction of yield losses otherwise normally caused by instability of ecosystems. But besides this more or less severe disturbances to the environment as a whole have to be considered. Most of the pesticides in use have a very broad spectrum of action, not only killing the pest populations but also the non-targed organisms (regulators, indifferent species etc.), so disturbing the whole ecosystem and leading to important ecological consequences. The "pest-picture" changed considerably, mainly due to the disruption of the biotic balance. After pesticide application many pest species became more dangerous, reaching epidemic levels very quickly. The intervals between two outbreaks became shorter than before. Some forest pests, for example, reduced the intervals of epidemic peaks from 7 to 3 years. In some species the infestation rate became higher than without control. New, secondary pests originated (e. g. red spiders) or formerly less important species transformed into dangerous ones. During the last few decades, about 400 pest species became pesticide-resistant, and this process even accelerates, so that under tropical conditions certain species can be expected to develop resistance within 4 - 6 years. Side effects on other components of ecosystems like soil fauna, birds, bees, fish etc. should not be neglected.

In this context cotton cultivation provides one of the most striking examples. In the cotton growing areas of Central America normally 3 - 8 main pest species occurred which were more or less effectively controlled by ecological means. After intensive insecticide-spraying the number of important cotton pests increased to 15 andyields declined.

Figure II. 4-5 shows the situation in the Canete Valley in Peru which is known as the "cotton-picture". In the Cycle 1, lasting from 1920 until 1949, cotton was cultivated under moderately intensive subsistence conditions which resulted in moderate yields. Since 1949 (Cycle 2) a highly industrialized and intensive monoculture was put into effect by mass pesticide application, irrigation etc. Costs had gone up, insecticide resistance occurred and new pests and outbreaks appeared which no longer could be controlled effectively. So the whole system collapsed in 1956, and instead of cotton other crops were grown. During the next few years (Cycle 3) a diversified agricultural programme evolved with less intensive cotton culture and with integrated pest control.

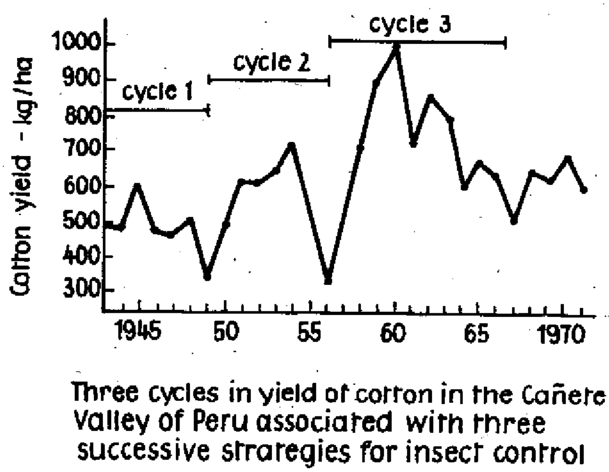


Figure II. 4-5 Cycles in yield of cotton in the Cañete Valley of Peru associated with three successive strategies for insect control (From ODUM, 1975)

Cotton yields increased until 1964, then dropped and reached an average level not better than in 1940. Now this integrated control phase is still underway and ensures a relative stability of the system.

A similar development occurred in the large-scale cotton growing schemes of Northeast Africa. In the classical areas (e. g. Gezirah) yields are permanently declining due to declining stability of the whole system which resulted in pest population increase. Due to improper clearing operations (no buffering forest areas left) and intensive pesticide application even in such areas which had been brought under cultivation in the last few years the pest situation got worse and yields dropped within 3 years by more than 50 per cent. These disturbances affect other components of the ecosystem, and the pest outbreaks, for example, are accompanied by invasion of rats, weeds and other undesired side effects.

Because of the <u>persistence</u> of some pesticides in nature they may be accumulated in the environment leading to <u>pollution</u> and <u>contamination</u>. Apart from the accumulation of pesticides their concentration increases in the different trophic levels. This process is called <u>biological magnification</u>, and an observed concentration increase from 0.00005 ppm DDT in water after mosquito control to 26.4 ppm DDT in cormorants (fish-heating birds) is equivalent to a 500,000-fold increase. In various regions of the world even in human body fat, values of more than 10 ppm DDT have been detected.

It was estimated that in the past 25 years no less than 1.5 million tons of DDT had been used, and due to its half-life of 10 - 20 years it can be calculated that about two thirds of this amount of DDT (incl. its stable metabolite DDE) are still in our environment and are distributed all over the world now by <u>long-range transport</u>. The long-term effects of this contamination cannot be evaluated accurately up to now but consequences have to be expected.

Some observations demonstrate already that dangerous side effects of insecticide contamination to higher vertebrates are possible. Disorder of the calcium-metabolism resulting in reduced thickness of eggshells of birds, hormonal disturbances causing delayed ovulation, inhibiting of gonad development, and disturbances in embryonic development are factors affecting the reproduction.

Fish is particularly vulnerable to insecticides and may be killed immediately. Birds react very quickly by reduction of their reproductive potential, and some species (e. g. eagles, falcons, ospreys etc.) became nearly extinct in certain areas. Mammals which are on the top of the food pyramid are affected too, and interruptions of pregnancy, resorption of embryos or abortion can be observed.

Therefore, insecticides should be applied carefully to minimize the above mentioned side effects, so that ecosystems can be stabilized by control of populations. The effect which can be expected is always limited in time and space because a pest population normally cannot be eradicated completely, and within a certain time it will recover from the low abundance which it reached by control. This process could even be accelerated, as already mentioned, because the surviving portion of the population consists of the most viable and most resistent individuals which sometimes reveal the highest reproductive potential. So they will be able to rebuild epidemic population levels within a short period particularly in such cases where the regulator-species of the ecosystem had been affected by the previous control operation too.

Another strategy to maintain or even increase the stability of ecosystems is to change the biotop of the pest populations making it less suitable for their existence. Large-scale agricultural and forestry ecosystems which are intensively managed are particularly vulnerable to stability-disturbing pest attacks because they provide favourable conditions to the pests (food in excess, favourable micro-climate, shelter etc.).

Large-scale and long-term monocultures may influence the pest populations by selective processes which change their genetic constitution rendering them more aggressive (e. g. plant-parasitic nematodes). On the other hand the genetically-based resistance of the cultivated plants is declining due to the loss of genetic deversity in the course of selection and breeding for high yields. So the only alternative would be changes in the cultivation technologies applied. These include:

- smaller cultivation areas
- diversification of the cropping system by using a bigger variety of different crops (e. g. sweet potatoes, cassava, bananas, rice)
- intercropping by growing different crops on the same plot in the same season
- consistent crop rotation.

This system is already used traditionally by native farmers for subsistence agriculture. They know from long expérience that the probability of pest outbreaks will be reduced considerably if this cultivation system is applied. Yields will be somewhat lower but this will be compensated by the reduced costs for pest control. The situation differs when large-scale cultivation of cash crops is intended. Then at least crop rotation has to be realized consistently supported by limited control operations.

In the long run stability-maintaining management strategies have to be developed and applied because human demands in basic commodities will increase. The ecosystems developed to fulfil these demands will become more productive, but also more homogeneous, often near homozygous, and thus more fragile and vulnerable to stability disturbances. The so-called "green revolution" is only one example for the development which is going on. Comprises must be found whereby ecosystem diversity can be enhanced without major reduction in productivity.

The management approach to stability problems should integrate different methods and strategies for all pests affecting a given ecosystem. This approach has been named "integrated pest management". This system must integrate different methods of population suppression (chemical, biological, ecological etc.), and employ actions, consistent with the quality of the environment, which rest on a profound knowledge of the ecology of populations and their interrelations with the environment.

The importance of this approach can be seen from the fact that UNEP allocated $ 4.0 million (= 4.3 per cent) of its funds for pest management systems. The concept demands a multiple and interdisciplinary approach, and its main idea is not eradication but suppression and manipulation of the stability-affecting pest populations.

The procedure of integrated pest management requires:
- a careful analysis of the ecosystems involved
- the decision of the economic threshold to justify any control operations
- analysis of all factors acting in the pest population
- appflication of measures augmenting the resistance of the environment (biological control, encouraging the regulating agents etc.)
- developing selective and limited pesticide application
- developing and applying cultural and mechanical methods with control potential (fertilizing, proper cultivation technologies etc.).

So ecological, economic and environmental aspects have to be integrated and combined with the objective to support and supplement natural control and to maintain stability. Emphasis should be put on natural control achieved by biological components contained permanently in ecosystems, such as predators, parasites, pathogens, plant variety and genetic deversity. Apart from them all facilities provided by sterilization, hormones and pheromones, genetical control and manipulation, attractants, repellents, antifeedants, breeding for resistance etc. should be used as well.

Biological control which is particularly useful in tropical regions comprises
- conservation
- inoculation
- inundation

of biological agents. It includes also the active formation of the biotop by introduction of alternative hosts which must be provided when the natural pest population is low. This will permit natural enemies to survive as a control agent during periods of pest scarcity. Furthermore it could require the provision of alternate hosts, which are subsidiary hosts as an obligatory part of the life cycle of an enemy. Therefore, the maintenance of non-crop plants (weeds!) and a high species diversity is of considerable importance to fulfil biological and physical demands of natural control agents. The desired increase of the buffering effects of agroecosystems requires at least an area of 8 to 12 per cent of the total area under cultivation, which should be kept under fallow or under low-intensity management.

Agricultural practices should be used to disrupt the life cycle of the pest or to encourage natural enemies, and to provide optimal conditions to crop plants to increase their resistance. Such practices are:
- adwell-timed and adequate sowing, tending and harvesting methods
- cultivation of soil, proper manuring, fertilizing and irrigation
- strip farming and harvesting
- crop rotation and crop isolation

to give some examples only.

Chemical control should only be used to supplement the above mentioned practices. The selection of the most suitable and less dangerous chemical compound and the correct method of application is of particular importance. Chemicals of low persistence and selective and systemic pesticides should be given preference. Correct application, permanent change of the compounds to avoid selection of resistance and proper timing of the application to save natural enemies are important ecological points to be considered.

Perennial crops (rubber, cocoa, coffee etc.) and forest plantations are particularly suited for integrated pest management because a long-term potential of biological regulators can be built up. The situation is less favourable in annual crops which sometimes may require more pesticide application. If all the above mentioned agricultural practices are properly applied then the concept is promising too and will contribute to the maintenance of stability.

The control of coffee leaf miners (Leucotera spp.) in Kenya is an example for a carefully balanced integrated programme using a few selective insecticides together with natural control by parasites without interference (HILL and WALLER, 1982).

II.4.4. Management of nature and landscape protection, biosphere reserves and rational utilization and protection of natural resources

II.4.4.1. Flora

The world's different ecosystems are classified mainly according to their biomass, productivity, metabolism, energy flow and stability. As to its efficiency, utilization, modification and preservation, each type of ecosystems has to be regarded separately. Since plants as primary producers are of central importance for ecosystems, the following list of terrestrial biomes (physiognomical plant formations with the animal populations that inhabit them) is based on a classification of vegetation zones. Autotrophs form about 99 per cent of the total biomass of the biosphere (1843.109 tons), thereof the phytomass of the terrestrial ecosystems is 500 times that of marine and limnic ecosystems; the proportion of forests amounts to about 90 per cent. However, the flora of an area as a stock of species for phytocoenoses is not only of fundamental importance for the structure and the function of ecosystems; the flora as the totality of plant taxons represents a natural resource, i.e. a gene pool for mankind, since green flora forms the basis for man's food, in particular by:

- direct utilization of nutritive plants (annually about 1200.10^6 tons of vegetable foodstuff, the raw material of which corresponds to about 10 per cent of terrestrial primary production)
- indirect utilization as feeding resources for domestic animals.

Besides nutritive and fodder plants, man utilizes other resources of the flora:

- raw materials (e.g. wood, fibres, rubber)
- energy resources (firewood, coal, oil)
- medicine (antibiotics, cardiac glucosides, alkaloids etc.)
- spices and luxury food and stimulants.

Human interference in connection with utilization, such as

- extraction and addition of organic substances and minerals;
- changes in the composition of species by direct (elimination or introduction) or indirect influence (impediment or promotion of certain species);
- contamination by poisons

results in changes and to some extent in the destruction of the plant cover and ecosystems. Thus, agricultural utilization, industrialization and urbanization lead to a transformation of natural landscapes into cultivated landscapes. The rational utilization and protection of natural resources has become a vital requirement of our time. Biological conservation aims at preserving

- ecosystems as mankind's ecological and economic bases;
- the basic entities of life, among them many have as yet unknown pratical importance;
- the biota and/or ecosystems as necessary bases for further development of the life sciences.

Biological conservation has then two theoretically founded aims, viz.:

- the preservation of functional ecological systems;
- the preservation of members of the biota (individuals, populations, species).

The rational utilization of ecosytems calls for knowledge of these systems and in particular of the ecological laws. Since physiognomical plant formations often have an ecological relevance, the principal biomes ranging from tropical to temperate floral zones of the earth are used as basis for discussing the most important ecosystems. To avoid misunderstandings, we classify the biome types according to UDVARDY (Classification of biogeographical provinces, IUCN 1975) and apply the formation classes and groups of the "International classification of vegetation" (UNESCO 1973). Formation types as such are often too abstract, since apparently resembling formations may represent different ecosystems having developed under different environmental conditions (e.g. grasslands, deserts). The paper includes only terrestrial zonal biomes which have particular importance for territories of developing countries, whereas boreal and arctic formations as well as the Australian realm have not been taken into account.

II.4.4.1.1. Structure, utilization and protection of the main formations of vegetation or ecosystems

A. Zone of tropical rain forests

Main ecosystems

Biome type: Tropical humid forest

Formation groups:	Closed forest/Mainly evergreen forest:
	Tropical ombrophilous forest/Rain forest
	Tropical evergreen seasonal forest
	Tropical semi-deciduous forest
Principal biomes:	Evergreen lowland rain forest
	Semi-deciduous lowland rain forest
	Alluvial rain forest
	Swamp and bog rain forest
	Montane rain forest (cloud forest)
azonal:	Mangrove forest
anthropogenous:	Secondary (rain) forest
	Tropical savannas and grasslands

Ecological characteristics

Tropical rain forests form the zonal vegetation of the equatorial climate zone (Inner tropical zone) characterized by daytime climate, heavy precipitation (2000-5000 mm/year) and steady average day temperatures (25 - 27^{o} C) in the course of the year. Greater deviations from these optimum conditions for the growth of plants are brought about by trade- and Monsoon winds, relief and altitude. The soil lacking in nutrients (laterization, red ferruginous clays), only covered by a thin litter does not seem to be compatible with the luxuriant vegetation. The dying overground phytomass is quickly reduced to minerals and the released nutrients are immediately reabsorbed by roots. In this cycle, hardly any nutrients are lost nor any wash-outs are caused by the heavy rainfall, since the nutrients are absorbed by the flat underground roots directly from the litter. Except coral-reefs, the tropical rain forest forms the most complicated ecosystem. It is characterized by rapid material cycles, high rates of biomass production and net productivity and by a concentration of the nutritive potential in live plants. Without disturbing interference, it may grow for thousands of years on the same ground.

Phytocoenosis as a structural element of the ecosystem

The phanerophytes are the dominant form of life with regard to the number of species (70 per cent) and to quantity. The tree layer is rich in species: 40-100 (200) species per hectare; due to the lack of light, the shrub and herb layers are in most cases scarcely developed (exception: montane rain forest). The constantly high humidity and warmth provide for an optimum of growth and development and provided for most favourable conditions for an almost incalculable abundance of species and forms. Due to the absence of an annual rhythm of temperature the plants have an endogenous cycle (autonomous periodicity of leaf fall and flowering time). To increase their stability trees often produce buttressed roots (low depth of the roots), unfold leaves at intervals (suddenly sprouting within a short time) frequently showing long leaves, formed that way that the water may run off at the top of the leave and cauliflory can be observed in more than 1000 species. The abundance of lianas and epiphytes results from their advantageous position in the struggle for light.

Floristic characterization

Neotropical realm

Characteristic plant taxons are: Caesalpiniaceae (Dimorphandra, Elizabetha etc.), Minosaceae (Dinizia, Parkia etc.), Myristiceae, Sapotaceae, Lecythidaceae, Euphorbiaceae, Lauraceae, Apocyaceae.
Main useful plants are: Hevea, Couma (extraction of caoutchouc) Berthollezia.
Main timbers are: Swietenia.

Africotropical realm

Characteristic plant taxons are: Caesalpiniaceae, Burseraceae, Icacinaceae, Meliaceae, Olacaceae.
Main useful plants are: Coffea, Cola.
Main timbers are: Entandrophragma and Khaya (African mahogany), Mimusops (makore), Chlorophora (iroko), Mansonia, Triplochiton (abachi), Terminalia (limba).

Indomalayan realm

Characteristic plant taxons are: Dipterocarpaceae (frequently dominant, thus forests become less varied), Sapotaceae, Anacardiaceae, Meliaceae, Guttiferae, Verbenaceae, Ficus, Artocarpus.

Main cultivated plants (now pantropically spread) are:
Myristica, Syzygium, Cinnamomum zeylanicum, Piper nigrum, Mangifera indica.
Forests have been mostly transformed into cultivated land, e.g. flood-plain rain forests into rice fields, lowland rain forests into Hevea brasiliensis-plantations.

Utilization of and perils for ecosystems

Extensive utilization by total clearing and subsequent burning in connection with shifting cultivation results in quick mineralization and leaching of the soil already lacking in nutrients owing to rapid material cycles. Therefore, agricultural utilization is only feasible on a limited scale. When cultures are abandoned secondary forests develop. In spite of the potential luxuriant growth of plants and because of the irreparable losses of nutrients, it is neither possible to regenerate the original state nor to bring about the abundance of species of primary rain forests. Repeated clearings of the forests lead to further losses of nutrients and extensive degradation. Finally, the transformation of forests into grasslands results in the creation of tropical savannas unfit for settlement and in grassland ecosystems. If man ignores this lack of soil nutrients, his interference with the highly balanced ecosystem of rain forests might have disastrous consequences (e.g. setbacks in the realization of programs to populate vast areas along the Transamazônica in Brazil). The agricultural utilization has to ensure the maintenance of the productivity of ecosystems, i.e. cultivation methods compensating the losses of nutrients to a large extent. To this end, mixed cultures of both agricultural and forest cultivation can be set up. After clearing, several high trees are left untouched or trees are planted on old clearings made by burning.

The tall trees protect the soil from being leached by heavy rainfall and against intensive solar radiation. Cultures of species of lower trees (intermediate tree layer, e.g. oil palms), small trees, bushes or high shrubs (inferior tree layer, e.g. cacao, banana) and herbaceous plants (e.g. manioc) in the subordinate layer can be planted under the tall trees. When the competion exercised by the species of trees planted simultaneously becomes too heavy, the cultivation of agricultural plants must be stopped. Of course, tropical forests cannot be regenerated by the combination of forest and agricultural cultivation, but such mixed cultures for the production of raw materials and foodstuff preserve the soil and protect it from being overgrown with weeds. If this method serves the purpose to repress or to stop shifting cultivation, it is instrumental in the protection of still existing original rain forests. In densely populated areas, these forests have been fully destroyed (e.g. Javanese lowlands) or replaced by secondary forests or secondary humid savannas. In the tropics, 28,000 hectares of the rain forest are destroyed every day. If man continues to deforest the Amazon area at the present rate, the rain forest once covering 8 million km^2 will be finally destroyed by the turn of the century. The destruction of the rain forest is not only caused by the expansion of settlement areas and the cultivation of plants but also by the winning of timber. Despite the richness of species it is only a few species of trees that are cut to win timber (in Ghana, the proportion of the most used and exported species amounts to 60 per cent of the total utilization rate every year: wawa, sapeli, sipo). Large forest areas have to be cut to get to the trees that are largely scattered over the rain forest (e.g. Ivory coast: one commercially useful Khaya stem per 5-10 hectares). This extensive utilization adds to the destruction of the ecosystem. A great number of timber trees rank among the sensitive, shade-requiring species which are bound to the ecosystem of the rain forest; they stop growing in secondary forests and they cannot be cultivated in plantations. In some areas, man's efforts to introduce species of trees and to cultivate them extensively in plantations have been crowned with success. To preserve the stability and productivity of agricultural and forest plantations it is in most cases essential to fertilize the soil and to control weeds and insect pests.

B. Zone of tropical rainy-green humid and dry forests and savannas

Main ecosystems

Biome types: Tropical deciduous or dry forests (incl. monsoon forests) or woodlands
Tropical grasslands and savannas

Formation groups: Closed forest/Tropical drought-deciduous forest
Closed forest/Extremely xeromorphic forest: Thorn forest
Woodland/Drought-deciduous woodlands
Scrub/Drought-deciduous scrub
Herbaceous vegetation/Tall, medium and short graminoid vegetation: Grassland with a tree synusia
Grassland with a shrub synusia
Grassland without woody synusia

Principal biomes: Tropical humid deciduous forest = monsoon forest
Tropical humid savanna (woodland)
Tropical dry deciduous forest or woodland
regional biomes: Miombo-forest Palm savanna
Mopane-woodland Llanos
Baobab-woodland
Combretum-woodland
"orchard-savanna"

	Thorn woodland, thorn bush savanna
	Tropical dry savanna
	Tropical grassland
azonal:	Mangrove forest
	Swamp forests
	Gallery forests
	Parklands
anthropogenous:	Secondary savanna, thorn scrub
	Grassland
	Subdesert shrubland

Ecological characteristics

In the tropical climate zone (external tropical zone) located both north and south the equatorial zone maximum rainfall occurs in summer months (summer rainfall) and despite its comparatively high temperatures, this zone is characterized by a distinct annual course of the daily average temperature (cool months = dry season). The dry season becomes longer (from 2 to 10 months) and the average yearly rainfall becomes lower (from 2,000 mm to less than 500 mm) the further removed from the equator. Water becomes the main factor limiting biomass and productivity, which are clearly inferior to that of the rain forest. The phenomenon that plants adapt their endogenous rhythm to the climatic rhythm leads to a seasonal aspect change (shoot, leaf fall, flowering time). Deciduous seasonal forests develop from evergreen forests and owing to decreasing rainfall and longer dry seasons deciduous humid forests grade into dry forests which finally pass into woodlands and savannas.

Humid months	Main biomes	Arid months
12-9.5	Tropical rain forests (evergreen and semideciduous humid forest)	0 - 2.5
9.5-7	Tropical humid deciduous forest (monsoon forest) and humid savanna	2.5 - 5
7-4.5	Dry deciduous forest and woodland, savanna	5 - 7.5
4.5-2	Deciduous thorn forest, thorn savanna	7.5 - 10
2-1	Semidesert	10 - 11
1-0	Desert	11 - 12

Phytocoenosis as structural element of the ecosystem

Humid (drought-) deciduous forest (monsoon forest)

Compared to rain forests the tree layer of this type of forest is clearly less varied, frequently some species are dominant. However, the more open stand of the forests gives way to the development of a more luxuriant shrub and herb layer. The less favourable water balance results not only in periodical leaf fall but also in the development of smaller stems, thicker crusts, more strongly branching crowns and smaller leaves. In the tropics, large areas are (or rather were) covered by semi-deciduous or deciduous forests, but it is just these forests of all types and continents that are destroyed and endangered on a large scale since they can be easily cleared by burning (burning down during the dry season) and owing to periodical precipitation they offer favourable conditions for agriculture and cattle breeding. Original forests have been largely replaced by substitute communities (anthropogenous savannas), i.e. by humid savannas (with tall grasses) or dry savannas (with low grasses).

Dry (drought-) deciduous forest and woodland

When the average yearly rainfall becomes lower (less than 1,500 mm/year) and the dry season becomes longer the forest is characterized by a more open stand and the rest period of the phytocoenosis becomes longer. However, the dry season does not correspond to a complete rest period; at the end of this period many species begin to flower. Owing to periodic forest fires, only species resistant to fires can maintain themselves. The dominant vegetation in dry forests is an open tree cover with certain species having a characteristic shape (e.g. baobab, mopane, combretum, umbrella-shaped legume grasses and fruit-treelike taxons). There are sliding transitions from these dry forests by way of forests with an ever decreasing density of trees and understorey grass into true savannas where the grass layer is dominant. An unstable balance between trees and grasses is typical of this biome. It depends on the grass layer how much water permitting the development of trees remains in the soil. In case of heavier precipitation dry forests or tree savannas are the dominant type, in case of less precipitation it is shrub savannas or savannas and grassland that are dominant. The quantity of water being at the woody plants' disposal during the dry season is limited not only by climatic factors but also by edaphic ones giving way to the development of savannas (e.g. Llanos on the Orinoko in South America and Campos cerrados in Brazil).

Savanna and grassland

Savannas are ecologically homogeneous grasslands with more or less regularly growing woody plants and in case of their absence this biome is called tropical grassland. Today savannas and grasslands are widespread tropical formations of vegetation, though in many cases their development is to be attributed to man's activities. Natural savannas occur in areas with less than 500 mm of annual rainfall. In areas bordering on the deserts these savannas which are caused by the climate pass on loamy sandy soil into pure grassland, the thorn scrub savanna on stony soil turns into subdesert shrubland.

Utilization of and perils for the ecosystems

Humid (drought-) deciduous forest

The above remarks on rain forests apply as well to these, except that they have been more drastically decimated and are still more endangered than rain forests since the dry season offers favourable conditions for clearings made by burning. After having been utilized between 2 and 4 years for agriculture the soil lacking all nutrients is no longer suitable for agricultural utilization. The fields are abandoned and anthropogenous savannas are expanding. In case of utilization for cattle breeding the pasture grounds are kept open by burning. Thus, grasses can shoot better, but many species of trees are destroyed and only species resistant to fire can maintain themselves. Valuable species of timbers grow in the tropical humid forests (e.g. Tectona grandis, Diospyros ebenum and Terminalia in Southeast Asia), but they are often only extensively used. As in the case of rain forests efforts should be directed on regular forest cultivation and combined agricultural and forest utilization.

Dry forest, woodland, savanna

Being in most cases unsuitable for agriculture, these ecosystems are utilized for cattle breeding. But annual burning and inefficient pasture farming may result in extensive degradations and the expansion of thorn scrubs, the pasture land becomes worthless. The intensive overgrazing leads to the disturbance of the unstable balance of competition between trees and grasses. The reduced and disturbed grass layer gives way to a more luxuriant growth of woody plants (minor losses of water caused by evaporation, larger quantities of water reach the ground; for natural rejuvenation diminished competition by grass roots). Grazing animals contribute to the spreading of seeds. It is in particular thorny species (e.g. Acacia) which animals do not like and fire-resistant species that spread. Owing to an extended growth of bushes pasture-grounds become worthless and thorn scrub (savanna) and thorn woodland as substitute communities of natural savannas are common. When these woody plants are cut and used as firewood in more densely populated areas, the degradation of soils leads to the expansion of anthropogenous deserts. Some species of the thorn savanna being of importance for economy (e.g. Acacia senegal for the extraction of gum arabic) are cultivated. Several dry forests provide excellent pasturages, e.g. dry forests where mopane (Colophospermum mopane) is dominant; due to their high protein leaves which are the favourite feed not only of cattle but also of elephants and antelopes. Rational pasture farming is a prerequisite for the protection of these ecosystems.

C. Zone of tropical-subtropical semideserts and deserts

Main ecosystems

Biome types: Warm deserts and semideserts

Formation groups: Scrub/Extremely xeromorphic subdesert shrubland

Dwarf-scrub/Extremely xeromorphic subdesert dwarf-shrubland

- Mainly evergreen
- Deciduous with / without succulents

Herbaceous vegetation/

Short grassland without woody synusia

Forb vegetation/Low forb communities:

Mainly annual forbs (ephemeral or episodical forb communities)

Principal biomes: Semidesert
Rocky desert (Hamada)
Sandy-pebble desert (Serir) and Pebble-cobble desert (Reg)
Dead valleys (Wadis)
Oases

Ecological characteristics

Within the subtropical arid zone (trade-wind zone), owing to the very long range of rainfall (200 mm/year or even less), minimum humidity and great variations of temperature (the high solar radiation results in high temperatures during the day; due to the strong radiation temperatures drop even below zero during the night), savannas and grasslands change into semideserts (yearly rainfall less than 500 mm) and deserts (less than 200 mm). We designate these areas as arid since the potential evaporation is much higher than the yearly rainfall. Arid areas are situated in temperate climate zones as well. Unlike these, subtropical arid/areas do not have a cold winter season. Thus, in spite of their physiognomical similarity it is a question of different ecosystems. In some areas, e.g. in the subtropical Iranian-Pakistan-Indian desert area and in the winter cold temperate Iranian-Turanian deserts it is difficult to delimitate the ecosystems. The limit of the productive date cultivation serves to delimitate torrid deserts against winter cold deserts. Biomass and productivity diminish to a minimum in the deserts.

Phytocoenosis as structural element of the ecosystem

In spite of floristic differences deserts of the different biogeographical realms have common characteristics, such as
- low density of the plant cover;
- ecomorphological adaptations to arid conditions (occurrence of ephemeres, poikilohydric plants, xerophytes and succulents) and

- a landscape characterized by rock rather than by vegetation. Whereas in semideserts a diffuse vegetation (regularly spread over an even ground) is dominant, the growth of plants in deserts is mostly restricted to depressions and erosion gullies (restrictad vegetation).

Floristic characterization

Palaeoarctic realm:

Saharan-Arabian deserts: Chenopodiaceae, succulent Euphorbia (only in Marocco), xerophytic dwarf shrubs of different families, Poaceae with xeromorphic leaves (Stipa tenacissima, Panicum turgidum, Arista pungens etc.), various ephemeras after winter rain; cultivation of date palms as useful plants.

Africotropical realm:

Southern Sahara (including Sahel zone): Poaceae (Aristida, Eragrostis, Paniceae), shrubs of the genera Acacia, Commiphora, Grewia, herbs of the genera Callotropis, Crotolaria, Aerva.

Southern and East Africa: Succulents of various families (Euphorbiaceae, Crassulaceae, Apocynaceae, Asclepiadaceae), Acacia, dwarf shrubs (e.g. of Compositae).

Neotropical realm:

Sonora desert: succulent Cactaceae and Agacaceae, ephemerophytes, poikilohydric ferns, xerophytic semishrubs (Encelia).

Peruvian-Chilean coastal desert (fog desert): Bromeliaceae, Cactaceae, different herbs (Loma vegetation).

Utilization of and perils for the ecosystems

Semideserts still lend themselves as pasturages. However, the overgrazing of semideserts leads as well to changes in the ecosystem, thus, Artemisia-formations expanded at the expense of the former grassland in the North African - Near East semi-deserts. Cultivations of date palms are typical of the Saharan-Arabian deserts, the largest subtropical desert area. Agriculture is only feasible in "runoff areas", i.e. by using erosion gullies and depressions to which natural vegetation restricts as well (restricted vegetation). The cutting down of woody plants (winning of firewood) in transitional zones to the deserts results in the expansion of desert zones by anthropogenous deserts.

D. The sclerophyllous vegetation of winterrain areas

Main ecosystems

Biome type: Evergreen sclerophyllous forests, scrubs and woodlands

Formation groups: Closed forest/Winterrain evergreen broad-leaved sclerophyllous forest ("Mediterranean")
Woodland/Mainly evergreen broad-leaved and needle-leaved forest
Scrub/Evergreen broad-leaved sclerophyllous shrubland
Dwarf-scrub/Mainly evergreen dwarf-scrub

Principal biomes: Evergreen sclerophyllous broad-leaved forest
Evergreen broad-leaved sclerophyllous shrubland, regional biome: Macchie
Mixed evergreen dwarf-shrub and herbaceous formation
regional biomes: Phrygana, Tomillares, Batha etc.
Evergreen cushion shrubland

A transitional zone embracing all continents (though covering only a small area) which is located on the 40th parallel and characterized by winterrain (Etesian zone), hot and dry summers and cool winters (with cyclonic rainfall). This climate without a cold season but with occasional onsets of frost and a long summer drought is typical of the Mediterranean area. Owing to the summer drought there is a great proportion of sclerophyllous and malacophyllous hard-leaved species. Evergreen sclerophyllous forests (Quercus, Olea, Ceratonia, in some cases conifers) form the zonal vegetation. Since these areas are mostly old cultivated land, natural forest ecosystems today scarcely or only fragmentarily continue to exist. After being cleared, burned down and used as pasturages these natural forests were replaced by open communities with dwarf-shrubs (see above-mentioned biomes) or in case of the utilization of brushwood by light shrub formations (Macchie). Inasmuch as slope forests were cut and used as pasturages as well as severe erosion and degradation of the soil became widespread.

E. Zone of warm-temperate humid forests

Main ecosystems

Biome type: Subtropical and temperate rain forests or woodlands

Formation groups: Closed forest/Mainly evergreen forest:
Temperate evergreen ombrophilous forest
Temperate evergreen seasonal broad-leaved forest

Principal biomes: Warm-temperate humid forest
Laurophylleous forest

Ecological characteristics

Owing to its high humidity throughout the year (maximum rainfall in the summertime) and the lack of wintercold in most cases, the warm temperate climate zone offers again very favourable conditions for the growth of evergreen broad-leaved forests. This forest zone is located mainly on the east sides of the continents because of the influence exercised by trade- and monsoon winds. The forests cinstitute an intermediate stage between tropical rain forests and deciduous summer forests. At increasing geographical latitude and diminishing annual temperatures humid tropical forests grade into subtropical and warm-temperate evergreen forests (this development involves a decrease of the size of the leaves and a change of the floristic composition). It is often difficult to draw a dividing line between the different types, and warm-temperate forests (laurel forests) of Eastern Asia are not infrequently assigned to subtropical rain forests.

Phytocoenosis as structural element of the ecosystem

The warm-temperate broad-leaved forests are noted for their richness of woody plants, the predominant species being evergreen plants with leather-like (semisclerophyllous) leaves in many cases. An increased number of conifers is found in some areas.

Floristic characterization

The common occurrence of species of tropical (Lauraceae, Theaceae) and temperate taxons (Quercus, Magnolia, Castanea) and the great number of systematically isolated "ancient" taxons which already concluded their development in the tertiary period or even before is typical of these forests. The latter includes conifer families such as Araucariaceae, Podocarpaceae, Taxodiaceae.

Utilization of and perils for the ecosystems

Owing to the favourable conditions for the growth of plants the forest areas have been cultivated to a large extent. Intentive cultivation methods led to the deforestation of the major part of the large East Asian laurel forest area, it was replaced by tea plantations and other cultures. Remains of original vegetation can be found in mountains.

F. Zone of deciduous summer forests (nemorose forests)

Biome type: Temperate broad-leaved forests
Formation group: Closed forest/mainly deciduous forest:
Cold-deciduous forests with evergreen woody plants
Cold-deciduous forests without evergreen trees

Under the conditions of typically temperate climate with distinct, but not too long lasting cold season and a long warm summertime with sufficient precipitation (growing season), broad-leaved forests have adapted to the cold season by fall of their leaves. The mostly complex phytocoenoses are today cultivated efficiently as forests or have been transformed into productive ploughed field.

G. Zone of winter cold steppes and deserts

Biome types: Cold-winter(continental)deserts and semideserts
Temperate grassland
Formation groups: Woodland/Cold-deciduous broad-leaved woodland
Scrub/Extremely xeromorphic subdesert shrubland
Dwarf-scrub/Extremely xeromorphic subdesert dwarf-shrubland
Herbaceous vegetation/Tall graminoid vegetation
Medium tall grassland
Short grassland

- with a tree synusia
- with a shrub synusia
- without a woody synusia

Principal biomes: Woodland-steppe-formation
Steppe
regional biomes: Eurasiatic steppe
Northamerican prairy
Pampa
Tussock-grassland
Semidesert
Desert

Under arid climatic conditions steppes, semideserts and deserts which as to their physiognomy remind us of tropical-subtropical grassland, semideserts and deserts, have developed in the temperate climate zone in continental areas. The ecosystems, however, are characterized by a cold-winter climate. In addition to low precipitation they have great differences of temperature between summer and winter. In spite of their higher range of rainfall and temperatures the pampas are to be assigned to the steppes too. Semiarid climatic conditions and treeless ecosystems are brought about by years of drought and by edaphic factors (compacted subsoil). Contrary to the presumption of former times it is not anthropogenic factors (fires ignited by Indians) but natural ecological ones that put the tree growth at a disadvantage in its competitive struggle with the grass growth. Stipa-Bothriochloa-steppes rich in species were widespread in the northern pampas with higher range of rainfall and Tussock-grassland was to be found in the drier southern pampas. By now these areas have been transformed to a large extent into pasturages (frequently ploughed up and planted to softer European grasses) and into farmland.

H. Further zonal formations which, however, can be disregarded here, are

Zone of boreal coniferous forests (biome type: Temperate needle-leaved forest)

Zone of the arctic Tundra (biome type: Tundra communities and barren arctic desert)

The highland ecosystems (mixed mountain and highland systems with complex zonation) forming treeless alpine biomes above the forest belt (designated as paramo and puna in tropical highlands above the mountain cloud forests) are noted for their variety, but have not been considered in detail here.

II. 4.4.1.2. The flora as natural and genetic resource

Richness of species and genetic diversity

The plant species are not evenly spread all over the world; the flora of an area results from the effects produced by environmental factors in the past and present time. The different development of floras on each continent has led to a clear distinction between six floristic regions characterized by a greatly different plant and gene stock. Whereas there are comparatively negligible floristic differences on the whole Northern hemisphere and only one floristic region is excluded (Holarctic region), the different development on the Southern hemisphere has resulted in five floristic regions

- the species-rich tropical floras of the Old and New World (Paleotropis, Neotropis) and
- the floristic regions covering only small areas (Australis, Capensis and Antarctic region).

The tropical and subtropical zones are noted for their outstanding richness of species. If one compares the number of seed plant species of the world's different regions, it turns out that almost two thirds of the total stock of plants and species occur in the tropics and subtropics.

Number of seed plant species for the world's different regions (according to Raven, 1976)
Of 240,000 species:

Holarctic region (Eurasia, North America)	about 50,000 species
temperate to arid Australia and New Zealand	at least 15,000
South Africa (Capensis)	about 10,000
temperate South America	about 10,000
tropical and subtropical regions	about 155,000
of them: Africa (incl. Madagascar)	30,000 species
Asia (incl. New Guinea and trop. Australia)	at least 35,000 species
America	90,000 species

The tropical-subtropical floras are characterized by an extraordinary richness of plant species. This diversity of forms is due to a large gene stock. The centres of diversity correspond to gene centres.

Whereas by analysis of the floristic conditions in the luxuriant tropical forests the botanist's attention had been drawn in time to the richness of the wild flora, the cultivated plants and their wild forms were being neglected for a long time.

It was only by the pioneering research work of Vavilov, a Soviet geneticist and plant breeder, that the attention was directed to an essential fact: The wild forms of certain cultivated plants are common in certain regions of the world. There, the wild forms have a broad genetic range, i.e. a remarkable accumulation of genes. These gene centres are not only centres of diversity of cultivated plants but also their places of origin or centres of origin (according to Vavilov's gene centre theory). Some cultivated plants have several centres of diversity and in the case of other plants, the centres of today's diversity of forms are not identical with centres of origin. With regard to the geographical position of the centres of diversity of cultivated plants and their wild forms it is remarkable, that they occur mainly in mountainous regions of the tropical-subtropical zones and in the neighbouring regions of the Holarctic floristic region (meridional floristic zone). The following world centres of diversity of cultivated plants can be distinguished. The species represent selected examples only:

1. The Chinese centre	soybean
	various fruit species e.g. apricot, orange
	China tea

2. The Indian and Indo-Malayan centres

a) The Indian centre	rice	egg plant	cotton
	sugar cane	African millet	
b) The Indo-Malayan centre	banana	coconut palm	
	yam		
	pomelo		

3. The Central Asiatic centre (NW-India, Afghanistan, central Asiatic Soviet Republics)

wheat-species	lentil	sesame
pea	flax	pear, apple

4. The Near Eastern centre (Asia Minor, Transcaucasian and Turkmen SSR, Iran)

wheat-species	rye	fig	
red oat	grape	melon	apricot

5. The Mediterranean centre

durum wheat	olive
broad bean	
cabbage	

6. The Abyssinian centre (Ethiopia)

wheat-species	lentil	sesame
barley	African millet	coffea

7. The South Mexican and Central American centre

corn	upland cotton
common bean	sisal
pepper	

8. The South American centre

a) The Peruvian-Ecuadorian-Bolivian centre

sweet potato	tomato	papaw
potato	cotton	tobacco

b) Brazilian-Paraguayan centre

manioc pea-nut cacao rubber tree pineapple

c) Chilean centre

potato

9. The North American centre

New World lupin species strawberry
sunflower

The phylogenetic research of cultivated plants and plant breeding was given a strong impetus by the discovery of the gene centres. The discovery was based on the extensive observation and gathering of plants in these regions and the wild flora and primeval culture forms (local varieties) had to be taken into account too. The utilization of the genetic potential of the flora requires a thorough knowledge of the latter.

Up to now there is a different level of knowledge of each flora of the earth. In Europa which is the birthplace of the systematic botany the floristic research has reached the highest level. Even there, however, further several hundred plant species have been re-described in the past decades.

Innumerable species are waiting to be discovered in the rather unexplored tropical areas.

The registration of the earth's genetic resources is an urgent requirement of our time.

Perils for and decrease of the genetic diversity

Starting out from the fact that the flora of an area results from the effects produced by environmental factors in the past and present time, its continual changes in the course of the history of the earth are easy to explain. Initially it was only natural factors that determined the flora and vegetation of an area, but owing to man's growing influence on his environment the natural factors are increasingly superimposed by anthropogenic ones. Today the floral changes caused by anthropogenic factors entail always a decrease of the richness of species. Man's direct and indirect interference in his natural environment results in changes of the vegetation (frequently with the intention of uniforming it) and in most cases in the decreasing diversity of the flora with endangering the existence of various plant species. The extent of the floral changes depends on the geographical zone, habitat factors as well as intensity, duration and range of human interference. Certain plant species are very sensitive to anthropogenic interference and can indicate the nature and extent of the environmental changes (bioindicators).

Provisional investigations show that 5 to 10 per cent of the world flora are being threatened with extinction, the precise number of seed plant species being 25,000 according to IUCN data. This number is expected to increase to 50,000 till the end of this century in the tropics alone. Thousands of seed plants have already become fully extinct. There is a more rapid but hardly known decline in mosses and lichens (as for example in Belgium, the proportion of extinct mosses is four times that of vascular plants).

	Area km^2	Number of species	Percentage of extinct and endang. species	already extinct or missing species
Continents	150 million	200,000	10	?
USA (incl. Alaska)	9,36 million	20,000	10.4	0.5
Europe	10 million	12,000	16.6	?
Great Britain	240,000	1,655	18.0	1.1
FRG	245,300	2,352	38.8	2.4
Hawaii	16,600	2,200	49.4	11.6

Of the cases of extinct vascular plant taxons some examples shall be mentioned here:

extinct species: e.g. Viola cryana (France), Silene hifacensis (Spain), 8 species indigenous to Algeria, 8 endemic tree species of the island of Rêunion;

extinct genera: e.g. Herya, Berenice (Rêunion), Junie (USA), Moscheovia (Israel), Megalopanax (Cuba);

extinct family: Medusagynaceae (Seychelles).

Numerous well-known taxons occur no longer in nature, but only in cultures, e.g. the genera Tamarindus, Ceratonia and the species Caria papaya or Myristica fràgrans. There is an exceptionally great number of extinct or threatened species in the island floras. In Madagascar, 50 of the 500 endemic genera of seed plants may be endangered alone by a forest fire or the cultivation of an area. The islands of Hawaii, the Saychelles, New Caledonia, Fiji or Juan-Fernandez have numerous endangered species. In St. Helena which had been discovered in 1502, 33 endemic seed plants were counted in 1810 when the island vegetation had been already destroyed to a large extent. It will therefore never become known which species had been indigenous to this island. Today 11 of 33 endemics have already become extinct and only 4 species still occur so densely that they are not being threatened by extinction. A great number of species of the tropics and the Etesian zones have only limited areas and due to this limitation they are severly endangered too.

The loss of wild forms and local varieties is increasing in the diversity centres of cultivated plants.

Necessity and measures of the conservation of natural resources

Each existing population of a species contributes to the biological diversity and genetic resources of the earth. Every loss of species and genes results in the decrease of diversity, consequently the balance of the ecological structure is disturbed and the possibility of improving man's fundamental living conditions is restricted today and in future. A decrease of diversity mostly entails a loss of the stability of the biocoenosis. However, this does not mean that an increased number of species must lead to an increased stability of the phytocoenosis; the species-rich tropical rain forest is much more sensitive to external interference then a species-poor boreal coniferous forest. The diversity of species involves the possibility that several species adapt to changing environmental conditions.

As a result of the loss of species the balance of biocoenoses may be disturbed, particularly when it is a matter of highly productive species of vegetation.

Species, several ecotypes or cultivars contain genetic material which can be utilized for today's and future generations.

Man has already cultivated some 2,000 species and moreover innumerable ornamental plants and plants utilized by man in their natural sites (e.g. forest or drug plants) must be added. It is by the further study of natural resources that more and more new useful and ornamental plants become known which directly or by breeding prove to be useful for man either in view of certain effects or their resistance to certain environmental factors or diseases.

The extinction of species leads not only to the decrease of genetic resources but also to phylogenetic effects. An unique irreplaceable type resulting from a long evolution has been lost and any further evolution is impossible.

Because of the imperative necessity of the conservation and rational utilization of natural resources as man's fundamental living conditions, for some time several international organizations such as UNEP, FAO, ICSU and IUCN have been directing their efforts to the study of the perils for ecosystems as well as for wild and cultivated plants and their protection. The slogan of project 8 of the Programme on Man and the Biosphere (MAB) reads as follows: Conservation of natural areas and of the genetic material they contain.

A Threatened Plants Committee (TPC) has been set up within the IUCN.

What are the possibilities of conserving the diversity of the flora?

Before answering this question we must know the flora of a country (incl. cultivated plants) and its endangered species. The necessity and possibility of conserving a species depends on its range, ecology, usefulness and the nature of the endangerment. Measures of the conservation of the diversity must be based on the knowledge of the decrease of the range and genetic resources of the species and of its causes. In addition, infraspecific taxons of the wild flora, in particular ecogeographical races respectively subspecies and ecotypes have to be taken into consideration.

Red lists and Red books

On international and national level the listing of endangered plant species (Red lists, Red books) has been started, on the basis of which systematic measures of conservation must be taken. Contrary to animal species which are dying out and aroused the public interest already a long time ago, people became rather late aware of the enormous increase of plant species threatened with extinction. A survey of endangered genetic resources of domesticated plants drawn up on the initiative of the FAO and IBP was published already (FRANKEL, 1973), but a general survey of endangered wild plant species is still missing. The IUCN Plant Red Data Book gives detailed case histories of 250 threatened plants from about 25,000 flowering plant species believed to be in danger. A Red list of endangered species only serves its purpose if the species are classified according to the degree of threat, since all endangered taxons cannot be protected at once and with the same intensity.

The Red Book Categories are used by IUCN to indicate the degree of threat to individual species in their wild habitats:
- Extinct
- Endangered
- Vulnerable
- Rare
- Indeterminate (? Extinct or Endangered)
- Insufficiently known (according to TPC 2,500 - 3,000 species).

Examples are given in TPC booklet "How to use the IUCN Red Data Book Categories".

Laws, international conventions and the like

If endangered species are known there is one possibility of protecting them by passing bills containing regulations for the protection in their wild habitats. Such laws mostly referring to the prohibition of the digging and collection of or the trade in rare and endangered species have naturally a limited effect. They may restrict man's direct influence on the flora but they prove ineffectual regarding environmental changes caused by anthropogenic factors which lead to the destruction of the habitats of representative species.

In this respect an important convention on international level should be pointed out, viz. the Convention on International Trade in Endangered Species of Wild Fauna and Flora which came into effect on 1 July, 1975.

It contains precise regulations for the control and prohibition of trade in these taxons. More than 30,000 tribes resp. taxons of plants and animals are to be protected (including all species of the family Orchidaceae, all species of the genera Aloe, Cyclamen, Rhipsalis, Pachypodium, all American cactuses) and 370 particularly endangered species are placed under a strict control.

This Convention can only be successful if it is signed by all countries and each country takes care that the entire population will be informed about it, and in particular that commercial pickers and sellers of such plants are controlled.

Practical measures

The conservation of biotypes (in situ conservation), the cultivation in other habitats (ex situ conservation) and the establishment of gene banks are practical possibilities of really but to a different degree protecting the genetic resources of wild and cultivated plants.

Conservation of biotypes or in situ conservation

To preserve the life span of wild plant species is the main and ideal method of conserving its ecosystems and genetic resources. If possible, populations of endangered species should be protected in reserve networks. There is a general agreement on this point expressed by all authors and in all studies of international organizations (e.g. FAO/UNEP, 1975). The following quotation of the Expert Panel on MAB Project 8 (Conservation of natural areas and of the genetic material they contain) serves to emphasize this agreement:

"The remaining and apparently best, alternative appears to be the conservation of sufficient natural ecosystems so that a significant proportion of earth's plant and animal species can continue to exist and evolve surrounded by and in harmony with man's continuously changing civilization." (MAB Report Series No. 12:27).

Although an extensive protection of biotypes will not be possible in many cases, attempts must be made to establish biosphere reserves for particularly endangered ecosystems and species.

The size of a protected area depends on the living conditions of the phytocoenoses and species to be protected, it is thus determined by the minimum area ensuring the viability of the respective ecosystem. In the tropics only primeval forest reserves covering sufficient territories can maintain themselves and preserve the diversity of species of a tropical rain forest in addition to their function in the cycle of nature (cf. Appeal of the Hyläa Committee, 1975). The genetic resources of badly endangered and especially valuable species must be preserved in Strict Natural Reserves. It is, therefore, not enough to separate an area as national park, unless reserves with a special protection status spared from tourism and economic interference are separated within the national park. A reserve should be surrounded by a buffer zone, the possible utilization of which be controlled.

The conservation of species of half-culture formations involves particular problems. In these cases the ecosystem can only be preserved if the respective cultivation forms are conserved too. Consequently, these protected areas require special care taking measures.

Protected areas must be established with regard to the infraspecific variation of a species. This is especially important in the case of forest genetic resources and it must be added that the reserve area has to involve a minimum number of breeding individuals as well.

If the creation of a national park should be necessary from both zoological and botanical points of view, attention must be paid to the fact that the vegetation may be destroyed by grazing protected animal species to such a degree that the plant species worth to be preserved will be more quickly extirpated than under normal conditions.

<u>Conservation by cultivation (preservation ex situ)</u>

If the conservation of a species in its natural habitat proves to be impossible in the long run, the cultivation in other habitats or in botanical gardens must serve as temporary solution. A great number of already extinct species could have been saved by cultivation. This is proved by the plant taxons which today only occur in culture, e.g. Fortunella, Tamarindus, Cicca, Ceratonia, Ultragossypium, Carica papaya, Myristica fragrans, Palaquium gutta, Aloe susannae, Franklinia alatamahaca, Trachetia erythroxylon. When endangered species are cultivated their still existing total genetic range has to be taken into consideration. Species can be cultivated by gathering seeds, vegetative reproduction and by transplantation as last possibility of saving them. In the case of the improvement of the environmental conditions in the natural habitat at a later date, man should take advantage of this opportunity and resettle offsprings of the populations of this habitat. This reintroduction in nature must be carried out under scientific control

Gene banks and seed banks

The diversity of wild and cultivated plants can also be preserved by storing spores or seeds in specialized institutions, the so-called seed banks. The method of storing it in the form of tissue and cell cultures is still in the stage of development. However, the conservation of genetic material in such gene banks has one disadvantage. It prevents organisms from evolving. During the time of their storage the environmental conditions under which they would normally exist will continue to change. Further difficulties of the storage in seed banks result from the limited storability. The seed of the different taxons differ widely in their longevity. It is just the tropical woody plants whose seeds cannot stand any drying process that have particularly short-lived seeds (only a few weeks). But particularly hardcoated seeds of some families have a longevity of more than 30 years (and in some cases this period is much longer). Seed banks are of particular importance for short-lived species (Annuelle, Bienne), since their permanent cultivation is very expensive.

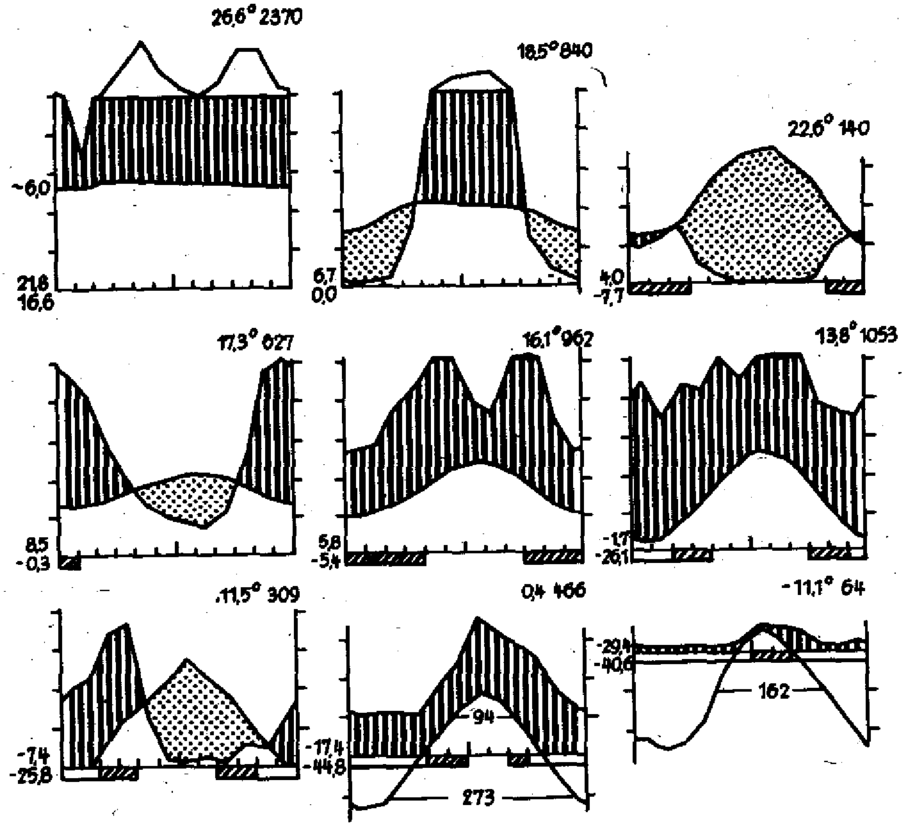


Fig. II.4.6.: Typical climate diagram for the most important vegetation formations of the earth (according to WALTER, 1970)

<u>upper line (from the left to the right):</u>
Tropical rainforest, tropical moist and dry rain-green forests and savannahs (tropical season forests), subtropical warm deserts and semideserts

<u>middle line:</u>
Sclerophyllos woodland of winter-rain areas, warm temperate evergreen moist forests, temperate deciduous broad-leaved forests

<u>below line:</u>
Wintercold steppes, semideserts and deserts, boreal coniferous forests, tundra

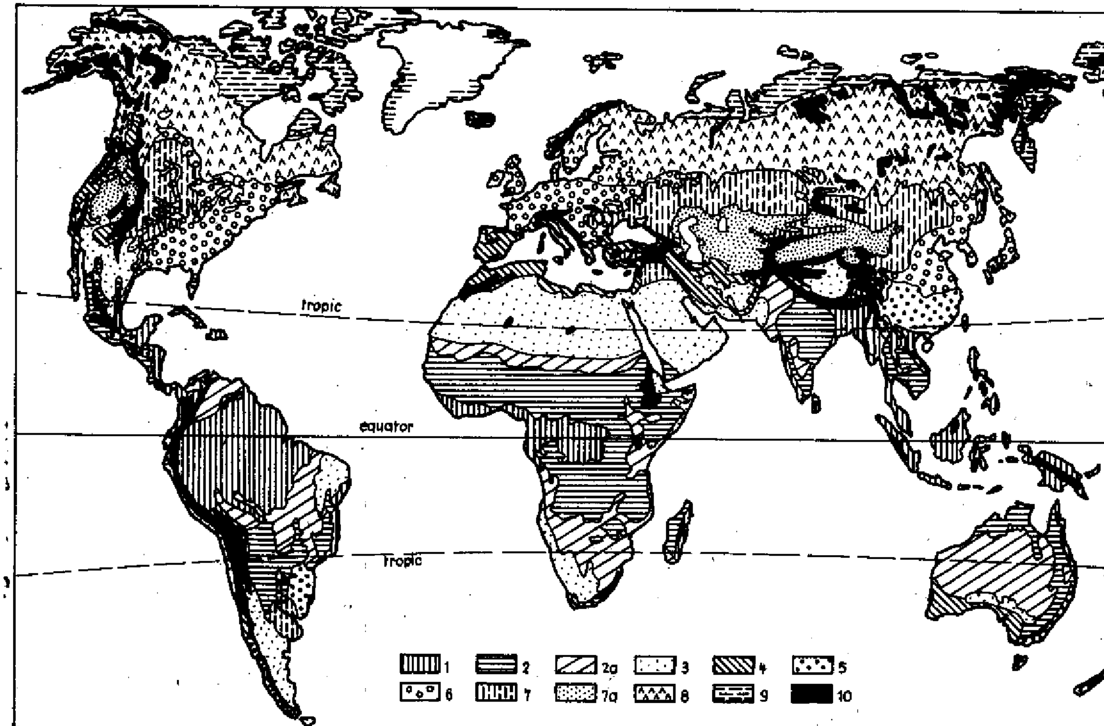


Fig. II.4.7.: Vegetation formations of the earth (great simplification, without edaphically and anthropogenically influenced vegetation zones) (according to WALTER, 1970)

I. Tropical-subtropical formations

1. Evergreen rainforest of valleys and mountains
2. Semideciduous and raingreen forests
   2a. Dry forests, natural savannahs and grasslands

II. Temperate and arctic formations

4. Sclerophyllos woodland (winter-rain areas)
5. Warm-temperate moist forests (laurel trees)
6. Cold-deciduous (nemoral) forests
7. Steppes

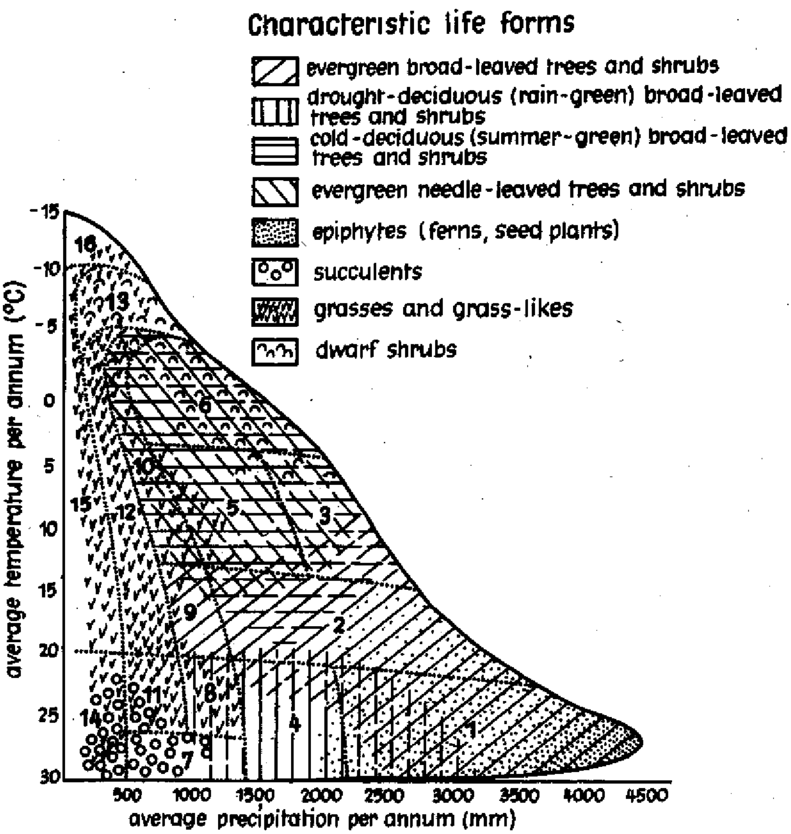


Fig.: II.4.8. Terrestrial biome types (climax vegetations) in dependence of average annual temperatures and precipitation (according to DANSEREAU and WHITTAKER taken from EHRENDORFER,1978)

1 – 6 Closed forests

1 Tropical rain forests
2 Subtropical warm-temperated rain forests
3 Temperate rain forests
4 Rain-green monsoon forests
5 Cold-deciduous broad-leaved trees
6 Cold-temperate coniferous forests

7 – 10 Woodland

7 Thorn bushes
8 Savannahs
9 Sclerophyllos woodland
10 Wood steppes

11 – 13 Grasslands and dwarf scrub vegetation

11 (sub) tropical grasslands
12 Temperate steppes
13 Tundra

14 – 16 Deserts

14 Warm deserts
15 Dry deserts
16 Wintercold deserts

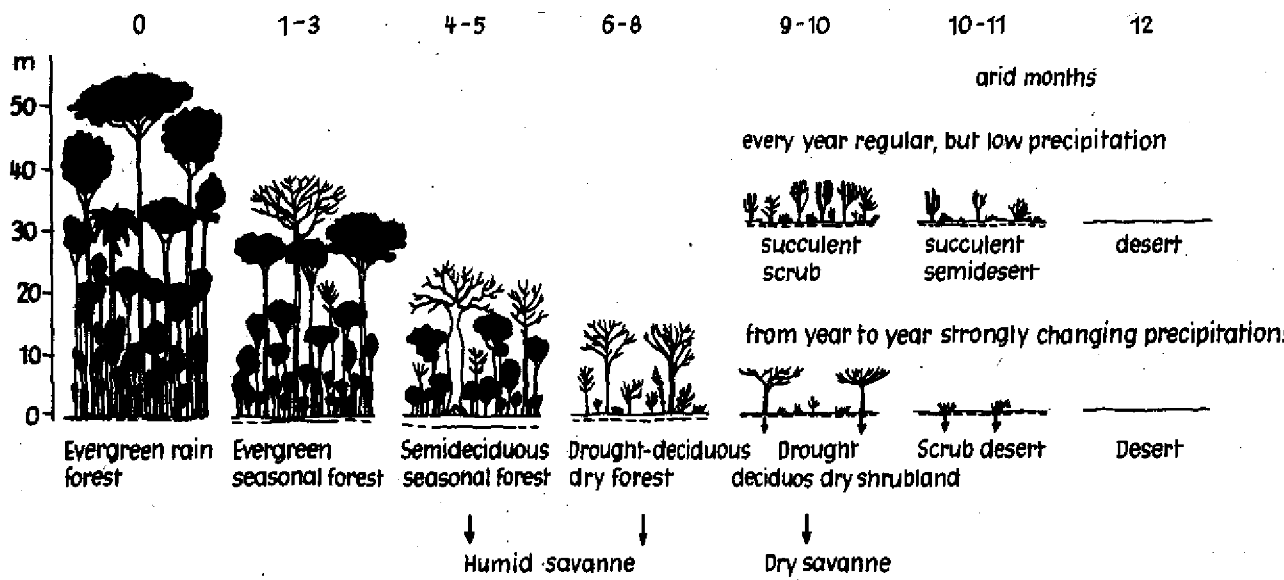


FIG.: II.4.9. Schematic representation of changes of vegetation formations depending on the number of arid months (by the example of the Andes foreland of Peru) (according to ELLENBERG taken from EHRENDORFER,1978)

Fig.: II.4.10 Profile through a multilayer rainforest in Guayana (only more than 4.6 m high trees were being taken under consideration) (according to DAVIDS and RICHARDS taken from WALTER, 1964)

II. 4.4.2. Fauna

Role and significance of fauna

Fauna as a natural resource is an essential component of ecosystems and of high importance for human society too. The main points indicating the role of fauna in ecosystems and in relation to man are:

- contribution to the cycling of matter, to the flow of energy and to the soil formation processes.
- disturbances of the stability of ecosystems by causing damages and losses of yield in agriculture and forestry.
- causing of diseases and parasitic infections in man and domestic animals; transmitters, vectors and intermediate hosts.
- stabilization of ecosystems by natural control and regulation of populations. Bio-indicators.
- formation of ecosystem components by pollination, seed and fruit dispersal, selective feeding etc.
- supply of meat, skin, milk and other raw materials and labour by wild and domestic animals
- objects of hunting, tourism and recreation
- gene reserves

This list demonstrates the manifold relations between man and fauna and reveals the importance animals have to man. So all efforts have to be undertaken to conserve fauna and to use it in a most rational manner.

All animal populations form typical communities in accordance with the vegetation types they live in.

Tropical regions contain large numbers of species of plants and animals, and humid tropical lowland forest is probably the richest habitat in the world as regards the number of species of plants and animals. This vegetation type covering not more than 7 per cent of the earth's land surface contains more than 50 per cent of the species of living organisms.

In temperate regions considerably fewer species occur and diversity decreases. A comparison of some animal groups in tropical and temperate regions results in the following figures (OWEN, 1976):

Mammals: Tanzania 289 species - Britain 47 species
Birds: Kenya 802 species - France and Switzerland 241 species
Snakes: Ghana 91 species - Britain 3 species

Similar results have been obtained for various insect groups with only Ichneumonidae as an exception to the rule. Observations made by the author in other tropical regions (Southeast Asia) confirm the above mentioned results.

The composition of animal communities is more or less constant. It is characterized and maintained in its composition by the vegetation type, which provides the habitat and the food for the animals. Both communities are connected in mutual interrelations, and each main vegetation formation contains a typical animal community. Therefore, the conservation of the fauna depends mainly on the conservation of habitats.

An effective conservation is the main prerequisite for the management and rational utilization of fauna as a natural resource.

Conservation status of fauna and wildlife

Though since the early times of the Ashoka-king (3rd century B.C.) strong efforts had been undertaken to protect wild fauna the results until now are not very successful, and the situation is still getting worse. In the past 2000 years more than 200 species of vertebrates became extinct, whereby most of them (more than 130 species and subspecies) have been wiped out in the last 100 years. This process is accelerated by the increase of human population as can be seen from figure II. 4-11.

Extinction of species is a general, biological principle in evolution. Reptiles flourished for over 150 million years but most of them (dinosaurians) became extinct by natural processes within 1 million years. Cahnging of living conditions were the main reasons for extinction but the disappearing reptiles had been replaced by other species (mammals, birds) which were better adapted to the new conditions so that species diversity and biological equilibrium in nature was maintained and evolution continued. Now the situation has changed drastically. Due to human developing activities living conditions of the fauna change so rapidly that species have no time to adapt to the new conditions and evolution is interrupted and stopped here. It is expected that - if the destructive of habitats continues at the present pace - about 1 million species will have disappeared for ever by the end of the century. About 25,000 plant species and more than 1,000 species and subspecies of vertebrates are threatened with extinction but small animal species (invertebrates) like molluscs, insects, corals etc. are even more endangered. Average people kon't know them very well, and their habitats are being eliminated in their entirety.

According to the IUCN-Red Data Book

305 species and subspecies of mammals,
400 of birds,
138 of reptiles and amphibians, and
193 of fish

are threatened with extinction.

A breakdown of the causes threatening these species includes:

67 per cent threatened by loss or contamination of their habitat
37 per cent by overexploitation

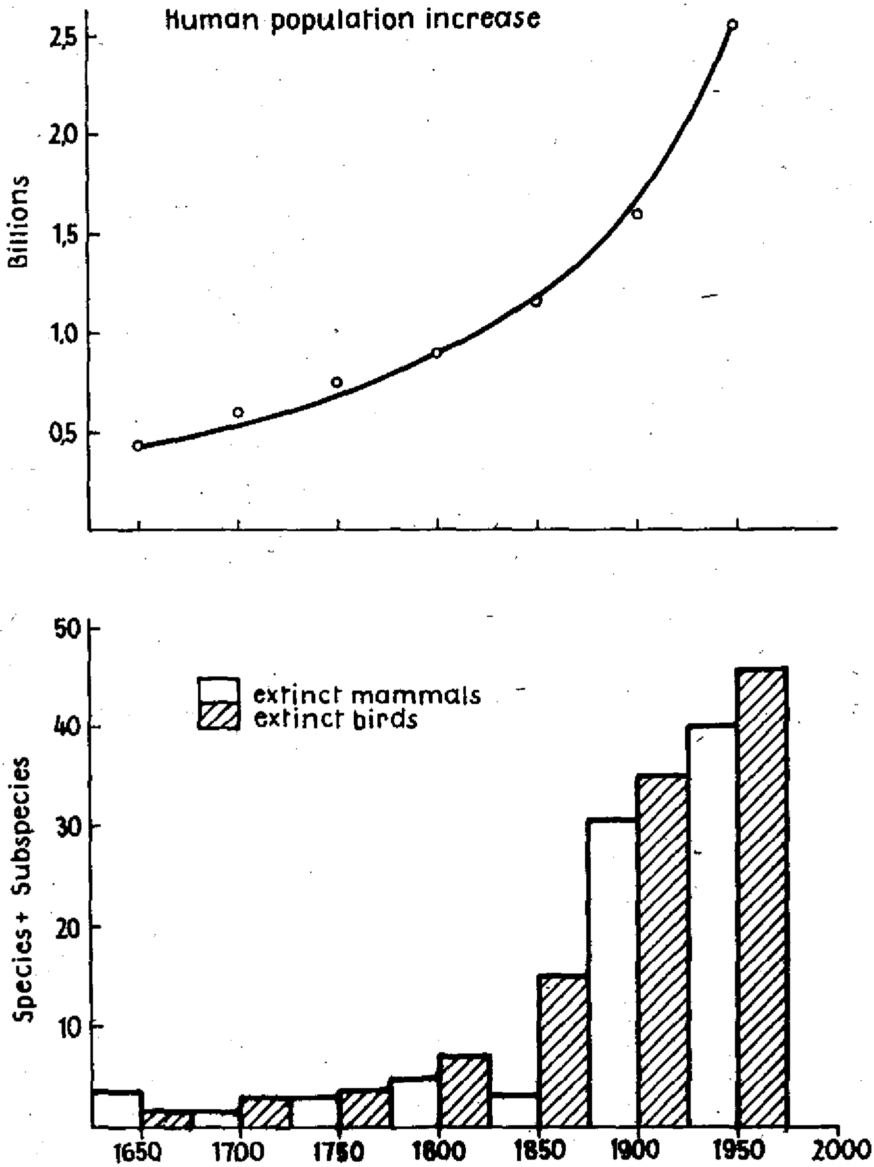


Figure II. 4-11 Interrelations between human population increase and the acceleration of extinction of animal species (From ZISWILER, 1965)

19 per cent affected by introduced exotic species
7 per cent competing for food with man
2 per cent affected by accidental killing.

These figures combined are well above 100 per cent because sometimes more than one factor may affect a threatened species.

In the past it was mainly overexploitation which affected fauna and wildlife, and there are striking examples of excessive hunting and poaching for trophies, meat and other reasons. But presently it is mainly the habitat destruction which is responsible for the decline of the population.

Although the species have survived, it is estimated that the abundance of most of them declined by 50 to 90 percent.

Species particularly threatened are characterized by:

- a small reproductive potential and/or
- a long individual development and/or
- a long life time and/or
- small ecological niches.

During the last few decades even common groups like insects declined in their abundance by more than 50 per cent.

People who are not very well acquainted with biological facts think it is enough to ensure the survival of a species if some individuals survive. But this is a false conclusion. We know that any animal species can survive and proceed with evolution only when a certain minimum abundance is guaranteed. If the population drops below a critical level the species is threatened. Several reasons can be made responsible, but it is mainly the genetic drift which is particularly strong in small populations, and increasing homozygosity due to inbreeding, which reduce their viability. The smaller a population the higher the probability that, by chance, a useful gene will disappear from this population. If environmental conditions change in such a way that this particular gene is required for adaptation, then a small population lacking this gene will not be able to survive. The "extinction-history" of the North American prairie-chicken (Cupidohen) illustrates this process (Fig. II. 4-12).

Principles of conservation, utilization and management of fauna as a natural resource

The following main principles have to be considered:

1. Careful analysis of the conservation status of the species concerned.
2. Implementation of legal regulations for the protection of the species.
3. Evaluation of the habitat, especially of its carrying capacity.
4. Implementation of regulations for the recognition of the conservation status and management of habitats. The main aspect is to keep the areas as large as possible. Reserves should cover all habitat components which the animals require - a complete ecological unit.
5. Management of the habitat for the improvement of living conditions.
6. Analysis of the population structure of the species concerned (abundance, age structure, sex-ratio, increase rate etc.).
7. Building up and maintenance of a viable population.
8. Formulation of the management objective and its careful realization by various measures for the manipulation of the population. The main aspect is to maintain a sustainable utilization.

Hence, management of the habitat and manipulation of the population are the main principles which have to be realized.

The management of the habitats includes:

- conservation of vegetation and soil (already mentioned in the previous chapter)

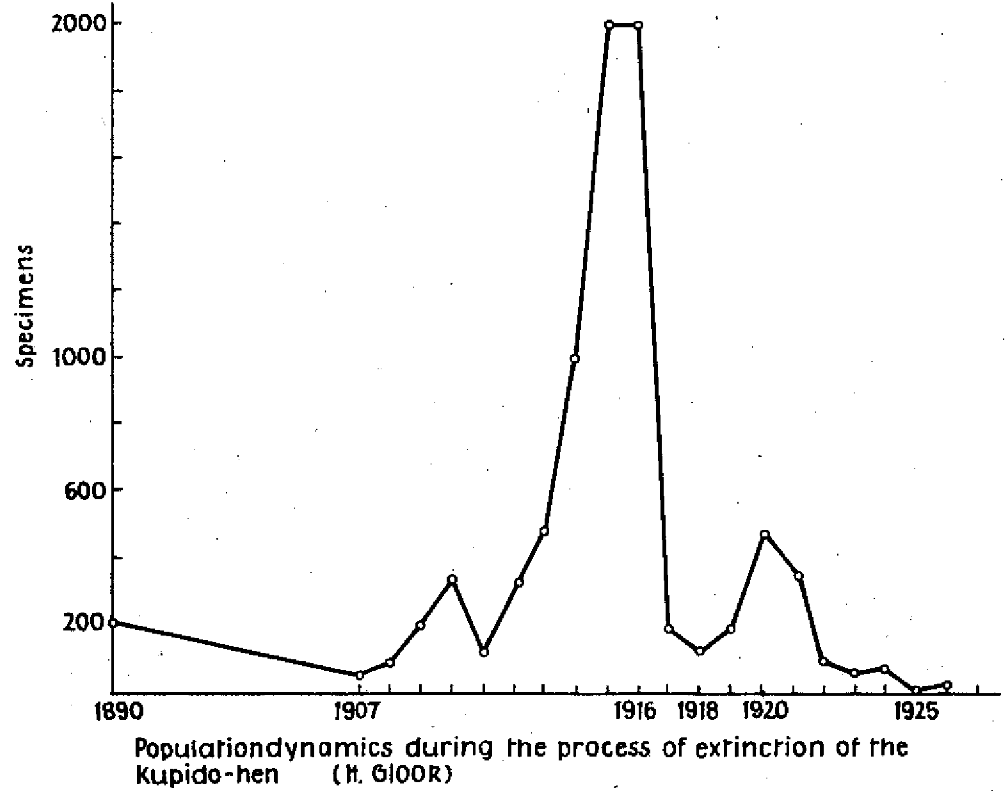


Figure II. 4-12 Extinction process of the Kupido-hen
(Prairie-chicken) (From ZISWILER, 1965)

- improvement of the vegetation by a regulated fire regime, by removal of undesired species (weeds, shrubs etc.) and by re-introduction of valuable plant species
- provision of a maximum of ecotones and edge effects to increase the number of ecological niches
- provision of an additional supply of water, shelter etc.
- exclusion of human activities (uncontrolled logging; no grazing of animals in these areas; etc.)
- implementation of legal protection measures by establishment of nature reserves, parks etc.

These management activities require a profound ecological knowledge. A well-managed habitat of appropriate size is the main precondition for the existence of viable animal populations.

Their proper management requires a sound animal stock which should be used only on a sustainable basis. The population can be manipulated according to the desired objective by selective removal of certain members of the population. Furthermore, the improvement of the genetic constitution of the population can be obtained also by selective removal of some individuals from the population, if the rule of Hardy and Weinberg is considered.

Declining populations loose more and more of their genetic potential so that it is very difficult to conserve and manage them properly.

Furthermore, the dwindling populations are affected by different ecological conditions and divided into seperate subpopulations. The genetic flow is interrupted between these subpopulations and evolution and survival may be seriously affected. So, for conservation purposes, a priority order should be considered for the establishment of the pattern of nature reserves to ensure the maintenance of genetic flow between the different subpopulations (Figure II. 4-13) and of genetic diversity of the species concerned.

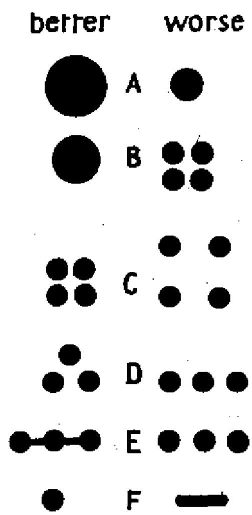


Figure II. 4-13 Suggested geometric principles for the design of nature reserves (From World Conservation Strategy, 1980)

For the preservation of genetic diversity priority requirements have to be formulated according to the imminence of genetic loss in the taxonomical categories involved. (See fig. II. 4-14)

The ecologically-based conservation objectives can be realized only by administrative and organizational efforts which have to be carried out also on international levels. Some selected activities, institutions and conventions involved are:

IUCN	(International Union for Conservation of Nature and Natural Resources)

Red Data Book of threatened species

WWF	(World Wildlife Fund)
CITES	(Convention on International Trade in Endangered Species of Wild Fauna and Flora) (Washington Convention)

RAMSAR-Convention

MAB	(Man and Biospere Programme)
WCS	(World Conservation Strategy)

The international activities will be dealt with in Chapter I.

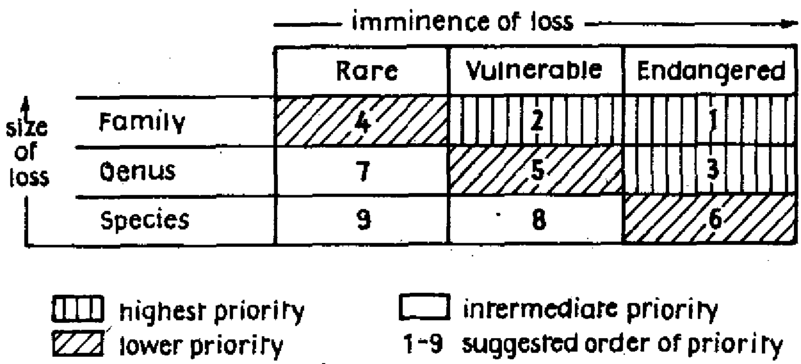


Figure II. 4-14 Formulation for determining priority of threatened species (From World Conservation Strategy, 1980)

References and further reading

Allen, R. (1980). How to save the world. IUCN - UNEP - WWF. Kogan Page ltd. London.

Bramwell, D. (Ed.) (1979). Plants and Islands, Academic Press London a.o.

Desowitz, R. S. (1978). Health and epidemiology in: Tropical forest ecosystems. A state-of-knowledge report by UNESCO-UNEP-FAO. Natural resources research XIV. UNESCO, Paris.

Ehrendorfer, F. (1978). Geobotanik. In: Lehrbuch der Botanik für Hochschulen, ed. 31, Gustav Fischer Verlag, Stuttgart.

Ehrlich, P. R., A. H. Ehrlich and J. P. Holdren (1973). Human ecology. W. H. Freeman and Co. San Francisco.

Farnworth, E. G. and F. B. Golley (1974). Fragile ecosystems Springer, Berlin.

Foley, G. (1981). The future of renewable energy in developing countries. Ambio 10, 200-205.

Frankel, O. G. and E. Bennet (Eds.) (1970). Genetic Resources in Plants - their Exploration and Conservation. IBP-Handb. 11, Oxford and Edinburgh

Freye, H.-A. (1978). Kompendium der Humanökologie. VEB Gustav Fischer Verlag, Jena.

Garms, R. (1973). Zur Verbreitung von Simulium damnosum in Liberia. Z. Tropenmed. Parasit. 24, 222-231.

Golley, F. B. and E. Medina (Eds.) (1975). Tropical Ecological Systems. Berlin and New York.

Goodall, D. W. (Ed.) (1977 ff.). Ecosystems of the World. Amsterdam.

Hedberg, I. (Ed.) (1979). Systematic Botany, Plant Utilization and Biosphere Conservation. Proceed. Symposium Uppsala, Almquist and Wiksell International, Stockholm and Uppsala.

Hill, D. S. and J. M. Waller (1982). Pests and diseases of tropical crops. Longman Group ltd. New York.

Huffaker, C. B. (Ed.) (1974). Biological control. Proc. of an AAAS-Symposium on biological control, held at Boston, Mass. 1969. Plenum Publ. Corp. New York.

IUCN (1978 ff.). TPC (Threatened Plants Committee) Newsletters, Secretary of TPC, Royal Botanic Gardens, Kew.

IUCN-UNEP-WWF (1980). World Conservation Strategy. IUCN, Gland.

Janzen, D. H. (1973). Tropical agro ecosystems. Science, 1982, 1212-1219.

Krebs, C. J. (1972). Ecology: The experimental analysis of distribution and abundance. Harper and Row Publ. New York.

Lee, A. C. (1972). L'accroisement démographique mondial et, en particulier, celui des pays en voie de dévelopment. Dévelopment et Civilisation 47-48, 8-23.

Lucas, G. and H. Synge (1978). The IUCN Plant Red Data Book. IUCN, Morges.

May, R. M. (1974). Stability and complexity in model ecosystems. (Monogr. Popul. Ecol. 6). Priceton.

Meggers, B. F. et al. (Eds.) (1973). Tropical Forest Ecosystems in Africa and South America. Washington.

Murdoch, W. W. (1975). Diversity, complexity, stability and pest control. J. appl. Ent. 12, 795-807.

Nei, M. et al. (1975). The bottleneck effect and genetic variability in populations. Evolution 29, 1-10.

Nickel, J. L. (1973). Pest situation in changing agricultural systems. A rewiew. Bull. ent. Soc. America 19, 136-142.

Odum, E. P. (1971). Fundamentals of ecology. W. B. Saunders Comp., Philadelphia.

Odum, E. P. (1975). Ecology. H. Rinehart and Winston, London.

Owen, D. F. (1976). Animal ecology in tropical Acrica. Longman Group Ltd. New York.

Petersen, H. (Ed.) (1982). Quantitative ecology of microfungi and animals in litter. Oikos 39, 286-422.

Saunders, P. T. and M. J. Bazin (1975). Stability of complex ecosystems. Nature 256, 120-121.

Shakow, D., D. Weiner and P. O'Keefe, (1981). Energy and development: The case of Kenya. Ambio 10, 206-210.

Šiljak, D. D. (1975). When is a complex ecosystem stable? Mathem. Bioscience 25, 25-50.

Simmons, I. G. (1974). The ecology of natural resources. Ed. Arnols Publ. Ltd. London.

Simmons, J. B. et al. (Eds.) (1976). Conservation of Threatened Plants. New York and London.

Smith, D. F. (1975). Quantitative analysis of the functional relationships existing between ecosystem components. III. Analysis of ecosystem stability. Oecologia 21, 17-29.

Smith, R. F. and C. B. Huffaker (1974). Die Strategie integrierter Schädlingsbekämpfung in den Vereinigten Staaten und ihre praktische Verwirklichung. Z. Pflanzenkrankh. u. Pflanzenschutz 81, 218-238.

Solomon, M. E. (1976). Populations dynamics. Studies in biology no. 18, E. Arnold Pulbl. Ltd. London.

Synge, H. and H. Townsand (Eds.) (1978). Survival or Extinction? Proceed. Intern. Conf. Practical Role Botanic Gardens in Conservation Rare and Threatened Plants. Royal Botanic Gardens, Kew.

Udvardy, M. D. F. (1975). A Classification of the Biogeographical Provinces of the World. IUCN Occasional Paper 18, IUCN, Morges.

UNESCO (1973). Programme on Man and Biosphere. Expert Panel on Project 8: Conservation of Natural Areas and of the Genetic Material they contain. MAB Report Ser. 12, Paris.

UNESCO (1973). International Classification and Mapping of Vegetation. Paris.

UNESCO (1974). MAB - Task Force on: Criteria an Guidelines for the Choice and Establishment of Biosphere Reserves.

UNESCO (1975). Teacher's study guide on the biology of human populations (Asia). The UNESCO-Press. Paris.

Walter. H. (1964). Die Vegetation der Erde. Vol. 1: Die tropischen und subtropischen Zonen, Ed. 2, Gustav Fischer Verlag Jena.

Walter, H. (1970). Vegetationszonen und Klima, Gustav Fischer Verlag Jena.

Watt, K. E. F. (1965). Community stability and the strategy of biological control. Canad. Ent. 97, 887-895.

Webster, C. C. and P. N. Wilson (1980). Agriculture in the tropics. Longman Group Ltd. London.

Weiner, J. (1974). Human ecology aspects. In MAB report series No. 16; 85-92, UNESCO, Paris.

Whitney, J. B. R. (1981). Urban energy, food and water use in arid regions and their impacts on the hinterland: A conceptual framework. In MAB-Workshop on "The ecology of settlements in arid regions" Khartoum.

Wittaker, R. H. (1975). Communities and ecosystems. Macmillan Publ. Co. Inc. New York.

Ziswiler, V. (1965). Bedrohte und ausgerottete Tiere. Springer, Berlin.