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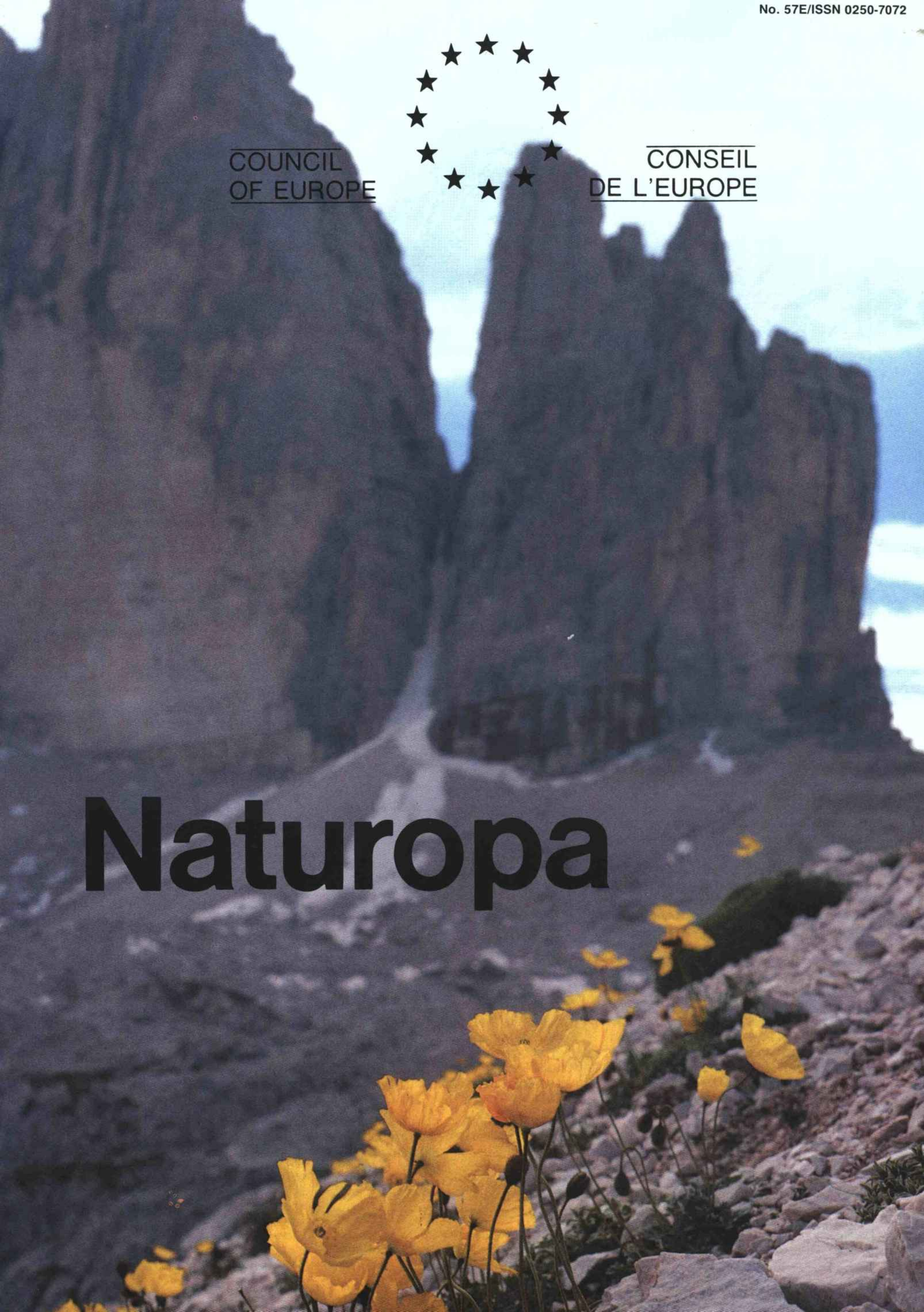

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Naturopa

No. 57 - 1987

A time bomb

Soil. Taken for granted for centuries. As, for that matter, the rest of our environment. Belatedly, soil is now being recognised as one of the guarantees of our livelihood which we are spoiling to the point where experts sometimes call it a time bomb.

Already in 1972, the Council of Europe recognised its irreplaceable value in adopting its Soil Charter. It is still valid: "soil is one of humanity's most precious assets", it "is a limited resource which is easily destroyed" and "governments and those in authority must purposefully plan and administer soil resources".

The 5th European Ministerial Conference on the Environment, held in Lisbon last June, recommended to the Council of Europe's Committee of Ministers to study the possibility of drawing up an appropriate draft convention on soil protection. This matter is under consideration by the Committee of Ministers. The Council of Europe will therefore continue to work to safeguard this precious resource.

After *Naturopa* 55, 56 and 57 which were in support of the campaign "Farming and wildlife", the next issue in spring 1988 will treat the problem of waste, recycling and man's behaviour in spoiling the landscape and the environment. ■

H.H.H.

Editorial

The land has become one of the main themes of our time, but not for any very commendable reasons. The focus is on its continued material existence and consequently presumably on the survival of human society. If you cut the ground away from under someone's feet, he falls; we are successfully performing the trick of preparing our own fall. We have become reckless in our handling of the vital commodity constituted by the land. With the lofty demands our civilisation imposes, uncontrolled urban growth, large-scale transport and supply networks and our spacious recreational facilities we are thoughtlessly consuming precious arable land, our rapacity apparently knowing no bounds. Furthermore we are exhausting what remains of our cultivated land through increasingly intensive farming, and polluting it with substances which at this stage would be the very fount of life for ourselves and future generations.

This must stop; there is no longer any justification for such behaviour. Having realised the danger to the land, and nature as a whole, we must act. A new ethic governing our handling of the land must be found to direct such action. The land has become a mere means to an end, a simple utility or consumer product in a technological development whose excesses have cast doubt on it, a mere factor in production and consumption, in the widest meaning of the term. We are today called upon to remind people of the natural and intrinsic value of the land, and to strive to reinvest it permanently with its true "nature".

Admittedly, European countries have for years, or even decades, been attempting to channel developments by means of their instruments for national and regional planning development policies, with varying degrees of success. In Switzerland we realise that we must implement measures much more effectively if we are to keep what little land is available in our country qualitatively and quantatively capable of assuming all the requisite tasks for present and future generations.

In order to shed some light on how this might be achieved, the Swiss Government has provided funding for a national research programme entitled "Land use in Switzerland". The programme includes the following objectives: long-term conservation of land fertility; curbing the loss of natural, undisturbed soil; improving the apportionment of land uses. The research actions are aimed at pinpointing measures in support of such objectives. In addition to legislative or technical measures, it would seem desirable also to deal in the research programme with problems of principle and ethics. The results of such investigations must be put into practice and so, rather than being used exclusively for analysing the current state of the land, they might also serve to point up those areas where we should be extending or changing our way of thinking; however, the results can be put into practice in the long term only if the population joins in on the venture.

For this reason we must use information and public relations to increase present generations' awareness of their responsibility in the matter of land conservation.

In Switzerland, we realise that our efforts are in line with those going on all over Europe. The same basic problems affect all highly civilised and industrialised countries, but they also have an impact on third world countries, on whose resources our civilisation is also dependent.

It is therefore no coincidence that the 8th European Conference of Ministers responsible for Regional Planning, to be held in Switzerland in 1988, has chosen as its theme "Rational use of land basis and limiting factor of our development".

In connection with the land, we should not forget a fact which the 1983 European Regional (Spatial) Planning Charter mentions in its preamble, viz. that our relationship with the land represents a substantial contribution towards our own identity.

Looking after the soil, which was the original meaning of "cultivating", is literally the basis of human culture, which arises out of the land. To have a cultural identity is also to have a home, to be able to identify with one's rural area, region, village or district. Without this possibility of identification with the land under our feet we lose our roots, we become homeless and drift around, no longer taking any part in what is going on around us. By losing his relation to the land, modern man runs the risk of becoming a restless, fickle being "dwelling" on wheels, surfboards and skis, with no real home.

Nowadays we have become much more sensitive to all these developments. The reactions of nature to our selfish or at least careless attitude towards her have given us a rude awakening, allowing environmental protection, regional planning, and the land at least a sporting chance. Let us make the most of these new perceptions, this new awareness of the problems, this orientation towards new values, which are probably in fact only old, hitherto forgotten values. Let us pave the way for a new direction and eventually a new order in our relation to the land and nature.

Once we have managed to develop a new sense of fair treatment of the land, let us also create the conditions whereby the limited resource of the land can be fairly and responsibly distributed among ourselves and future generations. I hope that the contributions in this number and their reception by the readers will prompt them to think about and work towards the achievement of these common objectives. ■

Elisabeth Kopp
Federal Councillor
Switzerland

Soil - a natural element

Winfried E.H. Blum

Terra fusca

Rendzina

Gley

Calcareous mountain soil

Photos W.E.H. Blum

Origins and properties of soils

When we look at a tract of landscape, for example a mountainous region in central Europe, we are struck by the fact that, depending on the nature of the rock, the relief, altitude, slope and exposure to the sun, the forms of vegetation or human utilisation of the land, the hydrological balance of the landscape and so on, a wide range of soil features is present, sometimes within a very small area. In the highest mountain regions we find only soils which cannot be developed beyond an extremely small topsoil zone, because their relative altitude means that they are exposed to continuous erosion (raw soils). At medium altitude, however, soils have been formed which present a clearly developed topsoil above the zone of alteration of the underlying rocks (rendzina). In areas still lower down we find soils with a well developed topsoil and an additional subsoil zone formed over the zone of alteration (*Terra fusca*). In the river valley plains, soils influenced by the groundwater are in evidence (gley).

This example alone shows that it is not possible to generalise about the soil: distinctions must be drawn between different types of soil and different soil communities.

Despite the large differences which exist between different types of soil and soil communities, nonetheless they all have important features in common, and these are briefly described in the following paragraphs.

The most important common characteristic is the way in which they have come into existence. Soils arise as a result of physical and chemical weathering of the rocks and through biological—i.e. biochemical—breakdown of organic substances from the remains of dead plants and animals. The humus-forming substances which arise as a result are worked downwards into the soil by living organisms, and mixed with the minerals in the soil which are released from below by weathering processes which affect the rock. The stronger the weathering and the more intensive the breakdown and conversion of organic substances, the more pronounced the soil development is.

So soils are horizontally separated loose strata (sections from the upper earth's crust or pedosphere), capable of reaction and full of living organisms, which reach from the upper surface of the earth down to the bedrock. They are constituted afresh by the conversion of basic mineral and organic material with the addition of materials and energy from the atmosphere, and these conversion and soil formation processes are going on continuously inside them (a dynamic system consisting of the three phases, solid, liquid and gaseous). From the ecological standpoint and that of environment conservation, this traditional soil definition can be extended to include loose sediments which reach deep down into the earth, and rock strata containing cavities, including the bodies of groundwater which occur in them. The soil, defined in this way as a three-dimensional section of the upper earth crust, can reach very deep down.

In Europe, the most important influence on the origin and development of soils was the effect of the ice ages and the interglacial periods in the quaternary era. In places where the ice cap or the effects of frost, water and wind eroded interglacial and older soils—and this applies in essence to the whole of Europe north of the Mediterranean—soils are younger than 14,000 years old, with a few exceptions (relict soils). This being a very short period, the soils in question still retain some essential features of the original rocks from that time, though they have the original vegetation forms to a much lesser extent. Other important common features of the various types of soil are anorganic (mineral) and organic components, the extent to which they contain living soil organisms, and the pore system.

The soil as a reactive mass

Through physical and chemical/biochemical weathering of the rocks, new and highly reactive anorganic components evolve in the soil. These are characterised by small grain sizes ($\varnothing < 2\,\mu m$) and large (external and sometimes internal) surface areas, which also possess electronegative, but seldom electropositive surface charges. The most important of these highly reactive mineral soil components are the clay minerals and oxides. Individual clay minerals have surface areas of up to 800 m^2/g. On average, the surface areas of clay minerals are between 100 and 200 m^2/g. As a result of these large surface areas and their electrical charges, these minerals are capable of binding or exchanging cations and anions in the soil.

When leaves, straw or other dead vegetable or animal material falls to the ground, as a rule it has already undergone an initial decomposition process (biochemical), and this is apparent in plants, for example, in the yellowing that takes place in autumn. As a result of two further steps in the process, mechanical breakdown by soil animals and further microbial breakdown and transformation through microorganisms, some of this organic primary matter is mineralised, i.e. completely broken down into water, individual elements and CO_2, which are available in the soil and in the stratum of air close to the soil for new plant growth (the cyclical principle). However, another part of the organic primary matter is converted by microbial action into high molecular organic material (humus) which may have existed for several thousand years and gives the topsoil its typical dark brown or blackish brown coloration, as well as making important physico-chemical and biochemical reactions possible in the soil. Humus has even greater surface areas than clay minerals (up to 1,000 m^2/g) and, because of its chemical surface structure, depending on the pH value of the soil will possess either electronegative or electropositive charges which make a multitude of combinatory and exchange processes possible.

These processes of decomposition and transformation of the organic primary substance in the soil involve, per hectare and 30 cm of soil depth, about 25 tons of living organisms, including about 10 tons of bacteria and actinomycetes (transitional forms between bacteria and fungi), about 10 tons of fungi, 4 tons of earthworms, and about 1 ton of other organisms such as mites, spiders, woodlice, beetles, snails, mice and so on. If this is compared with the maximum life support capacity of a fertile meadow, we find that a mass of organisms at least ten times greater can live actually inside the soil than on top of it.

To sum up, the numerous physical, physico-chemical and biochemical reactive possibilities of the anorganic and organic components of the soil can be said to depend on the large surface areas and the electronegative and electropositive charges they carry. If we assume that a three-dimensional section measuring one hectare and 20 cm deep through a field will produce 3,000 tons of soil, and if we also assume that 20% by weight of it is clay minerals (= 600 tons) and 3% by weight humus (= 90 tons), then for an average surface area of 200 m^2/g in the case of clay minerals and 1,000 m^2/g in the case of humus, it is easy to calculate that taking these soil components alone, the total surface area of the soil mass in question will equal that of a medium-sized European country.

The mineral and organic components of the soil described above are arranged naturally in such a way that cavities occur. These form the pore system, which is subject to constant changes as a result of various processes in the soil such as swelling and shrinkage, as well as animal and plant activity (e.g. through roots) and tillage of the soil by human beings. These pores provide habitats for soil organisms and determine the hydrological and atmospheric balance of the soil, i.e. the water and air (gases) it contains. They are divided into various categories according to diameter. In the wide ($\varnothing > 50\,\mu m$) and narrow ($\varnothing = 50$ to $10\,\mu m$) coarse pores of the soil, the water can seep away through gravity. Consequently, these pores are essential to the atmospheric balance of the soil and at the same time provide the most important habitats for soil organisms and for the roots of the plant cover. The medium-size pores ($\varnothing = 10$ to $0.2\,\mu m$) are able to retain water against the force of gravity, i.e. store it and make it available to plant roots and other organisms. The proportion of these pores in the soil is therefore crucial to the water supply of the biosphere. The fine pores ($\varnothing < 0.2\,\mu m$) also store water, but in a form which is not available to plants because of its strong bonding. So the pore system is the soil space inside which all the dynamic processes involving transitions between the gaseous, liquid and solid phases take place, i.e. between pore content and pore walls.

These soil characteristics are distributed differently according to soil type or soil community. However, because of the multifarious physical, chemical and biological/biochemical mechanisms they provide the basis for the way in which the soil is able to react with the environment, i.e. for the ecological functions of the soil. Apart from these are other technical/industrial soil functions in which the soil characteristics we have mentioned are of no real significance. These various soil functions are described in the following paragraphs.

The five soil functions

In considering the relationship of the soil to the environment, and on the basis of a comprehensive analysis of the present environment situation, soils can be seen as fulfilling five different functions, three of them ecological functions based on the above mentioned soil characteristics, and two technical/industrial functions basically dependent on other parameters.

In ecological terms, soils perform the following three functions:

— **The agricultural and forestry production function**, i.e. the production of biomass to maintain animal and human life in the form of foodstuffs, including renewable raw materials. Here the soil is regarded as a nutritive substrate providing air, water and nutrients for plant growth.

— **The buffer, filter and conversion function** of the soil. Here the soil is seen as a filter, buffer and converter between the atmosphere and the groundwater on the one hand, and between atmosphere, groundwater and plants on the other. An important physical buffer function is performed by the water storage capacity, that is to say the ability of the soil to absorb water precipitated and in due course pass it on to the groundwater or to plants or the atmosphere. This property is of the greatest importance, especially in mountains, since it regulates the water balance and protects the landscape from destruction. There are also essential physico-chemical and chemical filter and buffer reactions. One of the important functions here is that of maintaining the purity of the groundwater and of the food chain, both of these being vital to the continuance of life. Through the physical, chemical and biological/biochemical reactions already outlined, the soil is able not only to filter substances mechanically (within the pore space) but also to bond anorganic pollutants, e.g. heavy metals or radionuclides, so strongly through a range of physico-chemical reaction mechanisms that they cannot get into the soil solution and from there into the groundwater or the food chain. Another essential function is the biological/biochemical conversion function, i.e. the property which soils have of breaking down organic pollutants by microbial action and thereby rendering them partly or entirely harmless.

Buffer, filter and conversion functions are therefore soil functions which preserve and maintain life by protecting landscapes and keeping groundwater, drinking water and food pure; only in recent times has the full dimension of these functions been understood and to some extent researched as a result.

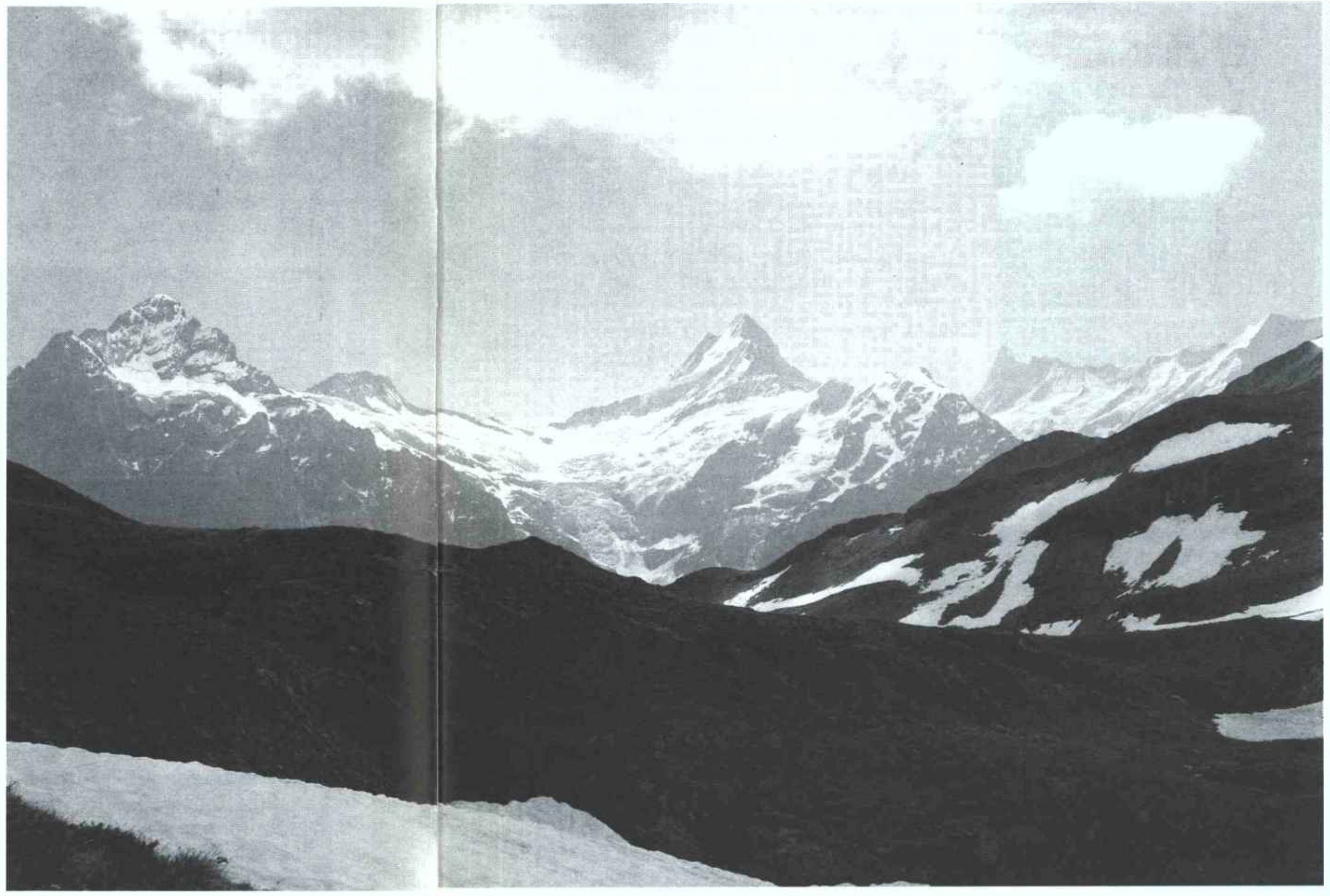
— **The gene protection and genetic reserve function** of the soil in preserving a variety of species. This function involves maintaining organisms which live in the soil. Gene conservation is one of the most important tasks in preserving the conditions for human life, because not only plants and animals living on the surface of the earth but also those inside the soil must be protected. At the present time there are threats to gene conservation in the soil from a variety of influences, and various kinds of pollution in particular.

From the technical/industrial angle, soils have two other essential functions, though these are not defined by the soil characteristics which have already been described but by other parameters:

— **The infrastructure function**, that is to say the provision of land or space for human settlement, industrial sites, transport infrastructures, leisure, sport and recreational facilities, and for the disposal of domestic and industrial waste, etc.

— **The raw material function**, that is to say the provision of materials from deposits in the soil such as clay, sand, gravel, minerals, etc. for technical and industrial production, as well as water.

It must be borne in mind that these two technical/industrial functions either wholly or at least in part exclude or greatly restrict the ecological functions of the soil.



F. Zvardon/PLURIEL

Competition between soil functions: a key to understanding the problems of protecting the soil and the environment

The basic problems of soil and environment protection at the present time lie in the competition taking place between the various functions of the soil.

Problems arise from competition between the ecological and technical/industrial functions, and also from competition within these two groups of functions.

In the course of past centuries, as a result of famine and food shortages, the land and the soil have mainly been regarded as a substrate for the production of food and renewable raw materials. Because the various cycles were largely self-renewing and little use was made of fossil energy sources and raw materials, so that the environment was relatively unpolluted, the other ecological functions of the soil, such as the filter, buffer and conversion function as well as the genetic conservation function, were scarcely affected. However, since the middle of the present century that situation has undergone drastic change.

As a result of rising population density, general infrastructure development, especially for transport networks, and increasing industrialisation, soils have been subjected to high degrees of pollution. In addition, the areas of land needed for housing, transport, industrial production, waste disposal and also for leisure and recreational facilities have grown to such an extent that they have come to compete in substantial measure with the ecological functions of the soil.

But there is considerable competition even among the individual ecological functions. For example, the use of fertilisers and other agricultural chemicals in order to optimise biomass production places undue strains on the filter, buffer and conversion function, especially bearing in mind the damage already caused by pollution from industry, transport and other sources. This is reflected not only in contamination of groundwater and drinking water by nitrates and phytochemicals, but also to some extent in the contamination of food by anorganic and organic pollutants.

The intensive use of agricultural chemicals and additives, alongside widespread general pollution, also presents a serious threat to the conservation of genetic material in the soil.

To sum up, we may say that through its physical, chemical and biological properties the soil was still fully able to perform its overall vital ecological functions as well as its technical/industrial functions without undue strain until a few decades ago. Since then, however, it has become alarmingly clear that these functions have been placed under intolerable strain by general and local economic and ecological mismanagement, with the result that the overall soil system has been placed in jeopardy. It is consequently of vital importance that political measures should be taken, on the basis of the knowledge we possess, in order to right that mismanagement and thereby protect and preserve the soil in its vital functions for the future of mankind. ■

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A living milieu, infinitely rich and complex

T.R.E. Thompson and J.M. Hodgson

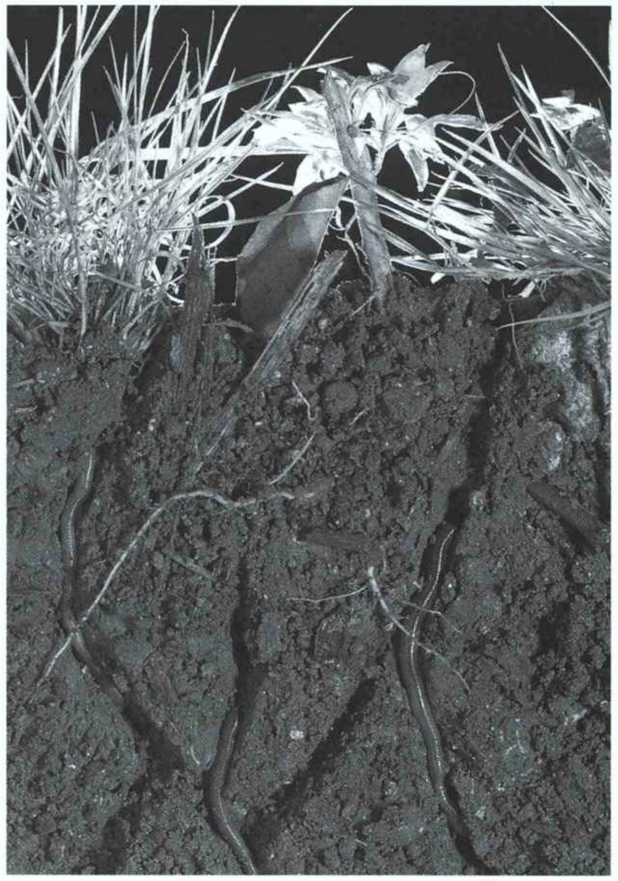


Photo Labat/JACANA

Lumbricus terrestris

Preceding articles have detailed the architecture of the soil, its physical and chemical components, and how these vary from one soil to another. The organo-mineral and mineral constituents of a soil are the most evident as they are readily seen and felt. To many users of land they *are* the soil. This is, however, too simple a view. No soil is complete without its living components—its fauna and flora. Without them it will not function. Using an architectural analogy, a building can be described and defined in terms bricks and mortar, its dimensions and its services, but, until people are living or working in it, it does not function. So it is with soil, for without its myriads of organisms, up to 20 million in a single cubic metre, its fertility would decline as its nutrients would be locked up in undecomposed plant and animal remains and its structure would deteriorate through lack of maintenance. Without the homogenising influence of soil animals, a peaty mat forms and deepens and soil horizons become more and more definite.

The soil community

The many species of organisms within the soil make their study a very large subject. They vary greatly in size and functions. Size is a convenient if artificial method of classifying them. Micro-organisms, those smaller than 0.2 mm, include animals, plants and bacteria. Soils also contain viruses but, being obligate parasites, these are unable to survive outside their host cells. Bacteria are by far the most numerous organisms in soil. There can be upto one thousand million in a single gram of soil, equivalent to a live weight of 890 kilograms in every hectare. Each species lives on a particular substrate varying from metallic oxides to organic material, and in doing so alters the chemistry of the soil. Nitrifying bacteria, for example, combine symbiotically with higher plants to convert nitrogen in the soil atmosphere to forms that are available to plant roots. Without soil bacteria none of the cyclic pathways for reusing major elements such as carbon, phosphorus and nitrogen would operate.

Both fungi and actinomycetes (organisms with properties of both fungi and bacteria) live on living and dead plants and animals. Their role in the breakdown of organic material is vital and many plant roots form close associations with fungi which assist in the uptake of nutrients. Such mycorrhizal associations can form within or around the tissues of the growing root and are easily seen as a white woolly sheath on the roots of many trees. Algae, because they mostly depend on sunlight, live in the surface layers of soil. Being able to photosynthesise organic compounds, they are often early colonisers of new ground where soil has yet to form. The micro-fauna also includes the protozoa, simple animals, many of which propel themselves by waving cilia or flagellae. They commonly prey on bacteria and other protozoa.

Photo Rothamsted Experimental Station)

The almost stoneless surface horizon of this well-drained soil overlying a stone line is composed almost entirely of worm casts. The layer has accumulated in the 23 years since this once arable field has been put down to grass.

Within the meso- and macro-fauna a wide range of animals are represented including nematodes, worms, mites, spiders, false scorpions, springtails, rotifers, beetles, flies, aphids, woodlice, bees, ants, centipedes, potworms, earthworms, slugs and snails. Living all or part of their lives in the soil, they affect its nature and composition. It is possible here only to outline their collective lifestyles and the roles they play in developing and maintaining the soil. The vertical distribution of the soil fauna varies between soils and also within the same soil with time and soil conditions. For example, seasonal variations in soil moisture and temperature encourage vertical migration of animals to avoid undue desiccation or waterlogging. Every species, however, has a preferred vertical distribution within the various layers of the soil. Detrital feeders from necessity live in surface organic layers. Species that hibernate or pupate within the soil demonstrate preferences for a particular depth related to temperature and moisture conditions.

The soil fauna can be separated into four groups according to feeding habits. **Microphytic** feeders live on bacteria and fungi and include species of protozoa, nematode worms and some species of gnats and ants. **Saprophytic** feeders live on dead and decaying organic matter. These include worms, mites, springtails and millipedes which perform the vital function of reprocessing litter and its incorporation into the soil. Nematodes and many insect larvae are **phytophagous feeders**, that is they feed on living plant tissues. The fourth group is the **carnivores**, which includes beetles, mites, spiders, centipedes and some nematodes. There are complex interactions between the various species mainly through competition for food and the predatory food chains within the soil. Depletion of one species may allow the rapid increase of other species on which it preys or with which it competes for food. Changes in the soil environment resulting either from natural processes or changes in land management can result in complex changes in the soil fauna and flora. Many of these interactions are not yet fully understood but the brief review that follows of the dynamics of earthworm populations will serve to indicate the complexity of the living soil.

Earthworms

Most European earthworms are members of the family *Lumbricidae*. More than two hundred species are known in Europe. All species live by burrowing within the soil and ingesting organic or organo-mineral material which they partly digest and pass as wormcasts either within the soil or on the surface depending on the species.

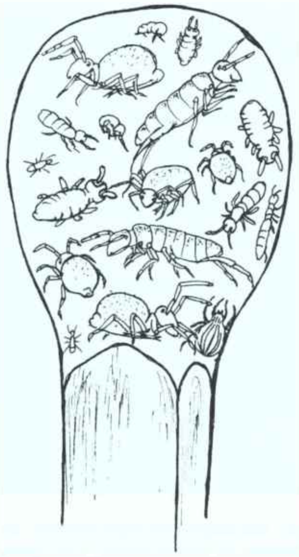
The value of earthworms in maintaining soil permeability and fertility was appreciated by early farmers and naturalists, but it was Darwin who first described their activities in detail in 1881 in his classic work on vegetable mould and earthworms. His calculations of the volume of soil deposited annually by surface casting worms on pasture, 18-40 tonnes per hectare, equivalent to a layer 5 mm in depth, brought home the extent of their activities. Total activity is far greater as surface casting is largely due to two species only. Casts are richer in total N and available P, K, Ca and Mg and less acid than surrounding soil. Earthworms can constitute 50-75 per cent of the total weight of animals in arable soils and, on this basis alone are a dominant influence on the life of such soils. The number of worms varies with the soil and its management. Over 7 million have been found in a single hectare of Welsh grassland soil. Arable land with a long history of organic manuring at Rothamsted Experimental Station in England carries some 2.5 million worms per hectare while similar land that has not received organic manure has less than half this number. An average forest soil has 2.5 million per hectare. Of the European species, *Lumbricus terrestris* forms the deepest burrows and can penetrate to two metres. Its influence on the permeability of subsoils is considerable, particularly on seasonally waterlogged soils with heavy, dense subsoil. Its vertical channels are preferred routes for water movement and, in the summer, are often lined with fine roots seeking moisture from deeper layers.

Several species of worms plug the tops of their burrows with the petioles of leaves from which they have eaten the blade. Species of *Allolobophora* forage on the surface for food which they then drag down into their burrows. Both activities are rapid pathways for the incorporation of organic matter into the soil system.

Earthworms thrive best in moist soil and the total weight of worms in well drained soil is proportionately higher in years with greater rainfall. In general they like well aerated conditions and avoid undrained soils. Some species, however, are able to tolerate the higher-than-normal concentrations of carbon dioxide found in poorly aerated soil. The number of earthworms is usually related to the availability of organic matter and the population falls as organic matter content declines as it does when a field is changed from grassland to continuing arable. Many species disappear from soils when pH of the surface horizons falls below 4.5.

Worms perform several roles in the maintenance and improvement of soil conditions. They fragment and partly digest dead and living organic matter, and introduce it to the reprocessing cycle of the soil. They continually mix organic surface material deep into the soil preventing the build up of an acid surface layer. Surface casting earthworms in particular increase the pH of topsoil by secreting calcium carbonate into their casts which are usually 0.5 units of pH higher than surrounding soil. Analyses of wormcasts and whole soil samples indicate higher values in the casts for all exchangeable and available major nutrients, pH and base saturation.

Worms aerate soil by increasing the network of coarse pores throughout the surface layers and, in the case of the deeper-burrowing species, the subsoil. Where surface-casting worms are present in uncultivated fields, the top layers of the soil have greatly enhanced porosity and waterholding capacity because the proportions of both coarse and fine pore space are increased. Worm casts are more water-stable than ordinary soil and they have a beneficial effect on structural stability. During recent decades, several trends have developed in the use and management of land; some are beneficial to earthworm populations, some not. Drainage of waterlogged soils, the development of minimum and zero tillage techniques, and the improvement of acid hill lands by lime and fertiliser increase the worm populations of the soil. On the other land the separation of arable and stock-farming in some regions has increased the proportion of farmland that receives no organic manure. The organic matter content of soils under continuous arable farming is small and earthworms are less frequent on such land. The extension of coniferous woodland, at least in Britain, has been largely on acid or very wet soils in which few worms are present anyway.



More than 100 acarids and collembola can be found on the head of a matchstick

Summary

The soil fauna and flora recycle organic matter to form humus and mix it with the mineral material. They also create and maintain the airways within the soil that are essential to plant roots. Some species control others that are pests to commercial crops.

Relatively little is known about the biology of soils and many of our soils under agriculture are currently being subjected to new and alien forms of management. Although we know many of the broad principles governing the effects, for example, of pesticides, heavy metals and new husbandry techniques on the soil fauna, insufficient is known of the overall impact of recent developments on the fauna and flora of our most important resource—the living soil.

Humus is complex material but it can be classified into 3 broad types, mull, moder and mor. Mull humus is usual in soils with large earthworm numbers. Plant remains falling on or dying within the soil are ingested by worms, partly digested and mixed with mineral soil. The plant remains undergo complex transformations that help actinomycetes, bacteria and fungi to decompose them further.

Worms and other macrofauna homogenise surface soil. Where they are absent, organic matter accumulates on the surface and a distinctive sequence of thin soil layers develops. There are the litter, fermentation and humification layers of mor humus. Decomposition is slow and dominated by fungal activity. The soil fauna is small and specialised. Moder humus is an intermediate form.

Mull humus is associated with fertile soils under old pastures and broadleaf woodland while mor is found on nutrient-poor land including heaths and upland moors. Mor also forms from the acid litter of conifers. ■

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A productive system

N. Fedoroff

Photo G. Lacoumette

The first signs of an agricultural economy appeared some 8,000 years in the Middle East, when man began harvesting grain from wild cereals and interfered with natural plant associations by making the first selections. This was merely the embryonic stage, but within a few millennia agricultural activities developed, with tilling of the soil playing a predominent part. From then until the coming of the industrial era, agricultural practices and techniques seem to have evolved very slowly, although technological innovations, such as irrigation, which has been in use for more than 5,000 years, have made for rapid progress in coping with natural constraints. 6,000 years of more or less continuous cultivation have, however, had considerable effects on soils in the regions most heavily used: erosion in every kind of climate, the transformation of sandy soils into dunes in regions exposed to the wind, and the sterilisation of extensive tracts through salinisation.

Agriculture: rationalisation and mechanisation

When the industrial revolution came in the 19th century, agriculture was rationalised and mechanised, but remained dependent on the soil and its properties. At the same time, its own effects on the soil increased considerably. In spite of his spectacular scientific and technical progress, man is still dependent for most of his food on plants, herbivorous animals and aquatic fauna, and is certain to remain so for a long time to come—whatever the futurologists may say.

The development of synthetic fibres has led to only a relative decline in the use of textile fibres of plant and animal origin, and, now that the first novelty has worn off, synthetic fibres are again tending to give way to natural fibres. Some experts predicted that the data-processing and audio-visual revolution would reduce the consumption of paper, but this has not happened—on the contrary, it is still increasing. Wood is still one of the mainstays of the building and furniture industries, regardless of all the alternatives available. With the coming of industry, fossil fuels and, most recently, nuclear fission replaced the burning of plant and animal products as energy sources, but the introduction of ethanol as a partial substitute for petrol in response to the oil crisis has now restored the importance of the plant kingdom in energy terms. Plants therefore play—and will clearly continue to play—a vital role in all our economies, whatever their level of development.

Cultivation in a natural or artificial environment?

Do the recent and promising experiments with the growing of plants in a totally artificial, or hydroponic environment, where the soil—consisting of inert pellets—is merely a synthetic and sterile substratum, mark the decline of soil as an active, vital medium? Plant production from hydroponic sources is still infinitesimal by comparison with output from natural soil, and the cost of the new method is still very high. Without denying the new technique's usefulness for certain types of "à la carte" production, it can safely be said that soil will remain an essential agricultural growing medium for hundreds of years to come.

In its natural state, soil rarely offers optimum conditions for plants to take root, and cultivation methods often compound the difficulties. Soil several metres deep, which is entirely permeable to roots, offers the best conditions, but many soils do not satisfy this criterion. In fact, soil-depth can be limited by solid or fragmented rock, or by denser, compacted subsoil, which roots cannot penetrate. Prolonged exposure of the soil to heavy rain can lead to the formation of a compacted crust, and this, in extreme cases, can stop young plants from coming up. In the arable layer, compacted clods, which roots cannot penetrate, are often formed when the soil is worked in a saturated condition, or as the result of internal clodding. Finally, the plough sole can make it hard, and sometimes impossible, for roots to get through to the subsoil.

The part played by water

Available and abundant water reserves can also make for optimum cultivation, provided that the soil can dry out again in a matter of days. Over-watering can in fact choke the roots and kill the plants. Useful water reserves depend on the useful depth of the soil, its texture and its mesoporosity. Reserves are greatest when useful depth exceeds one metre, soil texture is balanced and canalicular mesoporosity is as high as possible, thus permitting even distribution of the water throughout the soil mass. Water-loss is particularly high in regions affected by prolonged drought, and the presence of a sandy arable layer helps to limit water-loss through evaporation. Excess water or water-logging is normally the result of natural phenomena—either because the water-table is coming closer to the surface generally or locally (wet patches), or because the subsoil is not sufficiently permeable to let rainwater percolate. In this second case, a perched water table is temporarily formed. The water economy of the soil can be altered at will. In areas with a long dry season, the addition of a layer of sand or some other coarse material (mulch) increases the life of the soil's water reserves. Working the soil in the dry season encourages erosion of the surface sandy layer and thus diminishes the life of these reserves. Skilled use of the latest technologies (stabilising agents, controlled irrigation) is the only way of keeping these soils in a certain state of balance. Drainage, either via ditches or buried pipes, can be used to eliminate excess water.

Photo G. Lacoumette

Soil deterioration

Soil deterioration, resulting from excessive cultivation, is particularly marked in soils which are sensitive to compacting. The formation of a compacted crust first reduces infiltration and thus, in areas of limited rainfall, water reserves as well. It also encourages the washing away and erosion of surface soil. The plough sole also reduces infiltration, the result being the formation of a perched water table in the arable layer. Some of the particles suspended as a result of compacting or irrigation penetrate the subsoil and clog it in the long term; a perched water table then forms in the topsoil. More generally, man encourages water-logging by clearing land (which limits evapotranspiration), levelling tracts and firming the soil.

Soil provides plants with the main elements and the micro-elements which they need; the high-yield plants which are cultivated today obviously need fertilisers as well. Generally speaking, mineral fertilisation and chemical soil improvement, e.g. liming, are being effectively practised.

Ecosystem-soil relationships

Not enough is known about the relationships between the soil ecosystem and the soil as productive system, and this area is still comparatively controversial. It is now recognised that plants do not need organic substances to grow, and that some plants live in symbiosis with micro-organisms, e.g. the nitrogen-fixing bacteria. In fact, the functioning of the soil appears to depend to a large extent on the soil ecosystems. This controls the conversion of plant residues into humus, and the incorporation of humus in mineral substances, and thus plays a major part in formation of the clay/humus complex. All of the organisms which colonise the soil also serve to mix the soil and the upper subsoil, and thus contribute actively to aggregate formation and soil stabilisation. Finally, soil fauna (particularly earthworms) and roots are the cause of the mesoporosity which is essential to rapid percolation of water. If farming practices disrupt or destroy any link in the ecosystem chain, the effects on the functioning of the soil may be considerable. Thus the disappearance of earthworms results in local and incomplete incorporation of the humified residues in the mineral substance, and also in a marked decrease in aggregation. Destabilisation of the soil ingredients, an increase in sensitivity to compacting and erosion and progressive disappearance of canalicular mesoporosity, leading to a slowing down of percolation and ultimately water-logging, are the results. These changes are the final stage in a more or less irreparable disruption of the balance between the soil and its ecosystem. The vital role played by the soil ecosystem, about which nothing was known for a long time, has been constantly stressed in recent research. We can take it that this is no mere passing fashion, but a promising line of research, capable of restoring biological soil to the important place which is its due. ■

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Photo A. Bouchet/PLURIEL

Man and the soil

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People of the world moved from the hunting and gathering way of life towards a form of agriculture or animal husbandry at different historical times, some as early as 5,000 years ago (China, Middle East), some only nowadays (Amazon tribal communities). Such a transformation in the way of living implied the need to know which particular tract of land in the area of settlement was best suited to produce crops, fodder or fibres, and which was the best way to maintain or improve its productive capacity. So-called "primitive" farmers may have had only simple fertilisers, implements or transport at their disposal. At the risk of starvation, however, they learned very quickly how to handle and protect the soil.

Increase in plant production above the immediate needs of a farmer's family resulted in the emergence of towns. Often a conflict developed between the growing demands of towndwellers and the balanced use of the soil by the countryside farming communities.

A notion often prevailed that soil is a simple renewable natural resource, instead of one that would be finite unless continuously and carefully managed and nurtured.

Towndwellers wanted (and still want) cheap food and clothing. Low food prices forced farmers to strive for maximum production in the short term, leading to neglect of long-term husbandry needs of the soil and water resources. Exhausting these resources was often the result: decrease of inherent chemical soil fertility and organic matter, salinisation, or erosion by wind or water.

Such a sequence of events is not only a thing of the past. In many countries of the tropics and subtropics it is happening right now, and at an alarming scale. In Europe, farmland neglect was prevalent in the early industrial period, until during the pre-war depression years a movement of "return to the land" as the backbone of a nation's economy emerged. In Northern America, such a neglect led to the infamous dustbowls and land gullying of the 1920s and 1930s. These events gave origin or impetus to state soil conservation institutions and a first awareness that some of kind of national soil policy was needed.

Since the 1940s there has been an unprecedented rate of population increase in many parts of the world. From 3 billion in 1930 the population has now reached the 5 billion mark, and an absolute peak of 10 billion is foreseen for around the year 2050. Prospects of mass starvation have led to a massive drive to increase plant production worldwide. This has resulted in the "green revolution" in the tropics and large crop surpluses in the industrialised countries of Western Europe, North America and Japan. In the latter countries the production was extra stimulated through price supports, because the relatively small rural communities often hold the balance of democratic power. The excess produce is being dumped in developing countries, forcing the small farmer there to produce short-term maxima to compensate for the low prices. Mining of the soil is the result.

Strong soil degradation

We are now faced, precisely because of the drive for maximising food production, with a situation of strong soil degradation in many parts of the world. Chemical fertilising in the temperate regions is no longer accompanied by adequate attention to maintenance of soil organic matter. Large-scale mechanisation has resulted in soil structure decline. Ever more intensive crop protection against insect pests, and chemical weed control, has thinned the microbiological life in the soil. Industrial fallout ("acid rain") and the local dumping of bio-industrial waste has resulted in acidification of soil and water resources: dying of the few remaining forests and stillness of freshwater lakes. Man's use of mountainous areas for winter sports is destroying the local ecosystem and posing a severe threat of erosion, and excessive sedimentation and flooding elsewhere.

Short-term maximising of production from marginal soils in the tropics has depleted chemical fertility and has greatly increased wind and water erosion.

Intergovernmental focus

Of course these trends have not gone unnoticed. As early as 1972 a special UN conference was held in Stockholm that called attention to the problems of the world's environment. The establishment of a special United Nations Environment Programme (UNEP) was the result.

UNEP also took part in the establishment of a World Conservation Strategy document (1980) by the International Union for the Conservation of Nature (IUCN), an influential non-governmental organisation of conservationists. However, this document gave rather more attention to flora and fauna than to soil. In the meantime, UNESCO's Man and the Biosphere (MAB) programme, started in 1970, was building up a research network at a number of sites that were presumably representative of main ecosystems, from cold deserts and hot tropical rainforests. There again, the soil was given scant attention. Only in the 1980s did UNESCO obtain the co-operation of the International Soil Reference and Information Centre (ISRIC, Wageningen) to carry out soil characterisation work in some of the MAB reserves and research sites and to elaborate guidelines for soil survey and land evaluation in ecological research.

Being charged with the development of Environmental Management Guidelines, UNEP convened three expert meetings on the soil element. It resulted in the adoption by its Governing Council of a World Soil Policy document (1982: "aimed at conserving this most important of natural resources and using it on a sustained basis") and its elaboration into Environmental Guidelines for the Formulation of National Soil Policies (1983).

FAO adopted a World Soil Charter in 1981 "as a basis for international co-operation towards the most rational use of the world's soil resources".

Did this intergovernmental focus on soil change anything for the better? Hardly so! There were the different outlooks of the three UN agencies concerned: FAO's orientation on food versus UNESCO's scientific interest, versus UNEP's conservation interests. In the situation that the funds for each of the three agencies have shrunk considerably, the soil programmes have tended to be the first to be axed, not the least because it is such an ungainly subject with any remedial actions likely to be unspectacularly slow.

The scientific basis for soil-related development is moreover frequently found to be too technically oriented, overriding local farmers' experience as being out-of-date. Many large development schemes have failed because of inadequate attention to local soil conditions and management practices in the tropics and subtropics.

Precisely because the subject soil is so down-to-earth and location-specific, any formal action by UN agencies, or national government agencies or scientific groups is bound to be rather ineffective. One needs intensive contacts between scientists/project staff and local farming communities, as well as grass-root level non-governmental organisation to rally the land users to the cause of soil conservation. Every farmer loves his land and would dearly like to conserve it and keep it productive for his children and grandchildren. But how can he (or she!), if national government policies and international competition in food and trade force him to maximise his short-term production instead of optimise it in view of the sustainable capacity of his land?

This view of optimising rather than maximising production, and conserving fragile lands, is only nowadays emerging as a policy guidance in international circles. Autonomous institutions such as the World Resources Institute in Washington and the International Institute for Applied Systems Analysis (IIASA) in Vienna are producing substantive documents on the matter such as "World Resources 1987".

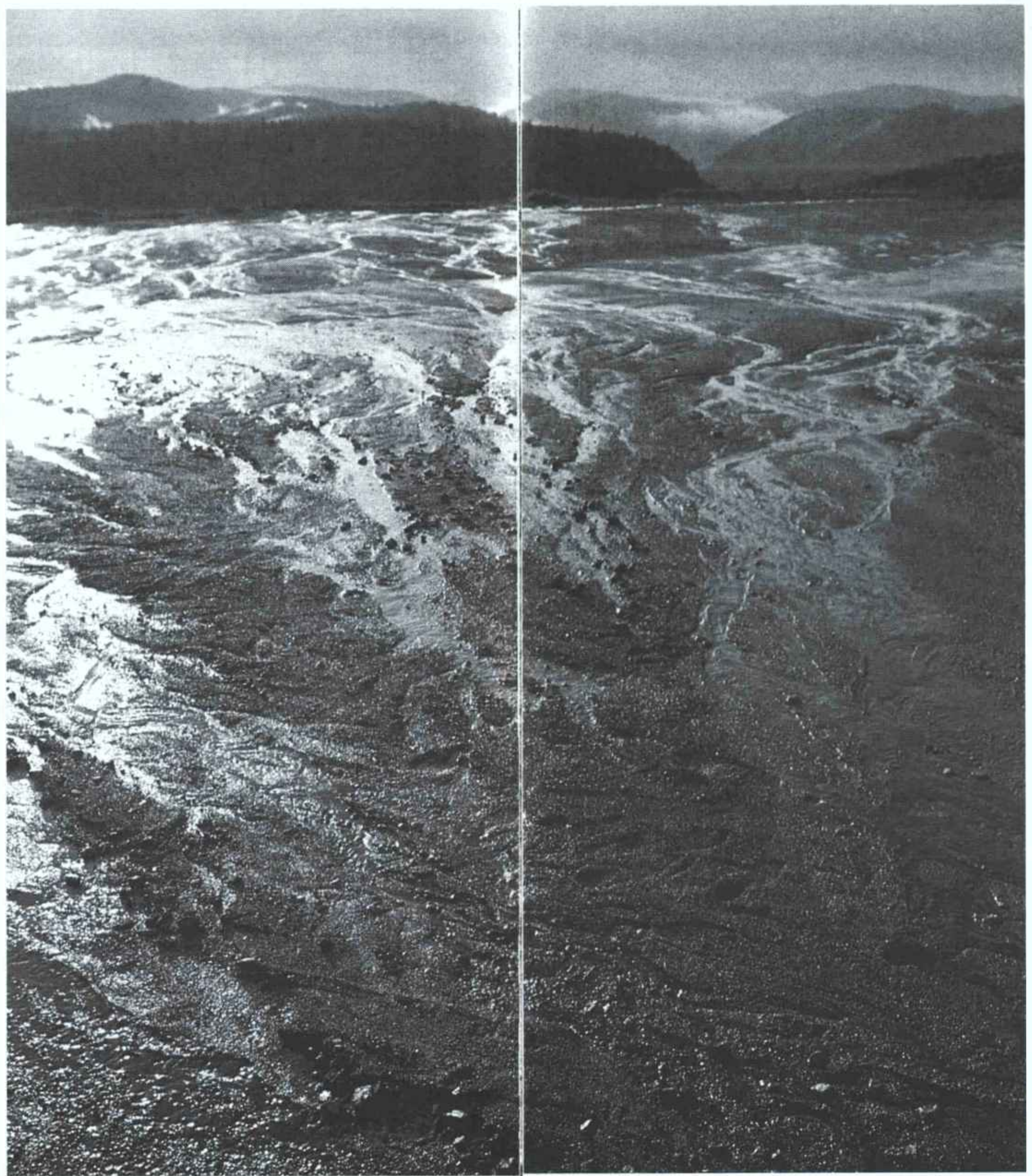

Photo G. Lacoumette

In 1972 the Council of Europe launched the European Soil Charter for "the soil is a limited resource which is easily destroyed" and "governments and those in authority must purposefully plan and administer soil resources".

The UN World Commission on Environment and Development, in its Brundtland Report (1987), stresses that environmental conservation and development are not antagonistic goals, but are intimately interwoven in a positive way. The report emphasises that the problems can only be tackled by concerted international and national action. Economics should not be the prime and absolute goal, but should be embedded in equal-weight attention to environment by all agencies and ministries. Care of the environment should not longer be the ineffective luxury of separate entities that receive lip service only.

The World Bank, that major supplier of funds for development, has finally deemed it fitting to create a special division on environment and development and now requires "environmental impact assessments" before any project is implemented.

The Brundtland Report also calls for the strengthening of UNEP, more particularly the Global Environmental Monitoring System (GEMS) with its facility Global Resource Information Database (GRID) in Nairobi/Geneva.

Need for reliable data

Indeed, the need for reliable quantitative data bases of natural resources at both global and national levels becomes more and more evident, not only to assess the present status of these resources in spatial/geographical contexts—for instance soil degradation status—but also to project and monitor their changes in the future, this in relation to the expected population growth till the year 2050, and also with respect to possible climatic change as a result of the strongly increasing demands of soils and other natural resources. The building-up of a reliable soil data base as a key element in an interactive graphical computer system on resources, as envisaged by GRID, is a priority of the international community of soil scientists and of ISRIC in particular.

Assessments should be derived from such data bases on what is going to happen with Planet Earth and its soil resources. This will hopefully convince very gradually the politicians that the global economy will need thorough adaptations and adjustments as regards the location of production and food, fibres, etc. One should use the temporary absence of food shortage at world level, and the situation of excess production in areas such as Western Europe, to change from maximising to optimising right now, conserving and improving the soil—allowing maximum production only from the moment when it will be really be needed, that is, in the year 2050.

Is there really a possibility for change, assuring a wise use of the world's land resources and a decent way of living for everyone, including the rural groups? Maybe. There are some encouraging developments:
— the success of soil conservation and agroforestry practices in parts of eastern Africa, in the Himalaya fringe, and in the Chinese loess plateau area;
— the spectacular increase in the productivity of the chemically extremely poor soils of central Brazil, easing the stress on the Amazon region with its fragile forest ecosystem;
— the success of village-level reforestation and water conservation in many parts of India and the increase of sustained production levels on the alluvial lands of northern India, Pakistan and Bangladesh;
— the encouraging growth of all kinds of national non-government organisations in the developing countries, promoting awareness on the wise use of land and its socio-economic implications;
— the growing influence of international non-government organisations, stimulating an awareness that no individual country has an absolute and single responsibility for its own land and people, but shares responsibility for Planet Earth as a whole;
— the emergence of "green" political parties in Western Europe that fight against the pollution of soil and water, criticise excessive production, and that are willing to forego some of our everyday luxuries. Directly or indirectly they may influence government decisions on farm subsidies and on development co-operation.

If such developments can be strengthened then we may, just may, be able to cope with the worldwide problem at hand. If not, then Planet Earth will make sure that it gets rid of a good part of the human life that is irritating its living skin by pilfering its natural resources.

A final statement, as the underlying philosophy of an effective world soil policy: "We do not own our land and soil resources for us to use or misuse at will, but only have it in custody to conserve and develop for future generations... our own children and grandchildren." ■

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Life in the soil

Erosion phenomena

Carlos Roquero

It is a generally accepted fact that, especially in arid and semi-arid countries, soil erosion is a process of soil deterioration of undoubted seriousness which is foremost among the forms of damage to the natural environment.

Yet most non-specialists with an interest in this subject do not have a sufficient knowledge of the specific characteristics of the general process of soil erosion, and one needs a very thorough knowledge of them to be able to judge the effects of erosion processes in relation to all the other processes affecting the natural environment.

The taking of decisions to remedy the undesirable changes caused by man in the world around him requires the fullest possible knowledge of the causal relationships and their characteristics so that, faced with the multitude of measures needed and the available technical and financial resources, which are necessarily limited, one can adopt the most appropriate courses of action.

Three groups of characteristics, those relating to fragility, progressiveness and irreversibility, make the effects of soil erosion processes particularly important and dangerous.

The fragility of the natural balance

The soil in its original state, the virgin soil, is a highly complex system based on a very fragile dynamic balance. It is composed of different layers or strata formed from the original rock towards the bottom, the remains of vegetation towards the top. There are five main factors in soil formation: climate, living beings, rock, relief and time. To study them it is necessary to break them down into other, more detailed factors and causes so that the complexity of the processes involved can be more easily understood.

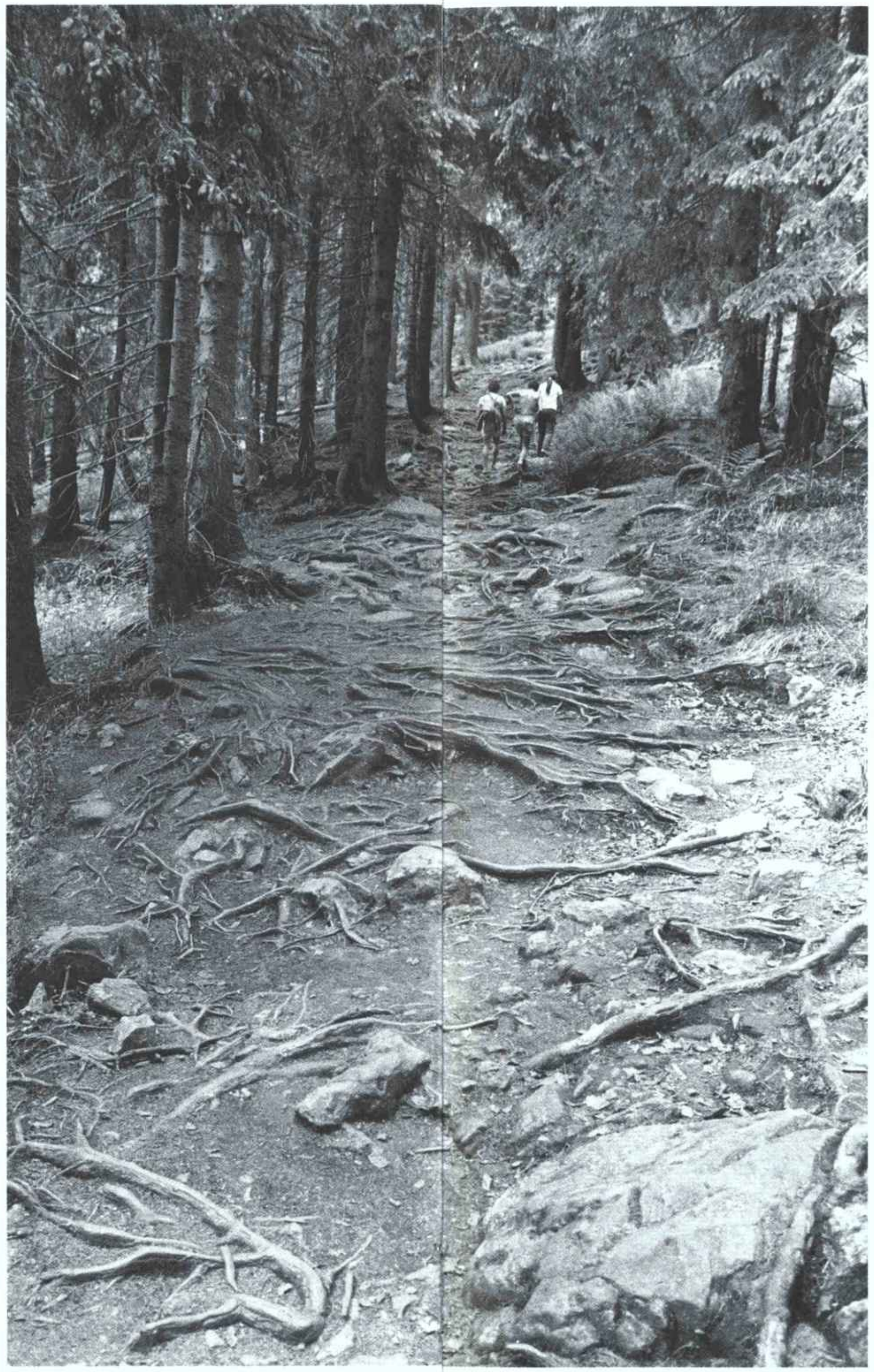

Photo G. Lacoumette

A specific soil type considered at a particular point in time is the result of a short-lived balance between various factors which can be regarded as the lithosphere's momentary response to the joint action of the atmosphere and biosphere over a certain period of time in a framework determined by an environment in turn determined by geomorphology.

Man exerts an influence on this fragile natural balance when he wishes to use the soil as a natural resource in order to attend to the satisfaction of his needs. These needs are so inescapable that absolute respect for natural conditions is inconceivable.

With rare exceptions, use of the soil for agricultural purposes requires the elimination of the original plant cover, so that the above-mentioned natural balance is severely disrupted: the same rainfall can be highly beneficial to soil formation where there is plant cover, because its kinetic energy is checked by the foliage, but prove very harmful if the raindrops strike the bare soil or soil that is protected only by cultivated plants.

The well-known "universal equation" of soil loss developed by W.H. Wischmeier and D.D. Smith makes it possible to quantify to a certain degree of accuracy how the natural balance is affected when the original conditions change.

In view of the small size of the particles which make up the soil and are exposed at its surface and the large inputs of energy which heavy rain presupposes, the serious danger facing the soil in the conditions in which most crops are grown is obvious.

The progressiveness of erosion processes

A characteristic which helps to increase the seriousness of the damage which erosion can cause to the soil is the progressiveness of these processes.

Once a certain soil type has already suffered the effects of erosion, it will have lost a greater or lesser amount of its components, initially from its surface layer, which is usually the most valuable in terms of the possible development of plants. In this way, after a certain time, which may be a few or many years depending on the various conditions involved (heaviness of rainfall, the soil's specific erodibility, the topography of the area, the types of crop grown, etc.), the soil's final state will be less valuable than its initial state, and as a result the vegetation, including cultivated plants, will achieve less growth, and the surface will be less protected.

This fact is of the greatest significance because, within this general process, an effect, the initial depletion of the soil, has in turn become a cause of further soil depletion. This is what is known in logic as "begging the question", because the facts are so closely interwoven that causes and effects cannot be clearly differentiated, and it is also what is known colloquially as "a vicious circle" because no one can say where the process begins or ends.

This cycle, which is so characteristic of erosion, makes its final consequences even more serious. It does not occur in other forms of damage to the natural environment, such as the pollution of river water or of the lower levels of the atmosphere, which, however marked they may be, do not exhibit this self-increasing effect.

Furthermore, this progressiveness increases the danger in cases where erosion phenomena only produce limited damage over a certain period of time (a year, a decade and even a generation) because the farmer does not appreciate its extent and fails to realise that, in course of time, the land his grandchildren will inherit will be less productive than that which he inherited from his grandparents. In the Mediterranean regions, for example, the current productivity is far inferior to what it was at the time of Roman colonisation: one can see how large towns of the time, now colossal ruins, could have existed in such areas, which are now barren, or almost.

The irreversibility of the results of erosion

The third specific characteristic of erosion processes which we have to consider is the irreversibility of their effects.

In other cases of undesirable alteration of the natural environment, the reversibility is obvious and this helps to make it relatively easy to restore the original conditions: the pollution of the lower levels of the atmosphere which occurs in so many large urban centres in periods of calm weather disappears, or at least its immediate effects do, as soon as a sufficiently strong wind blows, and river pollution is eliminated as soon as the discharge of pollutants into the river ceases.

On the other hand, the loss of a plant or animal species is obviously irreversible, and some other processes, such as the pollution of the upper atmosphere or the pollution or eutrophication of confined continental waters, come very close to this absolute irreversibility.

In the case of erosion, the damage we cause is irreversible because the processes of soil formation are so slow that, in many cases, periods of thousands or tens of thousands of years are required, if not hundreds of thousands of years. For this reason, in terms of the possibility of technological recovery within the periods considered in environmental studies, the damage caused by erosion is irreversible.

This irreversibility makes it necessary to pay special attention to these problems because, once the damage has occurred, there is no remedy in practice, and the process of decline, whose speed will be increased by the progressive factor, will affect the soil's future productive capacity.

It is for these reasons that erosion of the soil and its consequent deterioration lead to the impoverishment of agriculture and the population, contributing in the most acute cases to desertification and ultimate desertisation. ■

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Photo Ch. Decout/PLURIEL

Photo A. Kohl/PLURIEL

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Pollution

Our vital milieu is severely threatened by a number of pollutants, some of which occur in increasing amounts through various human activities, i.e. energy production (power plants, etc.), traffic, industrial production and agriculture.

Pollution coming from the air

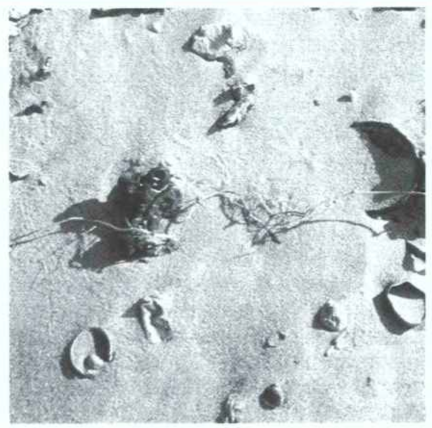
The production of energy is a basic feature of modern industrialisation. Energy is produced in a great number of ways, of which nuclear and fossil-fueled plants are by far the most important. Nuclear power plants emit only negligible amounts of noxious substances into the environment during their normal continuous functioning and the environmental concern considering nuclear power plants arises mainly from the possibility of accidents; the problem of waste is a matter of its own. The Chernobyl lesson tells, however, that one single accident may have large economic and cultural implications; among others, it may be characterised by a doubling of the background level of radiation of some isotopes in the environment. A number of radioisotopes do occur in elevated amounts in the soil, partly due to atmospheric nuclear explosions (in the 1950s), partly to accidents and/or leakages at nuclear power plants. The main isotopes thus accumulated are strontium 90 and cesium 137.

The pollution originating from conventional power plants comes essentially from sulphur dioxide, oxides of nitrogen and heavy metals. Sulphur dioxide and oxides of nitrogen are the main contributors, together with ammonia and ammonium compounds, in the acidification process of the environment.

The different types of soil most vulnerable to this environmental change are the soils intermediate between brown soils (normally developed for instance in nutrient-rich European forests) and podsols. The adverse effects are of direct and indirect nature. The direct effects are exemplified by the higher level of protons which, however, do not have any significant toxicity in themselves. The indirect effects are due to the increasing mobility of a number of toxic substances in the soil because of the decrease in pH (increased acidity). First of all, this may cause the death of root systems and the impairment of mykorrhiza functioning due to higher levels of aluminium and a number of heavy metals, such as cadmium; on another side, increased mobility causes a higher leakage of nutrients out of the soil system, thus provoking nutrient deficiencies. Changes in crop quality and groundwater composition due to acidification are yet to be carefully analysed but the overall change in the European environment may result in severely altered conditions for agricultural production and drinking water supply for the European community.

Eutrophication

The nitrogen compounds of the atmosphere—with the exception of molecular nitrogen itself—are some of the main agents of the eutrophication of the natural environment. The implications of having more nitrogen compounds in the agricultural land are not directly problematic but contribute to increasing nitrate percolating through the soil to the groundwater. There are, however, several indications that a number of natural ecosystems suffer strongly from this general eutrophication. Coniferous forests, ombrotrophic mires and oligotrophic lakes can be cited as examples. These natural systems may be used as early warning signals for highly economically significant changes in the ecological conditions of the environment.



Deposit of heavy metals

The atmospheric deposition of heavy metals is one of the major challenges of modern industrial society. Increasing fallout of cadmium, for example, may cause prohibitive changes as far as cultivation of crops is concerned. The possible future remedy may be the removal of a 20 cm layer of soil from most of Europe and Northern America in order to prevent unacceptable uptake of heavy metals in the human population.

Agricultural pollution

Agricultural practices comprise the use of fertilisers, pesticides and other phytosanitary products. An uncontrolled use of these products may cause a build-up of residues in the soil and consequently affect man and other living beings by the accumulations of potentially toxic organic substances.

There is a strong need, and indeed initiatives have already been taken within the EEC, to set guidelines for the acceptable variation in soil quality based on knowledge of the status of our European soils and a thorough understanding of the cause-effect relations between soil properties and ecosystem functioning. This effort should preferably be co-ordinated with a similar effort to develop ecological guidelines setting limits to the degree of disturbance sensitive natural ecosystems may tolerate. ■

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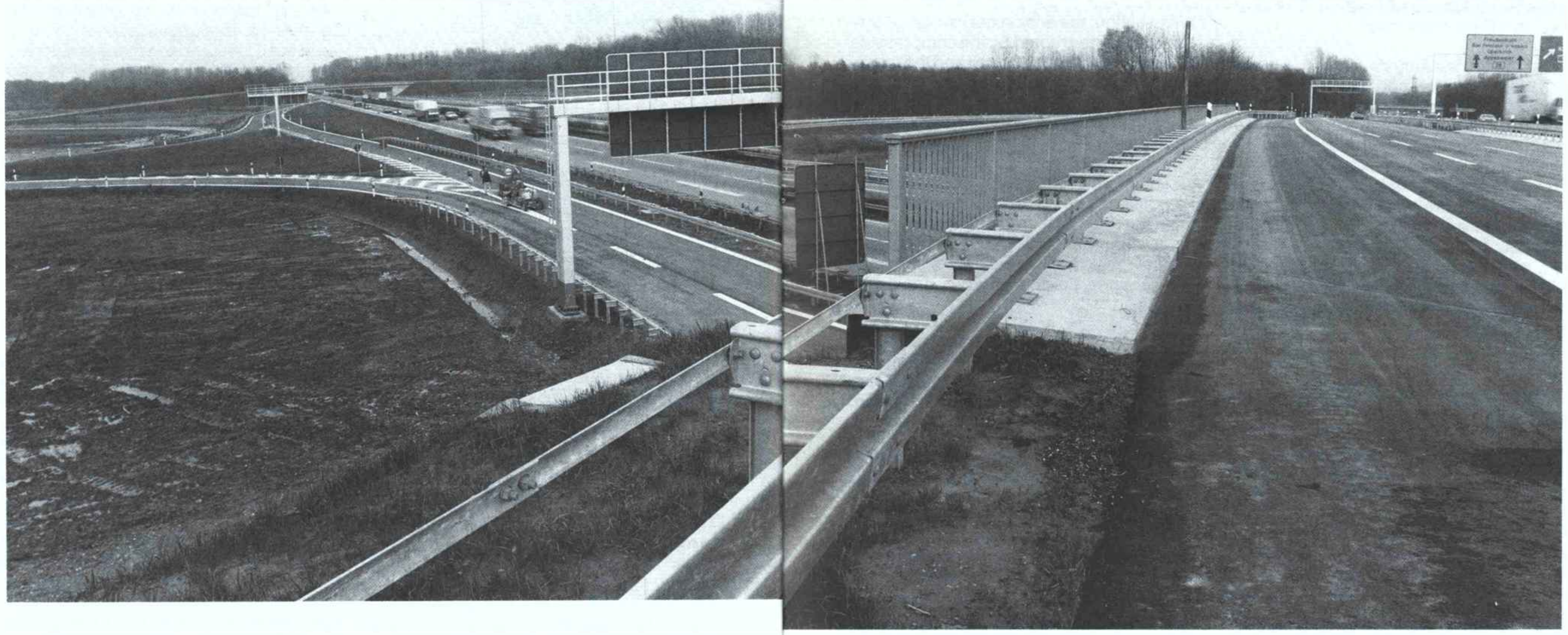
Photo G. Lacoummette



Regional planning and land use

Siegfried Losch

Owing to intensive settlement and economic activity, the Federal Republic of Germany is today one of the European countries which makes very great demands on its environment and resources. The demands on the environment are nation-wide. The Federal Republic has an area of 24.8 million hectares in which some 61 million people live in varying degrees of density: at present 56% of them (33.9 million) and 59% of the working population (12.1 million) live and engage in economic activities in only 27% of the area.

In such a densely populated country as the Federal Republic of Germany great demands are made on the soil and the strain on the environment is particularly noticeable. Among the potential dangers to the soil are:

— the intake and concentration of harmful substances, especially of acids and acid-forming substances, heavy metals and persistent organic compounds;

— the modification of the properties of the soil, of its nutritive elements, its water regime and of its life, as well as changes brought about by soil erosion, by the erection of buildings and the sealing of areas of ground and by the cutting up and isolation of existing landscapes when land is taken over for housing, industry, commerce, communications and other infrastructures.

Here we shall concern ourselves solely with the occupation of land by settlements. This usually exacerbates the conflicts involving the soil and its natural functions, since increased land settlement usually means "diverting land from the functions pertaining to its original undisturbed state and converting it to another state that is further from nature". This can harm the soil in many ways or even destroy it which, however, does not prevent open spaces, where the soil is respected, from being preserved in built-up areas. Here settlement areas are to be understood as forms of land utilisation characterised primarily by settlement functions (buildings and open spaces, business and shopping areas, communication facilities) or by directly related ones (recreation areas with their neighbourhood parks and gardens).

Development of settlement areas

In the Federal Republic settlements have been growing in area for years and this in spite of the fall in resident and working populations. The result is a constant spreading of settled areas out into the countryside.

Since 1950, the settled areas have grown from 1.9 million hectares to 3.1 million hectares at the present day. More land has been taken over for settlement in recent years than in the previous years. Between 1950 and 1960 the growth rate was 66 hectares per day. It rose in the 1970s to about 113 hectares and then again in the 1980s to some 120 hectares per day. Those daily 120 hectares were taken over chiefly for the purposes of communications, housing, industry and commerce.

Communications space

The space in the Federal Republic actually occupied by streets, squares, railways and airports in 1985 was about 1.2 million hectares. Representing 4.9% (in 1981 4.7%), communications facilities occupied more of the total area of the Federal Republic than all housing. Increased motorisation, growing communications services and improved road standards directed towards "an easy and regular flow" of traffic led between 1981 and 1985 to an increase in the space devoted to communications of 41,500 hectares. The building of many new roads contributed significantly to this. The non-local road network alone grew by about 600 km between 1981 and 1985, to which must be added an extra 7,000 km of new local roads.

The tendency towards wider and wider roads observable for many years also added to the area occupied by communications facilities.

The existing long-distance and local road network grew in the years from 1976 to 1985, while the Federal communication routes programme was in force, by about 23,900 km. In future more land can be taken over for new road building and improvements to the existing network only in accordance with the investments programme of the new Federal plan for 1986 to 1995. Some 64 billion DM are to be paid out for national and municipal roads. The figure is much higher if the sums to be spent on roads by local authorities and the Länder are taken into consideration.

More traffic and a better road network increase pressure

To the space taken over directly for communications purposes must be added the land indirectly affected. In the case of roads, for example, depending on traffic density, wind direction, vegetation, road profile, etc. and also on the type of road, the area indirectly affected can be as much as 18 times that occupied by the road itself.

The important harmful substances here are carbon dioxide, nitrogen oxide, hydrocarbons, heavy metals, as well as oil residues, rust, dust, grit, refuse and de-icing salt, but there are also the effects of vibrations, noise and air currents. These harmful effects can extend from the roads themselves into the adjoining areas to a distance of up to 100 metres and more. Despite the improvement in exhaust emissions by private vehicles, the increasing volume of traffic does not allow any significant reduction in the total volume of harmful substances produced.

In addition to the paved and hence sealed road surfaces themselves, there are also other areas such as embankments, shoulders, etc.; these cause irradiations and temperature variations which produce an effect on the existing climate at a distance of up to 40 metres—and, depending on the exposure, of even up to 100 metres. In such cases debilitated zones with an unfavourable soil economy and food cycle may be formed.

Besides this, when new roads are being built, the natural undisturbed soil within a range of up to 10 metres and more from the actual roadway can be drastically changed by the removal, restructuring or import of building materials. Then there are embankments and cuttings which affect the local wind system (cold air outflow). A dense network of communication routes can also lead to the formation of "islands", whereby existing biotopes are divided up into partial populations with no exchange of individuals between them. These isolating influences, which can even be exerted by local roads and field footpaths, reduce the variety of species and hasten the extinction of any threatened ones.

Residential and commercial areas

Residential building, according to the statistics, occupies about 3.4% of the whole Federal territory. This area grew between 1981 and 1984 by about 50,000 hectares. The considerable increase was caused by the still notable, albeit for many years declining, activity in this building sector in the Federal Republic. For this extensive activity new building land had for the most part to be made available. At present a slight regression is to be observed in building and hence also in the demand for land.

Industrial and commercial areas can only be assessed for the Federal Republic, since in some of the Länder the figures are included in those for residential building areas. In 1985, they represented about 3.8% of the total area. With all their dependencies, they must have grown in the period of comparison almost in the same proportion as the residential areas. Where industrial and commercial buildings are concerned, the preference still goes, as it always has, to space-consuming single-storey structures.

Persistent demand for building land

Higher residential land consumption by households and in particular the rise in the number of small households—which require more land per head than larger households—and more home ownership mean that a further demand for residential land can be expected, at least up until 1995. The result will be considerable building activity until that date, for which building land will have to be made ready. Only a small proportion of this land will be able to be provided by recycling or using space between buildings, so that more of the countryside will be taken over.

Although the working population is declining, more industrial and commercial zones have to be made available. Here the adoption, in particular, of one-storey warehouses, but also the expansion of businesses, will call for extra building land. The reutilisation of existing unused commercial and industrial installations and infrastructures, which in the Federal Republic can be very considerable, would only partially relieve the pressure on new land, since former industrial and commercial sites often have first to be redeveloped at great cost.

Growing area of built-on and sealed surfaces

For the qualitative effects of building operations on soil structure, water economy, micro-climates and vegetation, the degree of sealing is of particular importance. For housing, the proportion of the land surface that is sealed is about 20% and for industrial and commercial buildings it is slightly greater. But the proportion of sealed surfaces is easily increased. If the space taken up by entrances, parking places, garages and other dependencies is counted, the actual proportion of sealed surfaces is far higher.

With sealing, the ecological exchange processes are interrupted by the compression of the upper layers of the soil and the micro-climate changes. Precipitated water is quickly carried away by drains instead of seeping through and thereby renewing the groundwater. On sealed surfaces no plants can grow so that pollutants are not screened off or filtered by vegetation. By foundations and groundwork, as well as by main services and drains, but also by soil restructuring and the transport of topsoil, natural soil monoliths, and sometimes groundwater flows also, are drastically altered.

Besides the effects on the natural economy, which are difficult to evaluate in their totality, the development of settled areas also brings economic disadvantages in its train.

Photo A. Bouchet/PLURIEL

Criticism of increasing exploitation of the countryside and beginnings of action

Increased interference with ecology by settlements, especially with the expansion of settled areas, has stimulated criticism of the growing exploitation of the landscape. There is a demand for scientifically unambiguous ecologically orientated threshold levels. The difficulty in defining such threshold levels lies above all in "establishing a clear and qualitatively measurable causal relationship between the use of open space and strain on the environment". Since no such recourse to clear, scientifically backed threshold values is possible at present, policy-makers and planners are obliged for preventive purposes to determine such values politically and thereby dictate how much nature society is to have. A first attempt of this kind in the Federal Republic to lay down such threshold values for settlements in the Development Plan for the Land of North-Rhine-Westphalia was unsuccessful because of considerable political resistance on the part of local authorities.

In 1985 the Federal Government included two essential projects in its soil protection plans: qualitative and quantitative reduction of intakes of problem substances and reversal of the trend in land use.

In the future it would like, when weighing up its policies, to set clear priorities in favour of soil protection. In its soil protection plan it lists some 170 measures whereby it would like to achieve prevention-orientated soil protection—an effort which, despite goodwill, will not always be successful because of the numerous interests opposing it. ■

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Examples of measures taken:

In the Netherlands

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Agriculture and industry

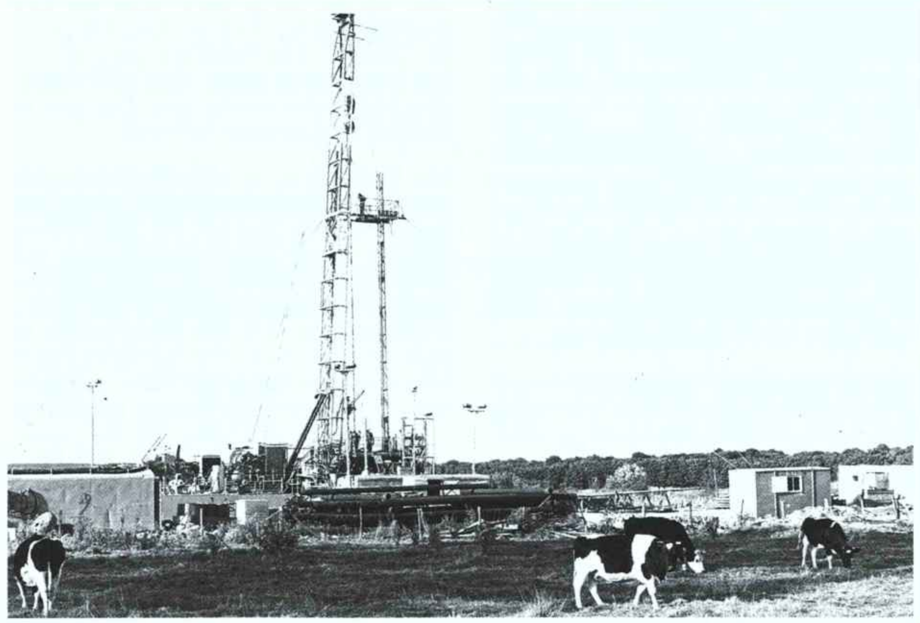

Photo R. Morin

The confrontation with a large number of contaminated sites, mostly former waste dumps and industrial premises, has led to a large operation (based upon the Soil Clean-up (Interim) Act of 1983) to clean up those polluted sites, with a yearly budget of about Dfl. 200 million, at an estimated total cost until the year 2000 of Dfl. 3 billion. However, preventive action in soil protection is considered even more important.

The Dutch Government has chosen two ways to protect soil. Firstly, the development of an integrated overall environmental policy (including soil protection) as described in the yearly Environmental Programmes. Secondly, the development of instruments for integral soil protection measures. Soil policy is developed in co-operation with provincial and municipal authorities and the target groups for source-oriented regulation.

The Dutch soil policy

In January 1987 the Soil Protection Act came into force, giving a framework to set quality standards for the soil and to regulate potentially harmful activities. Characteristic for the Dutch environmental policy is the "guest in one's own house" philosophy: man has the right to organise his environment according to his views and enjoy it, but he has also the duty to carry it over in good condition to future generations. Environmental policy follows two tracks: an effect-oriented and a source-oriented track. The effect-oriented policy defines the quality objectives with respect to the quality of the environment. These objectives set a framework for cleaning up existing contamination and for source-oriented policy. They indicate in which way the behaviour of target groups (e.g. industry and agriculture) has to be adjusted. The objective of the effect-oriented policy is to maintain an environmental quality such that the health and well-being of people and the long-term preservation of animals, plants and modes of use are ensured, in soil policy translated into the so-called multifunctionality concept: preserving the properties of the soil which are of importance for "keeping all options open" for future generations.

Most important in this concept are activities that cause irreversible effects to the soil and might endanger any use of the soil by human beings, plants and animals. Examples are pollution with heavy metals and nitrates in groundwater. Defining good soil quality in quantitative terms is important as a reference for source-oriented policy and clean-up operations. In September 1987 a list of provisional reference values was published, formulated after a large-scale technical discussion. Source-oriented policy varies for local or point sources and diffuse or non-point sources. Local sources have to meet the so-called ICM-criteria (isolation, control, monitoring). A detailed specification of these criteria is now in preparation for storage and dumping sites, discharge of liquid and solid wastes, underground storage tanks and the use of waste and other materials for construction purposes.

For diffuse sources an objective for the application of substances and the preservation of a good soil quality is to reach an acceptable equilibrium between input and output of substances.

An example of the diffuse sources approach is the regulation on manuring of agricultural land to prevent leaching of nitrate and phosphate to groundwater and other water reservoirs and evaporation of ammonia. In a step-by-step programme from May 1987 onwards to the year 2000 an equilibrium between input and output of minerals must be reached.

The Soil Protection Act distinguishes a general and a specific protection level, differing mainly in the acceptable risk-level for soil pollution.

The national government defines the general protection level by regulation of potentially harmful activities and by soil quality standards.

A specific protection level must be effectuated in special areas, defined by the provinces. This involves soil protection areas, valuable areas where the properties of the soil are not or only to a slight extent adversely affected by human activities, and areas that require specific protection for the drinking water supply, the groundwater protection areas.

Research and monitoring

Soil protection research has become a priority in science policy. In addition to existing research programmes in May 1986 a co-ordinated soil research programme was introduced by the Ministers of Environment, Science, Agriculture and Water Management. It covers a total extra budget of Dfl. 56 million for a 4-year period. Major topics are soil ecology, effects of substances and technology development. For monitoring purposes a national groundwater quality network has been completed. In addition a monitoring program for soil quality is in preparation. ■

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The Swiss national programme

Rudolf Häberli

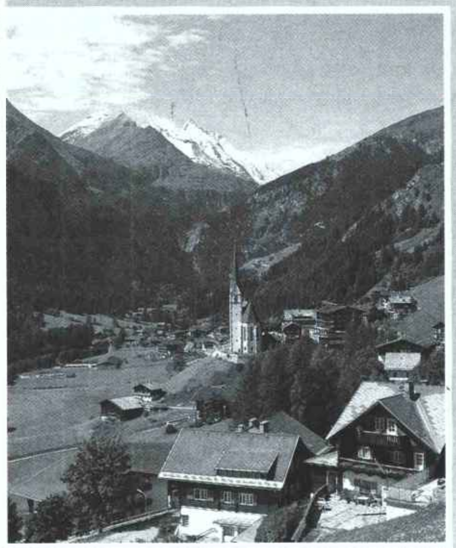
Photo Boehm/PLURIEL

In February 1985, the Federal Government of Switzerland gave the green light for the National Research Programme "Land Use in Switzerland" (the BODEN Programme) to go ahead and made ten million Swiss francs available for the purpose. The aim of this multidisciplinary programme is to work out practically orientated recommendations for the good husbandry of the land. The research began a year ago.

In a series of 45 utilisation-orientated projects, some 100 scientists are exploring how the three following main aims of the Programme can best be achieved.

The first is: **to keep land productive over a long period**. To that end a closer look is being taken, for example, at soil composition, soil erosion, the effects of harmful substances on the soil and the activity of living organisms in the soil.

The second is: **to prevent still more "green" land—fields, meadows and woods—from being supplanted by "grey" land—e.g. streets and houses.** The corresponding work under the Programme is designed to show how land can be "saved", how buildings, plots of land and areas can be better used, their utilisation better distributed and the use of building land as such reduced.

The third aim is: **to allocate the usable land as rationally as possible among the users**. In this part of the Programme aspects of the real estate market, the motivations of dealers in real estate and the effects of important legislation are coming under scrutiny. It is also being sought to show ways in which man's relationship to nature can be improved. What aesthetic criteria ought to underlie such an attitude of greater consideration for the land? Should nature too, and not only man, have rights? How do we teach and learn how to husband land properly?

The suggested solutions and measures will then be compared during a second stage of the Research Programme and scrutinised for their interconnections or conflicts of interests. The BODEN Programme will culminate in a collection of recommendations designed for practical action, which will be published in a series of brochures between 1988 and 1991. The Programme management issues periodical reports on the progress and results of the BODEN Programme in a "Bulletin" in French and German (obtainable free of charge).

The BODEN Programme is seeking to tackle the subject simultaneously from three different sides. Land is at the same time a natural feature, a place to be built on and settled and a subject of economics and law. The Programme's terms of reference state that the research is to give much the same weight to each of these three aspects.

But the interconnections have also to be enquired into. What is the use of elaborate technical proposals if they overlook economic and legal realities and never come to the notice of the decision-making bodies? What purpose does it serve to preserve the natural ecological quality of the soil if it is shortly to be built over, sealed and criss-crossed by communication routes?

And, lastly, what use are good suggestions as to how the existing stock of buildings could be better used or how, on less land, as much or more built-up space of comparable quality could be produced, if these suggestions are only taken up by a few idealists? If legal considerations make such land-economising difficult or impossible and the economic incentives point so overwhelmingly in another direction that even good ideas can scarcely be seriously discussed? Environmental problems, as they recognisably also concern land, are situated in a broader social context. They are an expression of the system of values underlying human action. Science too is subject to these values. But one of the duties of science is to detect such tie-ups and to ask whether one or other of these values should not, in present circumstances, be changed.

The BODEN Programme will not be able to solve the many-sided problem of the good husbandry of land in Switzerland. These questions are too complex and too interwoven with interests and other backgrounds to social behaviour. It will, however, help to bring some of these interconnections out for public discussion. An effort is being made to lay the scientific foundations necessary to that end. ■

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In Turkey

Feral Eke

Anatolia, cradle of many civilisations, has also been known since early times as one of the most fertile plains. The rich soil and rivers have supplied the many nations settled there with agricultural surplus.

Turkey is still an agricultural country whose agrarian economy can fend for its 50 million population. 50% of the population lives in rural settlements and agricultural products still constitute 59% of annual exports.

A major problem

However, soil erosion is a major problem in Turkey. It is estimated that 59% of 77,797,127 hectares of land surface is subject to soil erosion, and 500,000,000 m^3 of top soil, equalling 275,000 hectares of agricultural land, is lost annually through erosion. Three public authorities are responsible for undertaking measures against soil erosion, upper basin areas being controlled by the Directorate of Forestry, lower basin areas by the Directorate of Village Affairs and water spring areas by the State Hydraulic Works.

All the measures taken by these authorities share a common dimension, that of primarily educating the public and farmers on use of fertilisers and cultivation techniques. Annual programmes including infrastructural investments, credit allocation, technical aid and training are prepared by the Village Affairs Directorate according to the Soil Management Master Plan. Land classification and erosion maps are revised periodically to define new goals. The directorate has the objective of taking measures to protect at least 100,000 hectares against erosion annually.

On the other hand, the Directorate of Forestry is responsible for the upkeep of forests, establishment of new forestation areas and pastures, the objective being forestation of 300,000 hectares of land annually. The Directorate of Forestry also undertakes development projects for villages located near forests, in order to prevent the destruction of forests by the villagers either to obtain firewood, or open up fields on slopes, thus causing extensive soil erosion. Handicrafts, animal husbandry and other production modes are introduced into these villages to minimise their dependence on forests.

The State Hydraulic Works, whose main responsibility is to construct and manage dams, also undertakes forestation programmes to curb soil erosion and consequent sedimentation.

Loss of land in the 1950s

In the early 1950s, Turkey entered into a phase of rapid urbanisation. The mechanisation of agriculture, the population explosion due to improvements in public health, and the higher level of public amenities in cities contributed to a remarkable increase in rural-urban migration. The effects of this migration showed itself in further growth of larger cities, aggravating problems of urban sprawl. Agricultural land was lost to industry and housing.

A similar picture could be drawn in the tourism sector. A history that dates back to 8000 B.C. has provided Anatolia with a wealth of tourism assets. Tourism activities were quite limited until the 1960s when they increased with the construction of major highways and ports. Better accessibility opened up the coasts to tourism.

The development of coastal areas brought along another phenomenon: that of summer houses. The coasts, agricultural land and scenic areas with wildlife species were endangered.

General measures

The Stockholm Conference in 1972 on environment had its effects in Turkey as elsewhere. The need to protect the soil in particular and the environment as a whole gave rise to several measures. The first major step taken concerning protection of rural areas on the periphery of urban settlements and on coastal strips was proclamation of a by-law in 1972. These areas, hitherto informally managed by the village authorities, were placed under the jurisdiction of the provincial extensions of the Ministry of Resettlement, with the final approval of plans entrusted to the Ministry itself. Thus every individual development application was evaluated taking into consideration agricultural and environmental qualities of the proposed site. Furthermore, 1:25,000-scale development plans were prepared for areas of ecological interest and for areas with tourist assets.

The plans aimed at balanced development as well as preservation, designating areas for development and prohibition zones.

Photo J. Witt/PLURIEL

According to these plans, specific tourism zones are proclaimed annually where incentives are offered to potential investors in order to stimulate tourism development concurrent with environmental protection.

The second major step for environmental protection was the establishment of a special central body affiliated to the Prime Ministry, called the Directorate of Environment, and adoption of a comprehensive Act in 1983, the main guidelines of which are:
— polluter pays;
— a preventive approach rather than a curative ones is essential. Thus environmental protection will be primarily secured through land-use planning rather than abatement measures;
— the most appropriate technology to avoid or mitigate pollution will be chosen in every economic activity;
— all industries which may cause environmental problems must prepare an environmental impact analysis report, specifying measures to alleviate the harmful effects of waste;
— operational permits will be denied to firms which lack individually or collectively established waste treatment systems.

This Act has further been supported by the Environmental Protection Fund which puts the "polluter pays" principle into operation and the regulations concerning acceptable standards for water, air and soil quality.

Another important measure to protect the environment in which Turkey has been most successful is the establishment of natural parks. Thus 17 national parks covering 720,728 hectares have been created, several of which have been awarded the European Diploma by the Council of Europe. These areas are classified as:
— national parks;
— natural parks;
— natural monuments; and
— conservation areas,
where activities which may impair the ecological characteristics are prohibited. Turkey also has seven biogenetic and two biospheric reserves.

As a developing country, Turkey endeavours to establish a systemised approach which will provide a well-balanced integration of economic development and environmental protection issues. ■

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Photo Nardin/JACNA

Photo R. Morin

"Invertebrates are the most important component of wild fauna, both in number of species and biomass"; they "are vital to the fertility and formation of the soil, and to the fertilisation and production of the vast majority of cultivated plants". (Council of Europe "Charter on invertebrates")

At the Council of Europe

"Fire lives the death of air, air lives the death of fire, water lives the death of earth, and earth that of water". These words, uttered some 2,500 years ago by the Greek philosopher Heraclitus, point to the constant balance and inter-change among the four elements of nature. Problem is, man is increasingly disturbing this equilibrium, through pollution of the air, the water and the soil (he has not managed to disturb the sun, yet).

Another quote, this time form a more recent authority—the Council of Europe's European Soil Charter of 1972—goes to the heart of the matter: "Soil is one of humanity's most precious assets. It allows plants, animals and man to live on the earth's surface". It is also the end station for all the products and substances spewed forth by modern society. We may forget about it today but it will remind our children or grandchildren of our neglect in due course, just as we now have to pay the price for the environmental insouciance of the 1950s and 1960s.

The Parliamentary Assembly, and more particularly its Committee on Agriculture which I chair, has repeatedly pointed to the acute dangers facing the soil in Council of Europe member states—be it from the Chernobyl disaster, from the expansion of housing, roads and industrial installations, from soil erosion, from heavy metals in sewage sludge applied widely on agricultural land, to mention just a few of our resolutions and initiatives.

We realise that the work is hard, because it involves changing the attitude of the *Homo europeicus* from one of anthropocentrism—one where he is the entity around which all else revolves—to a more humble philosophy where we come to grasp that *we* are the visitors and the earth, air, water and fire are our—eternal—hosts.

Our task is not so dissimilar from that of Galileo 350 years ago: just as the earth is not the centre of the universe, man is not the only thing that matters on earth. Only, we have less time than the heliocentricists of the Renaissance, for the very survival of man, of innumerable plants and animals, will depend on our resolve.

We have called for many things in our various démarches in our Parliamentary Assembly, to the Committee of Ministers of the Council of Europe, in the European Campaign for the Countryside, at home in our parliaments, in our constituencies.

The most practical and immediate of these requests is the one for a European Convention for the Protection of the Soil within the Council's framework. We are pleased that, at our instigation, work has now begun at intergovernmental level to establish such an instrument, which would help crystallise the thinking and action of governments and parliaments in our member States.

The essence of parliamentary and government action is to foresee crises and "pre-act" rather than "re-act" only when they are over us and it may be too late. The warning signals about our soil are there, have been there for a long time, for all to heed. Let us act before nature acts for us. ■

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Photo S. Cordier/PLURIEL

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