Soil

Introduction

The soil is thin layer covering the Earth's crust, in contact with the atmosphere: its nature and composition depend on an equilibrium between environmental factors of a chemical, physical and biological nature. It represents an important natural resource because it allows the growth of spontaneous vegetation and as a consequence an environment that is rich and varied, where many forms of life live, mainly micro-organisms and insects. Here, thanks to the presence of microflora and microfauna, the nitrogen, carbon and phosphorus cycles are completed. These are fundamental for all living beings. The soil is also a source of nourishment because it allows the growth of agricultural crops and animal farming, furthermore it provides wood that is used by a part of the world population as fuel.

Soil knowledge

Soil composition

The soil consists of a mixture of solid particles, water and air. Solid particles can be inorganic or organic. The inorganic parts are mainly minerals: silicates, oxides and hydroxides of iron, aluminium, manganese, etc. that, according to their dimension, are classified in skeleton and fine earth, which are then divided into sand, slime and clay. These derive from the alteration of rocks into smaller and incoherent material, which accumulates to form superficial deposits. The deposit of incoherent material can occur in the same place as the rock was disintegrated.
The degradation processes of vegetal residues (leaves, fruits, dry branches or whole plants) and dead animals lead to the creation of organic fractions of the soil. Organic compounds can keep unaltered for long periods (non-humic compounds) or be subject to deep and fast changes in their original chemical structure (humic compounds or humus).
Water and air occupy the free spaces between solid particles (pores), and form a thick and extended network that allows water to move in the ground.

Soil structure

When the soil is not removed, the so-called mature soil develops. Paedogenesis is the name of the process that leads to its creation.
A mature soil is characterized by a series of layers, called horizons, which differ according to the soil structure and the composition of organic and inorganic parts.
The layers create the soil profile:

- Horizon A: rich in organic components, but lacks clay particles. Clay particles are transported by the water to the underneath horizons.
- Horizon B: lacks organic material, but is rich in clay particles.
- Horizon C: has particles of real soil and fragments of rock that have not been changed yet. More deeply, unchanged rocks can be found.

A natural resource

The soil is an important part of the landscape and contributes to determine the way in which natural vegetation, crops and human settlements are distributed on the territory. But the importance of the soil is mainly related to its double role as a reserve of nutritional elements and water and mechanical support (how would plants be able to stand upright if they did not have the soil to put their roots in?) for vegetation, leading to the creation of forests and protected areas. A direct observation allows us to see the fundamental importance of the soil: if we go to the mountains or to the countryside, we will see some bare rocks without plants, but next to them there will be wider areas covered by a thick soil. On this land

spontaneous vegetation or crops grow. The soil is also very important for men and other living organisms as it affects water composition. In fact, the quality of underground water reserves depends on use of organic and inorganic polluting products, deriving from agricultural and industrial activities or from cities. Various chemical and physical properties of the soil affect the concentration and permanence of polluting compounds in the soil, and the probability that they get in contact with superficial aquifers by polluting them.
The soil can be extremely important for men even if it is not changed and left in its natural conditions. This is the case of protected areas (parks and oasis): the survival of the delicate ecosystems of these areas mainly depends on the fact that the soil keeps in good conditions and does not experience changes. For example, in the past men considered wet areas as unhealthy areas to be reclaimed and used for agriculture. Today wet areas are considered as very important and fragile ecosystems, whose survival can be guaranteed only by preserving the particular conditions of their soil.

An agricultural and food resource

Agriculture causes a major transformation of the soil and represents the main exploitation of renewable resources (water, soil, flora, fauna, and atmosphere) of our planet. Agriculture is the main productive activity (sometimes the only activity) for many countries, in particular for tropical and subtropical regions. Agriculture uses the soil to produce food (fruits, vegetables, roots, and other parts of plants that represent the daily nutrition for more than nine-tenth of men), fibres and other useful goods. Agriculture is practiced almost at all latitudes, although in many different ways: from the most primitive low-income type of agriculture of the poorest parts of the Earth (Africa, Asia, central-southern America), to the modern high-productivity agriculture of mild regions (Europe and North America).
In order to face the world growing need for food (without being able to increase the surface of farmed land, as the land was not-productive or it was already occupied by the cities), agriculture experienced a real revolution. It has become intensive, that is based on high production and specialized. This means that the aim of agriculture today is to farm just a few selected crops in order to be more competitive and reach a better quality. This has all been achieved thanks to agricultural technical and technological progress, the introduction of more efficient irrigation systems and the growing use of chemical fertilizers and phytosanitary products, that are easy to use and economically convenient, although in some cases they pollute.

Soil formation

Paedogenesis

Soil formation is the result of long processes (paedogenesis) that are generally based on the alteration (that is change) of inorganic (minerals and rocks) and organic compounds (plants and dead animals or substances produced by them, like leaves and faeces) that are present in the area, their deposit and the subsequent formation of new minerals and organic molecules.
The final composition and structure of a soil depend on the following factors:

- the parent rock (or lithologic matrix), i.e. the original material (rocks, clays, limestones, etc) of the soil. You will find more information on rocks in the section dedicated to subsoil resources
- the climate, which is considered as the main responsible for the formation and definition of soil characteristics and properties
- water and temperature, which influence the majority of physical, chemical and biochemical processes that are important for the development of mature soil
  sun exposure
- the activity of biotic entities (vegetation, micro and macro fauna e flora)
- the height, defined by land altitude and inclination

- the length of time, as the different products of change and the definition of soil characteristics occur in different length of time.
- human activity.

The action of the organisms

Organisms can contribute to the disintegration of the parent rock:

- plant roots enter the rock cracks and can produce acid substances that facilitate disintegration
- some sea molluscs produce acid substances that dig holes in the rock and use them as a shelter
- lichens manage to penetrate into the rock granules with their microscopic layers
- some bacteria produce carbon dioxide, ammonia, nitric acid, sulphurous acid. All these substances react with minerals and favour their alteration
- dead organisms are subject to decay, a process that produces substances like humic acids, carbon dioxide and ammonia.

Those organisms that move in the soil can contribute to further crumble soil particles. Those organisms can be worms and coleopters, which transport bits of plants and animals from the surface to the lower layers.

How long does it take to form?

The time needed to form a soil depends on the latitude:

- in environments characterized by a mild climate, it takes 200-400 years to form 1 cm of soil
- in wet tropical areas soil formation is faster, as it takes 200 years
- in order to accumulate enough substances to make a soil fertile it takes 3000 years.

For these reasons the soil is considered as a non-renewable resource: once it has been destroyed, it is lost forever.

Soil classification

Many different types of soil

Soil thickness depends on soil inclination. If the land is inclined rock debris do not accumulate on the spot since, due to force of gravity, they roll down. If the land is very steep, the soil is completely absent as you can observe on mountain rocky walls.
Climate is the most active factor as far as soil origin is concerned: the most important elements are the intensity and frequency of rain, evaporation, temperature and wind.
Without rainwater chemical and biological activities are not possible. In fact, water melts a part of the mineral salts that are contained in the soil: they can react and give origin to compounds that can be assimilated by plants and animals. However, an excessive quantity of rain can filter the salts and move them away through lixiviation, impoverishing the soil. Therefore, in hot climate where precipitations are particularly intense (like in equatorial areas), many salts and nutritional elements (like nitrogen, calcium, sodium, potassium, etc.) are removed and the soil becomes less fertile. Instead, in dry climates, the poor water that is contained in the soil evaporates by making melted salts come to the surface: the soil is poorly fertile because it becomes too salty.
Temperatures can act in different ways: generally, chemical and biological activities are favoured by high temperatures, while they are hampered by cold temperatures and stop when soil water freezes. So, in tropical soils, organic and

inorganic material is completely modified from the chemical point of view, while in the tundra frozen soil appears crumbled, but only mechanically: in fact water penetrates into rock cracks, transforms into ice, increases its volume and breaks.
Also wind plays an active role in the paedogenetic process: it can increase evaporation and, in dry regions without vegetation, it can lift the superficial part of the soil and transport it for long distances (wind erosion). The transported soil deposits in areas that are different from their original place.

Types of soil and classification

The soil covers approximately a third of the whole Earth's surface, with a thickness that ranges from tens of metres to a minimum of few centimetres, according to the intensity and duration of the rock changing processes. The factors that are responsible for soil formation create different types of soil in large geographic areas and inside small regions. The soil, in fact, is different in each area of the world: each area has its own climate, rocks and vegetation and, therefore, its own soil, with unique characteristics. You can find some examples on the images.
There are many methods to classify the soil. They all aim at organizing the different types of soil according to determined criteria, based either on a paedogenesis factor or on another specific characteristic of the soil.
Although there are many links between the different official classifications, it would be useful to have one international classification, which is valid for all countries. Among the main soil classifications, we can mention the American Agricultural Department classification (U.S.D.A.), F.A.O. (United Nations Organization for agriculture and food in the world), and U.N.E.S.C.O. (United Nations Organization for education, science and culture).

Earth biology

Pedobiology

Soil is the 'place' where materials essential for ecological equilibrium are formed and decompose, but it is also where our food is produced. Unfortunately, it is also the waiting room of a number of environmental problems that begin in it and terminate elsewhere. Nevertheless, studies regarding soil biology (**pedobiology**), respect to those regarding let's say, air and water, are still rather slow: why?
The main reason is that the scientist perceives Nature in the same manner as everyone else, which is not always the correct way of understanding it. In other words, to understand Nature well, one must go beyond what one can see (or hear), and understand Nature by using simple reasoning. Let us consider for example our difficulty in imagining the many processes that take place at a microscopic or sub-microscopic level, such as those that occur in the sphere of cells; or the difficulty in adapting our way of perceiving the passing of time to the scale of biological evolution, that is measured in hundreds of millions of years. Well, these limits have represented one of the most important factors in the orientation of scientific research, in some cases with results that were rather negative for our knowledge: which is the case of soil biology.
An environment full of life
Even though not much is known about soil organisms, it is certain that soil is not an inert and sterile environment but, on the contrary, it is a dynamic one overflowing with life. The majority of the organisms live within the first metre in depth and, in general, the biological spaces they occupy and their biological activities are on a very small scale. The growth of cultivated plants, for example, depends on the way in which the solid particles of the soil are arranged to allow the formation of spaces with a diameter of about 0.2 mm. Moreover, these plants depend on the activity of micro-organisms that are about 1 µm (1,000 µm = 1 mm) in size, to contribute nutrient substances such as nitrates.
Soil is a resource of great environmental value, and at the same time, it is also an ecological system that recovers with difficulty each time its health is harmed by pollution produced by Man. It carries out an extraordinary activity of preservation of ecological equilibriums and plays a crucial role in the protection of human health. A proof is its complex activity as a biological and chemical filter, capable of slowing down and limiting dangerous chemical pollutants that, penetrating from the more superficial layers towards the deeper ones, could reach the layer with the water that we

drink.
As far as the inorganic chemical composition and the structure of soil are concerned the reader can refer to these topics discussed in the section ‘Earth’.

Life produces organic material

The organic part of soil comes from organisms that live over and under its surface. The variety of these organisms and the exorbitant number of substances that they synthesize, that range from simple amino-acids to large natural polymers, such as lignin, explain the great diversity of organic material present in the earth. In the soil not all the remains of vegetable and animal organisms are biodegradable in the same way. A good part of these residues remains practically unchanged for even rather long periods, accumulating in time. In addition to this, in many environments such as peat-bogs and moors of high latitudes or altitudes, the climate is dominated for most of the year by low atmospheric temperatures that slow down decomposition phenomena.
When soil’s organic material remains in time, a superficial layer is formed made up of a brown-coloured matrix that is capable of staying in this phase for indefinite periods of time even though it has lost the macroscopic characteristics of the original materials from which it derives. The substance obtained is called humus.
Humus has been studied for a long time, especially from the point of view of its chemistry; nevertheless, to date, it has not been possible to describe its composition in detail. For example, it is known that part of the organic nitrogen that it contains derives from the presence of amino-acids, amino-sugars and nucleic acids, however, the nature of the remaining part is not totally clear. What can be stated, however, is that humus is fundamental in guaranteeing a reservoir of organic material that is useful for soil organisms.

Earth biology

In the soil, the main biological role, in purely quantitative terms, is played by micro-organisms and in fact, researches have been concentrated mainly on fungi and bacteria. However, if it is true that micro-organisms represent the living creatures that are most ‘present’ in the hypogeal environment, it is also true that they alone cannot explain all the ecological phenomena that take place in the soil. For example, knowledge regarding the relations that concern the higher levels of the soil food chains is still rather poor. The consequence of this delay is a still incomplete and inadequate knowledge of biopedological dynamics. Many phenomena that are, for example, connected to the nutrient cycle, in fact concern organisms that occupy very different positions in the ecological networks of the soil and are still not well known to date. In spite of the difficulties, some studies have clarified the identity of single species that normally live in the soil and this has lead to the possibility of formulating some hypotheses on their ecological functions.
Today, the role of particular biological groups can be studied in different ways and allow the elaboration of a sort of organizational chart of hypogeal ecology. A principle often used when classifying these biological groups takes their dimensions into account. As a result, five fundamental categories of hypogeal organisms have been identified:

- microflora: bacteria and fungi;
- microfauna: protozoa and nematodes;
- mesofauna: springtails, mites, enchytraeids (potworms) and others;
- macrofauna: isopods, molluscs, miriapods, earthworms and others;
- megafauna: amphibians, reptiles and mammals.

Many factors

A mature soil, from the point of view of pedogenesis, can be defined as a layer of sedimentary rock that is inhabited by living organisms. For pedogenesis (a process that is truly never ending because all soils are slowly and continually changing) purposes, the soil is transformed into a tank, with a practically unlimited capacity, containing organisms. The

consequent biodiversity has a very high ecologic value that is also very useful for Man.
The characteristics of the biodiversity of the microhabitats in the soil are defined directly by a number of factors, but mainly by the variations in the availability of water and air and the temperature.

Water

The spaces (pores) that form between the solid particles play a decisive role as far as the presence of water in the soil is concerned, and consequently the presence of organisms. The water content is subdivided into the various chemical/physical forms that water can be found in: vapour, gravitational water, capillary water, hygroscopic water, crystallization water.

Gravitational water accumulates in the larger cavities and tends to precipitate to the deeper layers due to the simple effect of weight. It is probably the most immediate source of water supply for the hypogeal biological community.

Capillary water collects in microscopic cavities and spaces where it is held with a certain energy. Hygroscopic water binds to the various substances that are present in the soil with an even greater energy, thus its biological availability is even more limited. Crystallization water is not available for the organisms.

Therefore water is held by the soil with a certain energy that varies depending on its particular form. Water tends to move in the soil following this principle, obviously interfering with the capacity of plants and other organisms to reach and maintain the right moisture level. All this is of primary importance because it not only conditions the presence/absence of hypogeal organisms, but also their seasonal or circadian (daily) migrations.

Air

In principle, observation of hypogeal atmosphere shows a “qualitative” composition that is very similar to the epigeal atmosphere, with some significant “quantitative” differences, i.e. with regard to the dosage of the single gases. For example in the soil, CO_2 is present in a quantity that is about ten times greater than in the air of the epigeal atmosphere, while O_2 is present in minor quantities. Furthermore, the hypogeal atmosphere is often saturated with water vapour.

The lack of oxygen in the ground can support the breathing requirements of the resident biological communities for no more than a few days. However in normal conditions, it is very improbable that O_2 should represent a limiting factor, because sufficient air is stored in the pores to guarantee an abundant supply (bearing in mind that in air, the diffusion of O_2 is 300,000 times greater than in water).

Temperature

The temperature in the microhabitats in the ground is directly proportional to the atmospheric temperature and the solar radiation that reaches the surface layers. Furthermore, it is in turn influenced by biological factors, such as the presence of vegetation. Temperature range follows circadian and seasonal rhythms, and on the surface, the recorded temperatures range from a few degrees below zero to +60°C (depending on the latitude and altitude).

However at deeper and deeper levels, the temperature range becomes much less substantial. The high temperatures of the ground are often accompanied by arid conditions that interact in a rather complex manner with the hypogeal organisms, usually with negative results specially on their breathing systems. However, in relation to the thermal conditions in which underground life takes place, the most important factor that has been established is that rapid and very extensive excursions provoke effects that are much more harmful than extreme conditions characterized by a constant trend.

Hypogeal animals

An initial concept that must be understood before undertaking a digression on the fauna of the soil is that present day knowledge is not sufficient to list with certainty all the types of animals that inhabit this important natural environment. In fact, the data available nowadays regard animals that have already been studied in most of the ecosystems of the planet. But no one can certify that this data is actually complete with all the hypogeal species, because still today many areas of the planet have not been thoroughly explored as far as the biological component resident in the soil is concerned.

An incredible variety of animals

As we have seen in the previous special report dedicated to soil biology, a frequently used criterion to sort out the fauna that lives in the uppermost layers of soil is that of classifying it according to the dimensions of the various taxonomic

groups.
This criterion however is considered arbitrary and unsatisfactory because it is unable to offer information that is useful in understanding the relationships existent between one animal species and other cohabiting species. A much more useful way of proceeding would be that of considering not just the body dimensions but also the dietary habits and the role of each individual species in the hypogeal ecological network. A thorough knowledge of these aspects in fact would be very important in order to understand how the soil works where the word soil is intended as a natural system provided with its own specific ecological identity.
Generally speaking, the soil fauna belongs to the taxonomic groups of the Protozoa, Nematodes, Annelids, Molluscs, Arthropods and Vertebrates. Naturally this information reflects only a part of the biological knowledge that is necessary to be able to explain the ecological complexity of soil. To have a clearer picture other information is necessary, such as that regarding the abundance of a single species, the different distribution (in space and time) and the nature of the ecological relationships.
In this special report we will try to offer the basic knowledge regarding zoological groups in the soil, knowing well, however, that among the many species that live just a few centimetres below the surface of the soil, a network of relationships is established of which there is still a lot to discover.

Protozoa and Nematodes

Protozoa

Protozoa can be considered unicellular animals (formed by a single cell) that have dimensions ranging between 2 and several hundred µm (remember that 1000 µm = 1 mm). They are extremely abundant and well distributed in the entire thickness of the first centimetres of soil and their geographical distribution covers climates that extend from the warm and dry areas typical of deserts to cold and damp ones typical of the tundra. **Flagellates** and **amoeboids**represent the majority of soil protozoa, specially with respect to those very particular biological communities that form close to the roots of plants (**rhizosphere**). Protozoa are particularly important in the global ecology of the soil and their role is basically that of keeping a check on the bacteria population that they feed on.

Nematodes

Nematodes – that are, as can be remembered, small cylindrical worm-shaped pseudocelomates, i.e. without a real coelom – have dimensions that vary from a few tens of ?m to about 2 mm. They carry out a fundamental function in soil ecology because, depending on the species, they have different life styles: in fact, they can be predators or parasites of plants and animals. However, briefly it can be stated that, in the soil, the role of the nematodes is mainly that of keeping the abundance of other organisms in check and to demolish organic substances. Moreover, nematodes, as has been stated also for protozoa, are very efficient predators of bacteria.

Annelids and molluscs

Annelids

It is important to reflect on the fact that, unlike nematodes, annelids are worms with a real coelom and that phylogenetically they occupy a very different position respect to the former. The main representatives of this particular component of soil fauna are the oligochaetes, i.e. common earthworms with a circular cross-section, characterised by very accentuated body metamerism (the repetition of identical anatomical segments along the body's principal axis) and by a length that often exceeds 10 mm. Respect to the taxonomic groups discussed so far, oligochaetes are animals characterized by a minor dependence on the amount of water present underground. Contrary to what one might think, annelids, and oligochaetes in particular, are animals that have been studied a lot by biologists in the past, starting from*Charles Darwin* who took particular interest in them. In fact, their importance in the ecological equilibrium of the soil is undisputed since they participate in all the mixing processes of organic substances and mineral components present in soil particles, increasing their fertility.

Molluscs

Molluscs, whose dimensions vary from few mm to a few tens of mm, have been neglected for a long time in soil biology studies for the simple fact that historically they have been considered more as generically epigeal animals rather than real hypogeal ones. The latter idea, however, albeit incorrect, had a logical explanation since, in numerical terms, molluscs rarely appear among the animals that dominate life in the soil. Currently, however, recently updated information on the biology and ecology of molluscs indicates that these animals are part of many trophic relations in food webs characteristic of the hypogeal environment. From this viewpoint, the main taxonomic group is that of the Gasteropoda pulmonata (with or without shell) whose ecological function must be prevalently related to the demolition of organic material present in the topmost layers of the soil. Often, however, the specimens of this subclass have herbivorous feeding habits since the main food of many species includes leaves and other decaying vegetation

Arthropods

Numerically, arthropods certainly represent the major taxonomic group of hypogeal fauna. Moreover, as far as the range of their dimensions is concerned, arthropods that live in the soil detain a relevant record that is supported by the fact that their length extends from a few tens of µm of the most microscopic ticks to several tens of mm of the longer miriapods. Generally speaking, the most relevant group of arthropods can be identified in the above-mentioned ticks, in collembola (wingless insects in the subclass *Apterygota*), in miriapods and in araneids. Considering the characteristics of the environments that are being studied, however, even other groups of arthropods can be significantly represented, such as pseudoscorpions, isopods (guinea pigs) and several winged insects such as coleopters, dipters and hymenopters.
On the premise that the arthropods resident in the soil cover a wide range, it is impossible to identify a dominant trophic characteristic that allows us to place them in a single ecological role. In other words, the arthropod fauna of the soil is so rich in both taxonomic and morphologic terms that the life styles and feeding habits of the different species practically cover the entire spectrum of the ecological niches that this environment offers. For example, among the arachnids, scorpions, opiliones and pseudoscorpions are all predators; however, many ticks and mites (also belonging to the class *Aracnida*) feed on decaying organic matter as isopods (crustaceans) do too. Among the miriapods there are numerous herbivores such as symphylans while the majority of chilopods and diplopods are respectively predators and eaters of detritus. If one goes on to investigate insects, the possibilities are almost infinite with groups such as the orthopterans
that are totally herbivorous and groups such as the diplurans that are mainly predators instead. Moreover, in between these two extremes, there is an intermediate group that comprises a vast series of arthropods whose diet is very variable. Suffice it to give the example of coleopters, to prove what a great diversity of feeding habits can exist within the same zoological group. The same can be said about hymenopters, hemipterans and dipterans.

Vertebrates

In soil biology studies, vertebrates have received the importance they deserve only in recent years. The fact that these animals have on average a much greater mobility respect to invertebrates has probably made some of their adaptations to life underground be overshadowed, but nowadays their importance is being rediscovered. In the course of time, biologists realized that even though they were endowed with great ecological flexibility, many vertebrates had very strong connections with the soil environment.
It must be said that even the vertebrate soil fauna, at times called megafauna by soil biologists, shows significant variations in its dimensions, that vary from a few cm of the insectivores (such as the shrewmouse) and of the small amphibians, to the much greater dimensions of the cusk-eels and of the bigger rodents.
As can be imagined, vertebrates that have adapted to an underground existence include all the groups that are comprised in the entire series of tetrapods. Many of the latter, for example, spend a part of their life-cycle in natural cavities or in shelters dug in the ground for this purpose because of the advantages that this type of life style offers both in terms of protection from predators and in terms of a better regulation of some physiological functions (for example thermoregulation and water saving). Contrary to what one might expect after what has been stated with regard to ecological flexibility, vertebrates include some animals that can, or rather, must live in very limited ecological conditions such as those typical of some hypogeal habitats of tropical ecosystems. Amphibians with a worm-shaped body bear

witness to this – the adaptations to life in the soil of the so-called caecilians have reached a formidable level of specialization. These animals, besides having eliminated their limbs completely, are often characterized by a regression of their eyes and a reduction of their skin pigments. Hence, their life style is very similar to that of many invertebrates which they resemble due to 'adaptive convergence'.

Environment and territory

Soil degradation

The soil is a dynamic system that has reached a balance with the other surrounding elements. Man can compromise it with his activities and behaviour. The urban development of cities, industrial expansion, the creation of infrastructure like railways, roads, bridges, agriculture, modified the use of soil and sometimes determined its degradation. Soil degradation becomes apparent through some phenomena: desertification, erosion of the superficial layer, an unusual increase of salt content (salinization), acidification and the presence of pollutants. Soil pollution is a particularly serious phenomenon since it has repercussions not only on soil productivity, but also on the composition of the water it gets in contact with (especially drinking water and aquifer water) and on the atmosphere. This is why men have to carry out their activities in such a way as to ensure a high environmental quality of the soil, by eliminating the pollution that has been created in the past (recovery activities) and, above all, avoiding to overexploit the soil. The direct pollution of the soil by inorganic and/or organic pollutants can occur: - in agricultural lands, when the natural balance is threatened by polluted irrigations, by phytosanitary products, herbicides, fertilizers, etc.; - in urban, industrial, abandoned areas, also close to mines, as a consequence of the wrong disposal of waste water (water that is used for productive processes or sewage water), and as a consequence of waste containing chemical pollutants.

Erosion

The word erosion indicates the slow disintegration of the soil due to the action of agents such as the rain, run-off water (rain water that runs on the land surface), and the wind. Erosion is a natural process that depends on several factors like the topographic configuration of the interested area, the soil composition and structure (in particular, its granulometry), the climate (in particular as far as precipitations are concerned), and the state of its vegetation cover. Some human activities, such as intensive agriculture, deforestation, intensive animal farming, and the use of inefficient or inadequate irrigation systems, accelerate or intensify the erosive process.

Salinization

Saline soils form when the water leaves the ground mainly due to evaporation, transpiration, or percolation. This mainly occurs in dry areas, where precipitations are not sufficient to eliminate the salt from the ground. However, salinization is also frequent on irrigated grounds. If irrigation (which is fundamentally important in dry regions) is not done in a functional way, or with appropriate water, it can provoke an accumulation of salt (in particular chloride and sodium sulphate) that reduces the ability of plants to absorb nutritional elements from the roots, therefore making the soil sterile. The reclamation of saline soil is apparently a very simple process, as the salts can be removed with water. But before irrigating, it is necessary to increase the soil permeability, by increasing its porosity (pore number and dimension), in order to favour the passage of water and eliminate excessive salts. In nature some vegetal species tolerate salinity, as they are able to survive or produce (if they are very tolerant) even if there is an excessive quantity of salt in the soil.

Desertification

Desertification is a complex phenomenon that occurs in all those areas where temperature and humidity do not make it possible for vegetation to growth. Like for many other natural processes, men can have an influence on desertification, sometimes in very negative ways. Fires and the destruction of the savannah near tropical forests in order to create land for cereals and forage cultivation, are some of the worst examples of irreversible destruction of a delicate ecosystem that favours the desert moving forward. Millions of hectares of land are involved each year in new desertification processes. Degraded lands can be hundreds of kilometres from the nearest desert, but they can expand and get closer one to another, by creating desert-like conditions.

What areas are at risk?

Most of the regions that risk to become dry areas are near the world five deserts:

• Sonora desert between Mexico and the United States;

• Atacama desert in South America;

• a wide desert area that stretches from the Atlantic Ocean to the east, including the Sahara desert, Iran and former Soviet Union deserts, the big Indian desert of Rajasthan and last Taklamakan and Gobi deserts, that are located in China and Mongolia;

• Kalahari desert in South Africa;

• most of Australia.

This does not mean that desertification does not threat milder areas (even though they are quite dry), like the south of Italy, or some wet areas like the Amazon Forest.

What are the causes?

Mainly, the human causes for desertification are three:

• the over-exploitation of pasture areas and agricultural nearby areas, which provoke the disappearance of grass cover and reduce soil fertility;

• excessive presence of water, that in wet areas provokes a rise in aquifer levels, damaging crops from the root, while in dry areas it provokes salinization of the soil due to strong evaporation;

• deforestation, a phenomenon that, especially in wet regions, leaves the soil without vegetation, reduces water retention in the ground, and allows violent tropical rains to exercise a strong erosive action.

Soil pollution

Among the various air pollutants that act negatively on soil balance there are gaseous compounds of photochemical origin, like ozone and free radicals, sulphur and nitrogen compounds that are responsible for the increase in rain acidity. In particular, acid rains determine a soil pH reduction (acidification), which, for agricultural soil, can be useful as it satisfies the nutritional needs of many crops that tolerate soil acidity. Instead, on forest soil that is already slightly acid, it provokes a slow but progressive damage to the vegetation and sometimes it even provokes the death of vegetation. Another source of soil pollution is the water for field irrigation, which can contain natural organic substances, or artificial water, mineral substances, inorganic substances or micro-organisms that come from industrial waste or not correctly treated sewage water. This phenomenon can cause damaging pollutants to enter the food chain, as well provoking a reduction in agricultural production.

Pollution of agricultural land

Modern agricultural farms today use large quantities of industrial-origin chemical products (fertilizers and phytosanitary products). If these products are used in the wrong way and in excessive quantities, they can cause water, air and soil pollution, as well as being toxic for men and animals. The economic advantages of these substances made people underestimate their negative effects. Negative effects can be direct (when consuming them or getting in contact with them), and indirect, as they change the original balance of the ecosystem. In particular, the more and more frequent use of phytosanitary products and their ever-increasing number highlighted the problems related to their use and the effects they might have on the environment.

Sustainable agriculture

As we have seen, the soil is essentially important for human survival. Men have developed agricultural techniques that allow to obtain good productions at limited costs. Sustainable agriculture derives from the integration of traditional agricultural techniques, that use chemical products like fertilizers and phytosanitary products, with low-environmental impact biological techniques that require a deep knowledge of complex interactions between the soil, water, vegetation and animals. Each year 30-80 billion tons of soil are lost due to erosion: it is as if a train full of earth was unloaded 12 times a year in the space. One of the most efficient techniques uses some plants, especially herbaceous plants that, keeping earth particles in their roots, reduce the erosive effect of wind and water. Often herbaceous varieties are seeded after covering the soil with a thick biodegradable net, of vegetal origin (raffia or hemp), which supports the seeds during their germination. Farmers adopt some measures to reduce or block the wind or water erosion. For example, they plant trees along the borders of the fields, they plant herbaceous crops (like cereals) in order to cover the soil during those months that are most at risk of erosion (autumn and spring), they work less on the soil, etc.

Heavy metals

Heavy metals (cadmium, cobalt, chromium, copper, mercury, manganese, nickel, lead, zinc, molybdenum, tin) are among the main soil pollutants. In fact they are widely spread, highly toxic and persistent, as they stay in the environment for a long time (through the food chain, for example). If these pollutants exceed determined quantities, they provoke damages to those organisms that absorb them.

Why can heavy metals in the soil be harmful to living organisms? Usually the metal in the soil is absorbed by the plants and transported through their leaves and fruits. The leaves and fruits that contain the pollutants are eaten directly by the primary consumer (man or animal) that assimilates them in his organism. Pollutants can be absorbed also by eating the meat of an animal that was fed with heavy-metal polluted vegetables. Once they have been accumulated in the organism (man, animal or vegetable) in quantities that are higher than the normal quantity, they can produce serious damages and sometimes provoke the death of the organism. What has just been described is the method through which pollutants are transmitted inside the food chain: for this reason it is very important to have a high soil quality, in order not to have damaging substances in the food.

Why can heavy metals be present in the soil? In nature, heavy metals are present in underground deposits (see the pages dedicated to this resource) and, without men's action, they would very hardly manage to spread in the surrounding environment and particularly in the soil. At the moment, the main cause for their spreading is human activity. Heavy metals can be left in the environment or directly discharged by the industry only during some productive processes (for example they can be discharged by mining industries that extract them from the subsoil or by other industries that discharge fumes or polluted waste water), or by the consumer who uses products that contain them (for example paints, tyres, fuels, and others). These products, when they are used or if they are not correctly disposed of, discharge some heavy metals. Heavy metals, like other toxic elements, derive not just from industrial activities, but also from civil activities (they are contained, for example, in sewage waters).

Is it possible to eliminate this type of pollution? The governments of many countries have been paying special attention to this type of pollution and, in the last few years, they have forced their factories to respect strict limits in the emission of heavy metals. They have also forced the factories to produce goods that do not contain heavy metals or contain very small quantities of them. The aim is to keep their presence in the environment below certain threshold levels, that are safe for men, animals and the vegetation.

The problem of acid soil

Usually soil acidity is due to the presence of high quantities of hydrogen and aluminium. Although some acid soil derives directly from acid rocks, most of them are formed in areas with lots of rainfalls or farmed areas. In fact, acidification speed depends on the speed by which the majority of nutritional elements leave the soil (because of rain, or after being assimilated by crops, during harvest), leaving room to those elements that provide acidity. On acid soil it is very difficult for plants to grow, although the different species have a different sensitivity: some species are tolerant while others require a high soil acidity in order to grow and produce.

Is it possible to eliminate this type of pollution? Reclamation of acid soil occurs by applying calcium and magnesium compounds, like lime (calcium carbonate).

Treatment of polluted soil

Thanks to its absorbing power, its buffer capacity, and its intense biotic activity, the soil is prone to self-treatment, or at least, is able to reduce the negative effects deriving from the presence of pollutants. Of course the soil self-treatment capacity has some limits. If pollution goes over this limit, the soil can lose its “filter” function in an irreversible way, provoking many damages. Differently from the atmosphere and water, which decontaminate quite rapidly, the soil, although it has a high self-treatment capacity thanks to chemical, physical, and biological mechanisms, keeps contaminated for a long period. It was noticed that, in order to significantly reduce the content of heavy metals in a polluted soil, the quantity of water corresponding to tens of years of rain is not sufficient. The presence of polluting compounds in the soil, especially highly toxic ones, can represent a risk for human health and for the environment, and requires reclamation activities. The reclamation of a land can be based on the inactivation or degrade of pollutants (they are transformed into less dangerous or not dangerous substances) or their removal by using chemical, physical or biological treatments. Reclamations is normally done on agricultural land and areas close to industrial zones or abandoned dumps.

Sustainable use of the soil

The objective of sustainable management programmes is to keep and improve soil quality and make human activities compatible with this resource and nature. The soil quality concept, however, is often difficult to define and the criteria also depend on the final use of the soil. For example, the quality of agricultural soil is assessed according to its productivity (yield and quality of products) and to the presence of pollutants that are dangerous for consumers. The quality of forest soil is assessed according to its integrity and stability, while the quality of building soil is judged according to the presence of pollutants that are dangerous for its inhabitants. It is also very important to safeguard the integrity of ecosystems that are particularly precious, like wet areas, tropical forests and the savannah.