Earth sustainability

Introduction

Human beings and their activities can modify the natural landscape by building constructions, by obstructing waterways, by drilling through mountains, eliminating the vegetation on the mountain slopes. Often human interventions can be the cause of severe damages for nature. Furthermore, rains that tend to concentrate in short intense periods can provoke river floods, sudden inundations and a series of problems for the environment, nature, the economy and agricultural production. Also the soil, like the water and the air, is threatened by pollution. For example polluted underground waterways carry the poisonous substances into the ground, and therefore also pollute the soil. This problem is aggravated by the difficulty to eliminate particularly toxic waste, and the use of chemical substances in agriculture. A very serious consequence of soil pollution is that the agricultural products that we eat are often full of the poisonous substances produced by this pollution. Karst aquifers are a very important source of water in a large number of regions of the Earth: karst soils are by their own nature characterized by absence of water on the surface, and all the circulation of water takes place underground. These are resources that are very delicate to utilize and to be protected as they are particularly vulnerable to pollutants and excessive exploitation by man.

Landscapes

How man modifies the environment

he environment is a system whose processes are continuously interacting with the organisms that live in it. We have seen, for example, that rainwater changes the Earth's surface, and that vegetation plays an important role in rock disintegration and soil formation. There are many human beings in the environment. Man is the only individual to be able to build and use equipment that can modify the landscape in a very short time. Nature would take thousands of years to produce the same changes as the ones produced by man. Human activities on the environment strictly depend on the type of economic activity and how society is organized. In some cases human activities aim at recovering environmental upheaval.
As a consequence, man can be considered as an important landscape-modifying agent.

The construction of big works

The building of dikes, piers, roads, energy plants, etc. modifies the landscapes and interferes with natural processes. These changes have to be kept in mind during the first planning stages.
Let us image to stop a river flow by building a dike. We will have to take the following aspects into consideration:
• the stability of the building
• the quantity of river sediments that will not reach the sea but that will deposit on the dike lake
• the danger of erosion for the beaches that are located close to the river mouth
The accurate study about the environmental compatibility of a building during its design is called assessment of environmental impact.

Surface water erosion

In order to stop surface water erosion it is necessary to reduce water speed. At this regard and in order to protect a riverbed, men build river bridles, i.e. a series of steps along the river flow. In order to prevent floods, instead, artificial banks are built. When building them, it is important to calculate the natural space the river needs in order to let floodwater drain off. In order to reduce the quantity of water of a riverbed during a flood, water tanks (that can provisionally transmit a certain quantity of water) and drainage channels (that divert the river flow) are designed.

How to protect from landslides

Landslides provoke serious damages to things and people and they can be prevented by consolidating the area at risk. First of all it is necessary to detect the sliding land and avoid building or excavating in the area. Moreover, it is necessary

to prevent big quantities of water from running on the surface of this land: drains have to be built and vegetation growth is to be encouraged.
Support walls or gabionades are built to contain material that otherwise would move to the bottom of the slope.

Vajont landslide

In 1957 a dike in the Vajont river started to be built. Above the dike a lake was formed and geologists highlighted that the mountainsides that surrounded it were not stable: the sedimentary rocks on the sides were set on poorly compact layers of clay. After a first landslide, on 9th October 1963, 300 million cubic metres ran from the Toc Mountain to the lake and provoked a wave of 40 million cubic metres of water that went over the dike. The effects were devastating since the wave swept Longarone village and other villages away. In this case human responsibility is obvious, as the geologists' studies were not taken into consideration, nor during the dike designing stage or after the first landslides.

Environmental Impact Assessment

In Italy and in other European countries, the EEC directive of 1988 introduced the procedure for the assessment of environmental impact, which is a study that assesses the consequences that a work will have on the territory and its inhabitants. The study does not have to be limited to the interested area, but will have to include all near or far areas that might be affected by the activity.

Floods

In Italy watercourses are often characterized by dry periods and short but intense floods due to heavy precipitations. The water rise provokes an increase in the water running speed. As a consequence, the water goes out of its banks. Deforestation, fires, buildings in risky areas are some of the reasons why these phenomena occur (see image). The waters of the Po river run inside the artificial banks that stretch for 510 km, out of 652 km of the river total length. In this way the danger of sudden floods increases, the water goes over the artificial banks and invades the nearby areas by provoking serious damages to agriculture and inhabited centres.

Atacama desert in Chile like Mars

A group of scientists from different organizations discovered an area on the Earth that is similar to Mars surface. By studying this area, namely the Atacama desert in Chile, they may understand why the past missions on Mars have failed to detect any presence of life on the planet. Some experiments were made on microbes on the desert soil and even after 20 days' incubation in a lab no bacteria growth was detected. The unique conditions of the Atacama desert represent a big opportunity for scientists that study and develop new technologies.

Soil

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.

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.

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
• una 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..

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.

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.

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.

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.

Production and consumption

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

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).

Subsoil

The exploitation of a deposit

Before starting to exploit a mineral deposit, it is necessary to carry out a series of soil and subsoil analyses on the spot.

The study starts with a careful observation of the geological maps of the area. A geological map shows, with different colours, the area of each rock formation, highlighting the contact lines between rocks of different type and age. A specific area will be chosen to host a quarry according the quality and quantity of rocks, and how easy it is to be reached with the main ways of communication (railway lines, ports, motorways), in order to be able to distribute the product at a low cost. This choice is mainly driven by economic reasons. As a consequence, activities are set in those areas where the extraction and transport of materials result to be more convenient. Even before starting to extract, rock samples are taken and analysed in a lab to determine their physical and mechanical properties. Quarry extractions can take place in open air or underground. In the open air, the land is progressively excavated, by starting from the top, and building 10-20 m steps. When the resource is located deep underground, underground excavations are done (mines).

Subsoil exploitation

All subsoil resources will be exhausted sooner or later. Therefore rocks and minerals will not be extracted by men forever. This is why, like with energy, it is necessary to use them in an appropriate, efficient way, without wasting them and above all, supporting and encouraging the recycle of materials. But, apart from the problem of limited availability of subsoil resources, there are many more general problems related to pollution deriving from extraction activities. In fact, among those human activities with a high environmental impact, there certainly is the extraction of lithoids (clay, sand, gravel, stones, etc.) on water streams, hillsides or plains. Very often quarry owners abandon the quarry in such a degraded condition that it is no longer possible to recover it. For a few years different operations have been promoted, aiming at the environmental restoration of these quarries. The main objective is the reinsertion of the previously excavated areas into the surrounding environment, respecting the landscape, the quality of the water and of the soil that are located close to the mine, and which are often heavily polluted due to extraction activities. The best restoration is obtained if the quarry exploitation plan includes from the very beginning the recovery of the entire area, instead of waiting for the depletion of the resources and the end of the activities. In fact, it is much more difficult to act afterwards. Restoration works have to be carried out during excavation and not afterwards. In order to do so, it is possible to use the machines and equipment that are already present in the building site, with a clear reduction of costs.

Restoration of a quarry

• as for outdoors quarries in flat areas, the excavated area can be partially filled with the same land that was previously removed, and covered with agricultural humus. For this reason during activities in the quarry it is important not to mix the removed plant material with waste material. If, instead, the ground of a clay quarry gets in contact with a water table, it will be possible to convert the excavation area into a small lake. These lakes can be used for fishing, leisure activities, fish farming, irrigation, as a natural oasis, or can be devoted to water sports. As an example, we can mention the Fornace CARENA Park in Cambiano (TO), and the Ecological park of Unieco, in Fosdondo, Correggio Emilia;
• as for quarries located on a hillside, basically there is a need to reinsert the excavated area into the surrounding landscape, while guaranteeing the stability of the slope. It is necessary to rapidly obtain a vegetation cover that allows to efficiently consolidate the slope and mitigate erosions. A particular attention has to be devoted to the possibility to convert former quarries into dumps. With regard to clay, quarries are located on poorly permeable rocks that have the right characteristics to be considered as an appropriate “container” for polluting substances. Clays are indicated by the EEC as rocks that are able to solve the problem of radioactive waste. It can be concluded that the negative effects that derive from extraction activities can be widely limited if prevention is done during planning phases. And finally, it is important to highlight that the excavated area, once it has been recovered, is extremely fragile as an ecosystem. This is the reason why it has to be constantly controlled.

Caves

Karst aquifers

Karst aquifers provide a very important water resource in many parts of the Earth: karst terrains, in fact, are, by nature, lacking in surface waters, and all water circulation occurs underground.
However, these resources are very difficult to utilize and to protect. Karst aquifers, in fact, due to some of their

characteristics, are particularly vulnerable to pollutants and excessive exploitation.
An excessive and uncontrolled utilization of the reserves of deep phreatic zones can be a hazard for these kinds of aquifers: deep waters, in fact, move very slowly and need years or decades to be substituted, so an excessive exploitation could endanger the utilization of the entire aquifer forever.
But it is mainly with regard to the propagation of polluting substances that karst aquifers seem particularly vulnerable.
In sand or gravel, where the speed of water is very slow, the result of the prolonged contact of water and rock is that the former gets depurated of possible pollutants because of a mechanical filter effect, the natural deterioration of some substances with time and because of the action of bacterial colonies living on the surface of the granules. These processes allow the aquifer to eliminate many pollutants, especially the organic ones, through a mechanism of auto-purification that helps to protect the aquifer from pollution.
In the uppermost zone of the karst aquifer, water flows fast, similar to surface water flow regimes and the effect of auto-purification is practically nil: whatever enters a karst aquifer generally exits unchanged at the spring, often a very short time later. On the contrary, in deep phreatic zones, where circulation is very slow, pollutants can collect and get stored and more and more concentrated. Subsequently, the particular mechanism of flood propagation, the piston flow, can provoke the instantaneous release, at high concentrations, of the possible polluting substance which might have accumulated slowly over the course of time. Often these episodes of instantaneous pollution seem inexplicable because no current source of pollution can be identified: small quantities of pollutants that are well tolerated in other kinds of aquifers, become potentially very dangerous in karst aquifers.
Unfortunately karst areas have another property that makes them even more vulnerable: the presence of a great amount of depressions, sinkholes, shaft and dolines in the catchment zone. These seem ideal for use as convenient dumping grounds, where useless things can be concealed, at times even highly dangerous material. Too often one forgets, or pretends not to know that by doing this the entire karst system gets polluted. Since the location of the springs is not always known in karst aquifers, the contamination produced in the catchment zone can pollute springs several kilometres away, at times even in adjacent valleys: at times the self-interest of those who live at higher altitudes can cause severe problems to unknowing inhabitants living in the valley below. Unfortunately, knowledge of karst aquifers is still so limited that a few years ago there was a proposal to use caves for the storage of toxic and radioactive waste!