2 Soil as a Natural Resource of Croatia

… if Moses had foreseen what suicidal agriculture would do to the land of the holy earth, might he not have been inspired to deliver another Commandment to establish man's relation to the earth (soil) and to complete man's trinity of responsibilities to his Creator, to his fellow men and the Holy Earth… what has been called the "Eleventh Commandment".

W.C. Lowdermilk (1994).

2.1 Soil as a Unique Natural Body

An incredibly complex array of elements and compounds flows in balanced fashion, into our bodies along the nutrient chain. We are what we eat. In a sense we are unique, moist packages of animated soil.

F.D. Hole (1988)

Soil (pedosphere) is a natural, terrestrial body (sphere), a thin surface layer placed between the parent rock (lithosphere) and the atmosphere. The mineral component of soil is generated by processes of soil genesis: destruction and synthesis, removal and accumulation through the combined influences of water, air, temperature and different micro- and macro-lifeforms (flora and fauna). As all the factors of soil genesis in Croatia are highly varied in space and time, the soils of Croatia are very heterogeneous. The distribution of various soils depends on geomorphology—relief and topography, physical properties and chemical composition of parent rock, climatic conditions—daily and annual temperature variations, quantity, distribution and form of precipitation (leaching or accumulation of salt). A great influence on the distribution of soil types is plant cover, and to a greater or lesser extent sometimes the decisive influences are anthropogenic ones (Bašić 1976, 1982, 2009; Resulović et al. 2008).

In soil as a natural, terrestrial milieu, plants as autotrophic organisms originate and it is where the life of all organisms, including heterotrophic organisms, ends. As a natural body, soil is a more complex medium than the other members of the "ecological triad"—air and water. It may indeed be the most complex and dynamic system known to science. According to one theory the word "chemistry" is derived from "al-kīmīā," the ancient Egyptian name for Egypt (*khem*, *khame*, or *khmi*), meaning "black soil" of the Nile River, in contrast to the surrounding sandy desert (Zgorelec et al. 2012). Composed of mineral and organic, solid, liquid, and gaseous components, it contains large numbers of living organisms and plant roots and it is the medium which supports life in its broadest sense. Soil produces and contains all of the elements necessary to life, including air and water, which are movable systems, but the pedosphere is site-fixed and specific, and more stable than the other spheres. However, soil is a living system and it shows great variability in space and time (evolution) (Bašić and Franić 2003).

Soil genesis is a very slow process. The slowness of soil genesis reflects the fact that, as it says in Montanarella (2007), the formation of 2-cm layer of soil in nature needs 500 years. The formation of a 30-cm-thick soil layer requires 1,000–10,000 years—for example chernozems, Croatia's most fertile soil around Ilok in western Syrmium so soil should be considered nonrenewable. A substrate widespread in Croatia is limestone and this is the slowest in terms of soil formation. Durn (2003) states that the formation of a 50-cm layer of red soil (terra rossa) around Umag in Istria takes up to 2 million years, while in that time 50-m-high cretaceous limestone cliffs are dissolved. One can lose this layer if it is exposed to torrential rain for only one day!

Compared to water, air or biota, soils are not known to humans, because they are hidden under their feet and they cannot use them in the way they use air, water, or biota. Soil is a very complex, living system, which has all the characteristics of an organism: it emerges, develops from stage to stage, and is therefore subject to evolution (soil evolution), whose speed depends on the lithological conditions—the parent material from which the mineral soil is derived and is generally faster on loose, but slower on hard rocks. As current users of the land, we actually find different stages of soil evolution on different parent materials. Although the soil is a renewable natural resource because it is constantly produced, due to its slowness of formation it is conditionally renewable, so Varallyay (2000, 2005) tentatively classified it as a renewable resource.

Confirmation of the value and importance of soil is deeply engrained in the minds of Croatian men. Photo 2.1 shows the karst landscape near Primošten city in Dalmatia, which can be seen today at the UN headquarters in New York.

F. Bašić, *The Soils of Croatia*, World Soils Book Series,
DOI: 10.1007/978-94-007-5815-5_2, © Springer Science+Business Media Dordrecht 2013

Photo 2.1 Vineyard with "dry walls" typical of the Croatian karst—the "dry walls" built from the stone dug up during the clearing of the soil—historical testimony of the persistence and energy of domestic man in the fight for survival. There is truth in the poetic words that the soil is wetted by the sweat of the Dalmatian vine grower

As the pedosphere is a "sphere of interaction of all spheres" and as they are interdependent we support the ideas of Varallyay (2005) on equal treatment of soil with the other members of the "ecological triad": water–air–soil. It is evident that all these goods are equally important, but the soil (land) is the basis of one's personal property.

Many of the problems are generated by inappropriate land management at the "local level," and the consequences are reflected regionally, continentally and, ultimately, at the global level. According to historical and social policy acquis, modern civilization property rights are unquestionable, land is private property, but the problems generated by wrong land management are public ones (Urushadze 2002).

In Croatia there are 18 million land parcels situated on agricultural land representing the property of over 450,000 farm households, companies, and individual owners who do not live by agriculture, but their property right is unquestionable (Bašić 2006, 2007). It remains to be seen how and whether it is possible to monitor the management of these soils, and turn this management in the desired direction, thereby reconciling the rights derived from private property on the one hand and public interest on the other.

2.2 Soil Functions: Roles of the Croatian Pedosphere

As soil science as an autonomous natural science began and for a long time developed within the agricultural and forest sciences, the focus of interest was yield, which means soil fertility and its physical, chemical, and biological components. Yield was one of the criteria for land valuing and soil classification. The aim was usually maximal yield, with maximal use of machinery and consumption of agrochemicals including biocides. Under the pressure of data on the hunger of populations, in the center of interest of the world food market was food security, meaning the food production function of soil. All other functions were marginalized or ignored. Trends toward more intensive and specialized farming systems have very successfully increased the ability of mankind to ensure food security and feed the world, but, in some cases, at the expense of social and/or environmental goals (Blum 2002). One of the consequences of such a one-sided orientation was degradation of the environment—water (hydrosphere), soil (pedosphere), air (atmosphere)—as well as problems with food safety (BSE, *Escherichia coli* outbreaks). The agricultural scientists and decision makers should achieve an optimal balance between social, environmental, and economic objectives on the national, regional, continental, and global levels (Birkas et al. 2008).

Step-by-step with the affirmation of sustainability, well-known non-food functions of soil move into focus. Agricultural activities have evolved from a period of economically acceptable yield, to sustainable yield and today socially, economically, and environmentally sustainable yield of biomass for food, feed, timber, and biofuels. While sustainable agriculture is based on long-term goals and not a specific set of farming techniques, it is usually accompanied by a reduction of input in favor of managing on-farm resources. A good example is the reliance on symbiotic and/or nonsymbiotic nitrogen fixation from legumes instead of use of commercial nitrogen fertilizers. Low-input agriculture is only one of several alternative farming systems that are adaptable to sustainable agriculture. Low-input farming is based on a reduction, but not elimination, of commercial agrochemicals like fertilizers and pesticides. Croatian farmers accepted this opportunity primarily motivated by reduced costs, only very rarely to minimize any negative impact on the environment. Let us analyze the food and non-food functions of soils in Croatia, as appropriate policies in support of food security and safety, land tenure security, soil and water protection, and rural development are key elements for sustainability at the national level (Bašić 1998; Bašić and Franić 2003; Bašić et al. 2003).

2.2.1 Primary Production of Organic Matter: Soil is a Source of Food, Feed, Timber, and Biofuels!

The most important, irreplaceable, and primary function of soil is its productive function, its position as the initial and final link in the chain of bio-transformation, and its role in supplying plants with water, air and nutrients for photosynthesis as a key process for life on Earth. Varallyay (2005) recognized soil as the primary food source of the biosphere, the starting point of the food chain. As a spatially (horizontally and vertically) variable, temporally dynamic polydisperse system, soil can simultaneously satisfy—to a certain extent—the ecological requirements (air, water, and nutrient supply) of living organisms, the production of natural vegetation and the production of cultivated crops. He places this ability of soil under the umbrella of one unique property: soil fertility, which varies greatly and has changed considerably depending on natural factors and human activities, such as land use and soil management.

Water supply is a key issue in relation to water content in the soil, because it determines the strength with which water is retained in the soil, which the absorbing strength of plant roots needs to overcome. This process involves the entire root system, with special significance attached to the vast areas of root hairs, illustrated by the fact that for corn at 1 mm root length there are already 422 root hairs (Dubravec, Regula 1995). On the basis of the productive function of soil, which is a factor in maintaining cultural and natural vegetation, agriculture and forestry—two branches that form the backbone of the Croatian economy—supply Croatia with food, feed, fiber, and timber, and are calculated to provide sustainable production of biofuels. Of the total land area of Croatia, 3,212,816 ha or 56.7 % is used for agriculture, and 2,351,270 ha or 41.5 % of the land is used for forestry, which gives 0.74 ha of agricultural and 0.55 ha of forest land per capita (Bašić et al. 2001).

In spite of quite favorable agroecological conditions, yields of the main arable crops in Croatia are below the maximum possible (i.e., the biological potential of the various crop varieties and/or hybrids). The reasons for yield being below maximum (100 % of biological potential) are stated by Mihalić et al. (1981) to be dependent on the soil and these reasons are shown below expressed as percentages:

• Low natural fertility of soils and lack of amelioration	20 %
• Lower quantity or unfavorable distribution of precipitation	16 %
• Unsuitable soil tillage	13 %
• Unsuitable crop variety	16 %
• Unsuitable crop density	14 %
• Crop diseases and pests	10 %
• Other factors	11 %

This assessment was made 30 years ago, but comparing with the recent situation there is no change… or maybe there is, but in the wrong direction, because of decision makers (politicians) favoring the destruction of modern public farms, by fighting for electors, land privatization and fragmentation of already maximally fragmented, practically "atomized" land. Instead of increasing the national wealth by building the infrastructure for land reclamation they allow the destruction of what has already been built! Trees growing in canals for drainage on abandoned land are mature for cutting! (Bašić 2009).

About 95 % of the food that arrives at the table of human society is produced by the soil. The balance in terms of food security for humanity is far from satisfactory; we are still far from any prospective and effective solutions. In spite of these facts, soil is expected to assume the role of providing renewable, economic, socially and environmentally sustainable production of biofuels, which further increases the already (too) high pressures on soil (Tomić and Bašić 2011).

2.2.2 Environment-Regulatory Functions: Soil is a Regulator!

This group of complex functions includes climate regulatory functions, reception of toxic substances (soil is a receptor!), filtering, accumulation (soil is an accumulator!), and transformational activity (soil is a transformer!), between the atmosphere, hydrosphere, and the plant cover (biosphere). In other words, soils protect the environment, and especially humans, through protection of the food chain and underground drinking water reserves.

2.2.2.1 Climate Regulatory Function: Soil is a Source and Sink of Greenhouse Gases!

Soil is a source of emissions of greenhouse gases, primarily CO_2. Namely, soil is the final link in the chain of biotransformation of organic carbon, which results in CO_2 and water as final products—the same compounds that are used in the process of plant photosynthesis. This means that soil is also a sink of CO_2! Layers of soil that are completely saturated with water in the absence of oxygen undergo carbon transformations that end with the formation of methane—CH_4, a more effective greenhouse gas than CO_2. In addition, the transformation of nitrogen fertilizer in the soil results in the emission of NO_x, a quantity of which falls from the atmosphere after electrical discharges during summer rains. As a source of emissions of these compounds in the atmosphere, soil participates in the so-called "greenhouse effect" (Bašić 2009). Although the total content of organic matter—humus in the soil (humosphere)—is low, this negligible (1–3 %) humus is a national treasure of the utmost importance (Toth et al. 2007). Humus regulates chemical and biological processes, it is the food and energy source of soil micro-organisms, or, as stated by Mihalic (1997), it is the "fuel" for the "biological fire" in the soil as a reactor. Its positive impact on soil structure strongly influences the water–air relationship and the hydrothermic conditions of soil, with a great influence on soil fertility (Bašić 2007, 2009). The humus layer of the Earth (humosphere), according to Lal (2000, 2001, 2003), is the third largest "C-pool," and contains 23×10^{14} kg (2,300 giga tones—Gt—billion tons) of carbon dioxide. Globally, the total amount of organic carbon in the humosphere is three times greater than the above-ground biological mass. In the equatorial area it is nearly the same, but in arid-steppe areas this value is ten times higher in soil than in the above-ground mass. Conversely, the "C-pool" of the humosphere—pedosphere is directly associated with the "C-pool" of the biosphere (6×10^{14} kg = 600 Gt) and atmosphere (77×10^{13} kg = 770 Gt). A change in the contents of C in the humosphere of 1×10^{12} kg (1 Gt) corresponds to a change in the concentration of CO_2 in the atmosphere of 0.47 ppm. Thus, an increase of C in the humosphere (which can be achieved by sustainable management of soil) of 1×10^{12} kg (1 Gt) reduces the increase in CO_2 content in the atmosphere by 0.47 ppm. It is estimated that the concentration of CO_2 in the atmosphere by the middle of this century will increase by 50 %. There is no doubt that deforestation, plowing of prairies and steppes, and agricultural expansion in the nineteenth and twentieth centuries caused CO_2 in the atmosphere to increase to a level that may cause climatic changes on Earth. To illustrate this: it is estimated that in the USA the removal of natural vegetation to create arable land, the treatment of these soils and the creation of an agroecosystem caused the loss of between 3 and 5×10^{12} kg (3–5 Gt) of carbon. It has been calculated that about 9 % of the total CO_2 emitted in the EU originates from agriculture. Our estimation is that Croatian soil emitted 723×10^6 kg of CO_2 in 1995 (Mesić et al. 2006), and the total emissions from agriculture and agricultural manufacturers (machinery, fertilizers, pesticide application equipment) amounted to 3.6×10^9 kg of CO_2. Summing the amount of CO_2 emitted by agriculture and other sources, such as forestry, Croatia as a small state represents a small and "innocuous" source, whose "contribution" to the global "greenhouse effect" is a modest one. Conversely, we estimate that the passive form of carbon—durable humus in the soils of Croatia—sinks 225×10^6 kg of carbon annually (Bašić 2007).

2.2.2.2 Soils as Natural Transformers of Various Pollutants: Soil is a Natural Transformer!

Organic substances accumulated in soil are exposed to (micro)biological destruction which ends with the two substances that were at the beginning of the cycle—in photosynthesis, i.e., CO_2 and water. In this way, the soil represents the first and last link in the biological cycling of matter and energy. Thanks to the transformation function of the soil, all postharvest residues in agricultural soils are transformed into the organic matter of soil—humus, including leaves of deciduous trees and conifer needles in forest ecosystems (Martinović 1997).

Similarly, soil transforms all organic pollutants such as PAH, residues of pesticides and petrochemicals into harmless end-products (Photo 2.2).

2.2.2.3 In its Function as a Natural Filter, Soil Preserves Drinking Water!

In its function as a universal cleaner (filter) of rainwater, soil protects underground drinking (potable) water from pollution. The importance of this function is illustrated by the fact that 65 % of the EU population uses drinking water from groundwater (Nestroy 1996). The effect of filtration depends on soil cation exchange properties. The cation exchange process or adsorption of cations is the best known and most important way to protect groundwater from pollution. Specifically, the colloidal complex of soil contains humus and clay. These are the most important negative charged colloids in the soil through which it has the ability to adsorb ions of opposite charge (cations) by forces strong enough to protect against leaching to groundwater and at the same time weak enough for sorption through the roots. The cation exchange capacity (CEC) of the active surface of 1 g of montmorillonite clay minerals is greater than 700 m^2, which is the seat of a negative charge, followed by illite clay minerals, with the smallest CEC capacity belonging to kaolin clay. Cations of plant nutrients but also positively charged radicals and organic compounds, which are initially retained and then subjected to microbial degradation, are adsorbed on this surface.

Biological sorption refers to the binding of environmentally hazardous substances—pollutants in living organisms, particularly plant biomass. In this way soil prevents the leaching of these substances into groundwater and the soil is cleaned of these substances if that plant mass

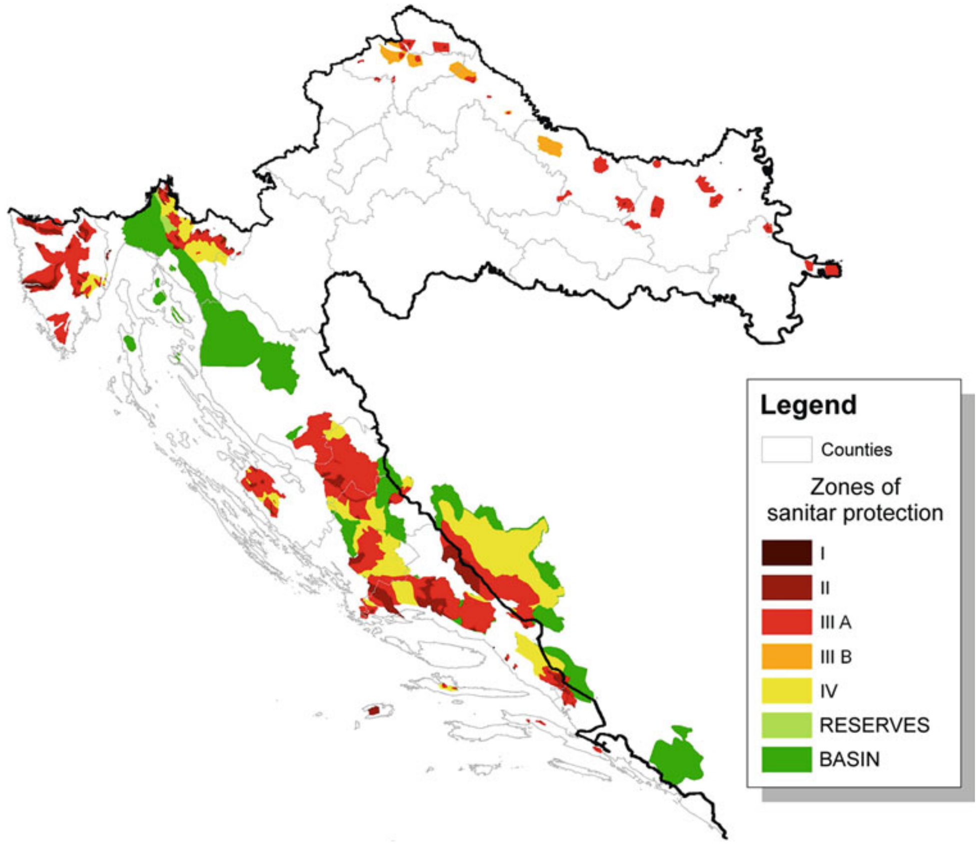

Fig. 2.1 Water protection areas. There are four zones of protection of water; the I one with strongly reduced any activities risky for water eutropication, the IV as most liberal one

is removed from the soil. In this way, by choosing plants that have a selective ability to accept certain pollutants such as heavy metals, soil can be cleaned of contaminants by a phytoextraction–phytoremediation process.

According to soil characteristics, the capabilities and effectiveness of this filtration in Croatian territory differ in the following areas.

- *River basin of the Drava River*. This important area, especially in the western and central parts, is dominated by soils of light texture—gravelly and sandy, very permeable to water with low content of colloids—clay and humus. Pollutants that fall on such soils quickly enter and penetrate into the soil and reach the groundwater. However, these soils also quickly remove pollutants from the soil and clean the water.
- *The soils of the Sava River basin* differ by a significantly higher contents of clay, which accepts and strongly retains pollutants. Because of the poor permeability, pollutants slowly penetrate to groundwater. However, once the soil is defiled by pollutants originating from the upper layers, there is a problem as these soils are slowly polluted but also cleaned slowly. Naturally, in the valley of the river basin, light, sandy soil and gravel is found, as can be seen along the Drava, and also heavy, vertic soils.
- *The karst area* has a special karst hydrology. The quantity of water in numerous rivers and smaller water flows does not correspond to the total surplus of rainwater, which disappears into the highly permeable karst underground. The underground hydrological system is very sensitive and vulnerable; the high-quality drinking water should be preserved from pollution by agriculture—i.e., by nitrates, residues of pesticide, plant nutrients, and heavy metals. Particularly sensitive and vulnerable are soils of karst fields, which are used for intensive farming, and where groundwaters are close to the surface. The spatial distribution of water protection areas is shown in Fig. 2.1.

The most serious polluter of underground drinking water emitted from the soil is nitrate from nitrogen fertilizers, but without nitrogen a high yield cannot be achieved. This problem of world agriculture remains an unresolved issue. In some areas the nitrate from the soil washes away in the post-harvest period after removal of the previous crop, for example in the northern USA states around the Great Lakes. To remediate this problem from sowing to harvest, the use of special "cover crops" has been suggested, whose task is the uptake of the nitrate which remains after removal of the previous crop, to avoid leaching and eutrophication of water in the lakes. Elsewhere, it is wise to consider the limitation of the dose, timing, or form of application of nitrogen fertilizers for the major arable crops. Working as a powerful buffer, the soil system inactivates all substances that rapidly enter its mass or that were released after mineralization of organic

Photo 2.2 Incineration of crop residues is an unacceptable practice. After harvesting of corn a few tons of crop residue remain, from which humus is formed via microbiological processes. The process is desirable because less of the carbon is released as CO_2 and there is greater C sequestration in humus

Photo 2.3 Many bumps on the roots of soybean in the heavy gley soil in the area of Daruvar show the great success of inoculation. These are really a small "biological factory" of nitrogen

matter and thus prevents the stress caused by change in the soil, and shocks to the biosphere—pedoflora and pedofauna. It buffers the acidic components of the soil by using cations such as Na^+, K^+ Ca^{++}, Mg^{++}, etc., and provides resistance to sudden and large changes in soil chemistry. Buffering can be performed by other mechanisms, such as the binding of foreign substances via the colloidal cation exchange complex.

In its biological regulatory function, soil is a habitat and gene reserve for a number of micro- and macro-organisms, or pedoflora and pedofauna; it represents the start and end of biological cycling, is a gene reserve, and is the foundation of biological diversity. The number of living organisms below the surface is many times higher than that on the soil surface.

This is eloquently illustrated by the fact that good, fertile soil in the arable layer contains about 25 t/ha of living organisms, including a number of extremely useful ones, such as symbiotic (genus *Rhizobium)* and nonsymbiotic nitrogen-fixing bacteria (*Azotobacter*, *Clostridium pastorianum*) that use elemental nitrogen from the air and transform it into a plant-available form. This ability of symbiotic fixing bacteria is used in practice for inoculation of legume crops (Photo 2.3). Redžepović (2008), who used selected *Bradyrhizobium japonicum*, which can provide the plant with up to 180 kg nitrogen per hectare, presented outstanding results in this field. The economic value of this work is reflected by the fact that the bacteria on soybean tied 132 kg/ha of nitrogen and reduced the requirements of energy for synthesis of nitrogen fertilizers.

Environmental benefits of soil inoculation using nitrogen-fixing inocula are priceless, because they significantly reduce or completely stop nitrogen from leaching into groundwater and streams (Huić-Babić et al. 2008). The fertile soil has a high biological activity and biodiversity. In addition, fertile soil increases the total number of organisms and their diversity. Biological degradation of soil indicates the degradation of physical and chemical characteristics of soil. Soil's rich life represents a "genetic reservoir," i.e., a vast wealth of genes, from which in the future genetic material will be derived for the different future needs of agriculture. Biotechnology is seeking a way to manage beneficial soil biological processes, moving them in a desired direction. Options in this regard are unpredictable and virtually inexhaustible (Butorac 1999; Bašić and Herceg 2010).

2.2.3 Soil Provides the Space for Settlements and Infrastructure: We are Living, Producing, Transporting, Playing… on Soil!

Soil characteristics have had a major influence on land use, today and in the past. Specifically, the pedosphere provides

Photo 2.4 On the island of Korčula, the settlements were built outside the fertile karst fields. Fertile soil in the field is a guarantee of continued survival

space for agriculture, forestry, expansion of settlements, urban areas, roads, recreational areas, and finally space for waste management. For example, in EU 27 rural area dominates, about 2 % of total area is under buildings and roads, with a range of only 0.5 % in Ireland, 12 % in Hungary, 13 % in Italy, and as much as 14 % of the Netherlands. In Croatia, settlements cover 0.8 % of the total land area, with the least in the mountain region—0.2 %, and the most in the Pannonian Croatia—1.2 %. It is unnecessary to mention that the land area is considered permanently lost for the primary purpose of the soil—the production of organic matter—and treated as an irrevocable—the irreversible loss of soil. It is absurd to demand and expect a complete halt to this process, but it should certainly be brought under effective control. The most efficient tool to achieve this aim is public awareness.

Soil was not taken into account for the selection of road routes, the position of livestock farms, or the creation of settlements—urban residential areas (Photo 2.4). When making decisions on the routes of roads or highways a solution should be the shortest possible route in terms of intersection with valleys or river valleys with fertile soils. For those parts of a route, the use of indoor sewerage systems is reommended, to collect and deposit pollutants. Poor decisions on location can have permanent and far-reaching consequences for the use of these facilities. One good example is certainly among the best in Europe, the route of the Zagreb—Split highway.

2.2.4 The Function of Soil as a Medium for Waste Disposal: All Communal and Industrial Wastes Terminate on/in Soil!

Waste disposal is only one of the spatial functions of soil. The effectiveness of a landfill depends greatly on the soil on which it is located, and the choice of location is very delicate and a highly professional matter. Elimination criteria for selection of the best or least unfavorable locations are well known, and most relate to the closeness of different objects, protected natural areas, water protection areas, cultural monuments, forests of special value, or areas with endemic plants, etc. Regarding the soil, the basic requirement for good accommodation is the location of the landfill in an area that excludes the possibility of emissions of pollutants into the environment, especially into water, but also air or biosphere, i.e., the plant life at or around the landfill. Moreover, to meet that condition, the soil should contain a large amount of colloidal substances, i.e., clay and humus, and in particular those with a high adsorption capacity, such as montmorillonite clay and "mature" humus of high quality and cation exchange capacity. If nature has not fulfilled this requirement, one achieves the same by placing layers of clay on the bottom of the landfill, impermeable to water and perfectly retaining contaminants. The total production of waste in Croatia is 13.2 $\times 10^8$ kg annually, of which 1.2 $\times 10^8$ kg is

Photo 2.5 Nova Gradiška municipal waste landfill situated in a fertile field. Soil under the landfill is not contaminated by the usual pollutants

municipality-based (270 kg per dwelling) and 1×10^8 kg is of hazardous varieties (Kučar-Dragicevic 2006). The EU-27 member states produce annually around 2×10^{12} kg of waste, of which about 4×10^{10} kg is hazardous waste, and 7×10^{11} kg crop residues from agriculture. Counting the total area of the EU-27 and the number of inhabitants, area per capita is 0.86 ha of land area. In terms of area of land, there is less than 4×10^3 kg solid waste, or 2.15 kg/m^2, with a trend of steady growth of around 10 % annually. Part of the waste is incinerated and 67 % goes to landfills. Both procedures cause environmental damage. Landfills are placed on agricultural land, and a discharge from the landfill can be a source of pollution of soil, water, and air, which threatens the health of humans, livestock, and wildlife.

In Croatia crop residue is not treated as waste. Because of the chronic "hunger" of Croatian soils for organic matter—humus, there is a law which forbids the burning of crop residue; instead, the residue is plowed in, using N fertilizers to balance the C:N relation, to allow microbiological transformation into humus of high quality.

From the standpoint of soil protection, the best procedures are to avoid entirely the risk of soil pollution by harmful substances, primarily heavy metals, PAHs, dioxins, pesticide residues, radionuclides, and mineral hydrocarbons (Photo 2.5). For this reason, it is not permitted to allow any substance to enter the soil, including compost, without analyzing the content of harmful substances.

2.2.5 Soil is a Significant Gene Reservoir: A Larger Biomass Lives in Croatian Soils than in the Above-Ground Biomass: Soil Diversity = Biodiversity!

Soil is a habitat and significant gene reservoir for the biosphere and an important medium of biodiversity. A considerable heterogeneity of organisms live in or on the soil or are closely related to the heterogeneity of the pedosphere. This function has particular significance in the stabilization and conservation of Croatian biodiversity, which is very high, taking into account such data as the fact that about 2,250 plant species live on Velebit mountain.

2.2.6 Soil in the Function of Landscape Shaping: Soil is the Base of Croatian Natural Beauty and an Emotional Foundation of Patriotism!

Landscape is the "emotional foundation" of patriotism and the feeling that man belongs to an area. A key function in its formation and maintenance is soil, because it determines landscape features and the benefits of options for possible forms of land use. Man has left "impressions," i.e., "messages," on the landscape. Changing the natural vegetation and entering into the space created by agriculture is the "cultural landscape" created through natural conditions,

Photo 2.6 Removal of natural forest vegetation, changing the natural surface and building terraces has led to a new shape of surface—an anthroscape—in settlement Stipančići near Bol on the island of Brač

which enriches the space, making it even more beautiful, affordable, and attractive for rural tourism. Protecting the landscape diversity of each area is inseparable from the protection of soil in the same area. Anthropogenic influence may be so radical (for example surface terracing) that a natural landscape completely changes into an anthroscape (Photo 2.6).

Fighting for survival, our hard-working ancestors, without any mechanization, prepared a "flowing anthroscape" as a mute witness of past living conditions on Croatian islands (Photo 2.7).

2.2.7 Soil as a Source of Raw Materials: Soil Supports Industrial and Other Production!

Soil is an important source of raw materials, especially for the construction industry. Examples include the excavation of stone, soil, or loess for brick, the digging of clay for ceramic crafts and industry, the use of sand and gravel as building materials, bauxite from red soil (terra rossa), or the use of peat as a raw material for the production of substrates for closed spaces (greenhouses, flower pots). Exploitation of these raw materials is closely monitored in terms of soil damage, for example through opencast mining, or by covering fertile soils with these materials. All mining works, including of course oil and gas exploitation, contribute more or less to soil damage. For example, this happens by removing or damaging the surface, fertile soil layer to accommodate the plant for the exploitation of mineral raw materials, by the construction of access roads that change the natural hydrological conditions, or through the burying of pipelines for transportation of oil and gas. It is estimated that approximately 0.05 to 0.1 % of the land area in Europe has been damaged by opencast mining, and this is not a small area. In Croatia, there are 593 localities used in mining exploitation, which cover an area of 4054 ha, or 0.07 % of the total area (Photo 2.8).

The law specifies a process of soil recultivation and remediation. The obligation of the mining industry is to return the soil to the same state as it was in before mining began. Gas exploitation is also an environmentally hazardous industrial process, because mineral hydrocarbons are mixed with various pollutants, like mercury, mercaptans, H_2S, enormous quantities of CO_2, etc., which must be collected and eliminated from the environment (Photo 2.9). The state of the environment—agroecosystem and forest ecosystem—around a gas refinery is constantly monitored.

2.2.8 Conservation: The Archival Function of Soil: Soil is a Conservator of Croatian Natural and Human Heritage!

Soil conserves information on the conditions of soil genesis and geogenic processes and this information is useful for the interpretation of soil evolution. In addition, traces of

Photo 2.7 Numerous walled fields—in the past cultivated arable land or "sailing gardens"—are today pastures totally unused, on an Adriatic island

Photo 2.8 Oil exploitation equipment on arable land of the Sava River valley (*photo* I. Kisić)

plant life, such as pollen and paleontological material, allow the reconstruction of living conditions of a given area in past times. Soil is an information source allowing the reconstruction of human life and its activities as witnessed by the archeological remains covered by soil and protected from devastation and destruction. For the dating of historical events and changes, archeology is based precisely on these residues.

Completing the explanation of soil functions, the goods and services that are provided by soil are presented in Fig. 2.2, as demonstrated by Blum (2004).

Photo 2.9 After years of oil production the ground is covered with infrastructure and when the wells are exhausted, there follows a procedure of recultivation, i.e., returning the soil to its original condition, as seen at the first oil field in Croatia—Gojlo, near Kutina city (photo: I. Kisić)

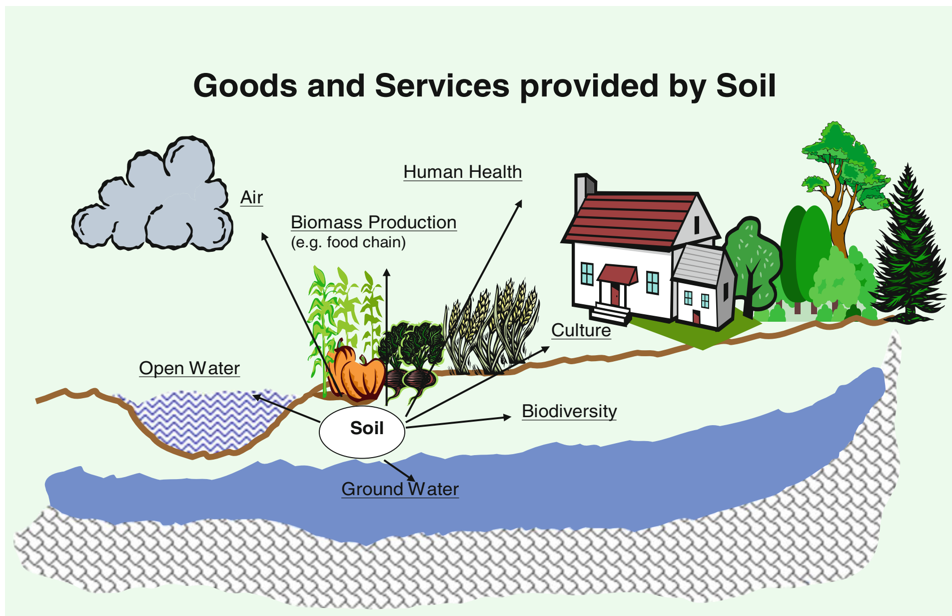

Fig. 2.2 Soil functions (Blum 2004)

2.3 Concept of Multifunctionality (MFCAL) in Land Management

Global trends are fully confirmed by Blum's words. At the crossroads of the millennium—1999—when each message has a "double effect," the functions of agriculture and soil were defined by the International Conference organized by FAO and the Government of the Netherlands in Maastricht, entitled "Multifunctional Character of Agriculture and Land—MFCAL (Mesić et al. 2000). The concept proposes a radical change in the centuries-old criteria for evaluation of soil and the efficiency of agriculture based on quantity and quality of the yield. Instead, after determination of management impacts on other spheres, the focus has been redirected onto "non-food" functions of soil: first, the regulatory function in terms of emissions of "greenhouse gases," the transformation of pollutants, water filtration capacity, protection of water from pollution, etc. It also has an important spatial focus—accommodation of industrial plants, roads, settlements, waste dumps, environmentally, aesthetically and economically acceptable design and protection of landscape, the role of soil in the protection of biological resources as sources of raw materials, and the protection of archeological heritage (Varallyay 2000). The concept is based on the fact that in soil management, depending on the circumstances, any of these roles can become dominant, and everything else may be marginalized, while some are also mutually exclusive.

The problems of soil degradation are caused by the competition that exists between forms of soil use, giving preference to some soil functions, while ignoring or marginalizing others. The new concept of sustainable land use and protection of soil can be defined as the spatial and temporal harmonization of all soil functions in soil and land use, minimizing irreversible ones. Competences for this concept are partly within the scientific realm but more so within the public and decision-maker (politician) spheres.

Of course, not all the described soil functions are carried out simultaneously, and some are mutually exclusive or in competition, which is an important issue for sustainable land management, because one should perhaps favor a second function or marginalize others.

Taking into account all the functions of soil, let us conclude that the soils of Croatia are an excellent natural treasure, a treasure that should be recognized, researched, explored, protected, evaluated and used in accordance with the principles of sustainable development for the prosperity of the nation, and the welfare of its present and future generations.

The importance of soil for Croatia is described by Prof. Gračanin, whose inspirational words are printed under the title of the previous chapter.

Of course, the importance of soil as a natural resource and a powerful regulator of matter and energy flows in all terrestrial ecosystems is recognized in professional circles all over the world, but in the education system and public awareness it is not yet prominent enough. Identification of driving forces and the main processes of soil degradation and their inventory as a precondition for an efficient soil protection is the focus of research activities of soil scientists on national, regional, and EU levels, which means a continental and finally a global level. Croatia started with these activities on regional; Alps-Adia, Danube River basin and Mediterranenean level. For the definition of a considered land policy, including land management and soil protection, the Joint Research Centre (JRC) EU in Ispra, Italy established a Soil Bureau with top professionals, who engaged scientists from all European countries and formed a European Soil Bureau Network—ESBN, with the main task of creation of a European soil policy. Within ESBN, numerous projects have been realized along the lines of knowledge of the soil, and its degradation and protection. Of epochal importance is the first edition *Soil Resources of Europe* (Jones et al. 2005), followed by *The Soil Atlas of Europe* (2005) and the publication on soil degradation (Van-Camp et al. 2004) with six volumes and almost 900 pages.

ESBN prepared the text of a thematic strategy for soil protection, which would be promulgated in the form of a Directive of the EU obligatory for all member states.

There is no doubt that multifunctionality is a new concept, but it already has much influence nowadays and even more on the future of soil science, since this science is at the crossroads of its development, as recognized in the book with the encouraging title: *The Future of Soil Science* (Hartemink 2006). This book introduces the view of selected soil scientists on this sensitive topic. There are two clearly differentiated tendencies. One of them deals with respecting the importance of environment/regulatory ("non-food") functions of soil. This is the case with soil scientists in Europe and developed countries; they expect to see the future of soil science within the environmental sciences. They insist on soil monitoring and "green energy" and more or less accept soil (land) as an essential resource for (environmentally, socially, economically) sustainable production of biofuels. The other tendency is a focus on productive functions of soil (food) and here we see soil science as agriculture and forestry, putting pressure on achieving ever higher yields of growing crops and forestry. Croatian soil scientists are in a transitional position, deep in traditional "food-oriented" ideas but active in research on non-productive ones. The awareness of decision makers and public of the importance of soil is far below that necessary for significant changes. Both tendencies promise a permanent increase of anthropogenic pressure on soil, which means an increase of all processes of land degradation. These processes are additionally stimulated by recent chaotic climate changes.

Of course, multifunctionality of soil needs new, adequate soil analysis—methods and interpretation, using the newest laboratory equipment, computer and nano-technology. Along these lines one might expect a re-orientation of soil analysis and especially of its interpretation. In which way? First, the main criterion for the evaluation of the productive functions of a soil should be the state of all physical, chemical, and biological properties of the rhizosphere of soil and its dynamics. New methods should be more and more in situ (field)-oriented. For example, the redox potential of soil tells more about the state of soil than do single data on pH, CEC, or humus content obtained by the best analysis. In other words: the differences between soil properties obtained from the analysis of a soil sample and the actual suitability of soil in the rhizosphere for plant growing are too big! There is a very wide field of multidisciplinary activities for finding efficient and acceptable solutions to this problem. Correct use of computer technology is of valuable support, but it can lead to a "virtual sphere of soil science". We are witnesses of the consequences of similar tendencies in the world's financial system.

It is true that throughout history, soil (land) was at the root of radical historical changes, from forming the first civilization, Moses coming back to the promised Holy Land, followed by the slave-holder system, feudalism, up to capitalism with the market economy, of which the recent "fruits" are "yellow-colored European fields" of oil rape and/or sunflower for biofuels. By putting so much pressure on soil, mankind is cutting the branch on which it is seated. One can say: there is nothing new on "the blue planet"! It is to be expected that one of the consequences will be that the main occupation of soil science in the next generation will be soil-protection oriented! But contrary to the previous generation, the "maneuvering space" for action is going to be more and more reduced.

In this context we believe that new changes will follow, first in land tenure relationships. It is true that private ownership of land is the basis of recent society and the market economy. But there are already numerous interventions of society in this relationship: from incentives in agriculture to completely "non-market" interventions (similar interventions in the financial system have catastrophic consequences for the global economy). The interventions are on the global level (such as declarations on protection of some sites, protection of biodiversity), the continental level (directives and strategies of EU), and the national level (acts and regulations on protection of protected natural area, water protection areas, good agricultural practices, etc.). Therefore, landowners have to accept all regulations in spite of the fact that it reduces their private property rights. Soil (land) is private, but almost all activities on the land are regulated by society. The mechanism of incentives is compensation, or paying satisfaction of farmers and landowners, but at the same time it disturbs the market relationship on the global market of agricultural products. As we see, because of the vital importance of soil functions it is an unquestionable fact that land management is a very responsible job, which needs efficient use of complex knowledge of soil to begin with. The minimum demand of society is to look for clear and, from the point of view of soil protection, efficient (sustainable) land management. For driving a car it is necessary to have a license, but for land (soil) management it is not! The solution is to change land tenure relationships—land property rights. Just like air and water, as a member of the "ecological triad" soil needs to be a public good and property. Land management for all soil (land) users, including the farming system—crop rotation—has have to be "soil friendly", that is to say, responsible toward society. But products of soil (land)—food, fuel, timber etc.,—are in every case private property and we have competition on the free market. A precondition for a correct land use would be some qualifications, which would include a clear defined minimum of knowledge of soil for land users. In other words, it should be the rule that every square meter of land (soil)—agricultural, forest, urban—has to be under professional supervision of the owner (society). It includes obvious monitoring of soil and changes in land management according to the results.

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