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Functions of soil for society and the environment

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Abstract

Six key environmental, social and economic functions of soil are described, as well as the reversible and irreversible threats, caused by their uses. Sustainable use of soil is defined by the temporal and/or spatial (local or regional) harmonisation in the uses of the 6 functions, excluding or minimising irreversible ones, which is not a scientific but a political task.

1. Soil functions

Soil is one of the most important parts of the natural environment and largely non-renewable. World-wide, all economies depend on the goods and services provided by the natural environment. Soils as a natural resource perform a number of key environmental, social and economic functions.

1.1. *Ecological functions*

1.1.1. *Biomass production*

Production of biomass, ensuring food, fodder, renewable energy and raw materials. These well-known functions are the basis of human and animal life (see Blum & Eswaran 2004).

1.1.2. *Protection of humans and the environment*

Filtering, buffering and transformation capacity between the atmosphere, the ground water and the plant cover, strongly influencing the water cycle at the earth surface, as well as the gas exchange between terrestrial and atmospheric systems and protecting the environment including human beings, against the contamination of ground water and the food chain (see Figure 1). This function becomes increasingly important because of the many solid, liquid, or gaseous, inorganic or organic depositions on which soils react through mechanical filtration, physico-chemical absorption and precipitation or micro-biological and biochemical mineralisation and metabolisation of organic compounds (Blum 1998a). These biological reactions may also contribute to global change through the emission of gases from the soil into the atmosphere, because globally, the total pool of organic carbon in soils is about three times higher than the total organic carbon in the above ground biomass and about twice as high as the total organic carbon in the atmosphere.

Under this aspect, soils are a central link in the biotransformation of organic carbon and continually play a role in releasing CO_2 and other trace gases into the atmosphere. These gases are very important for processes of global change, which in this case involve large-scale feed-back of many localised small-scale processes. As long as these filtering, buffering and transformation capacities can be maintained, there is no danger to the ground water or to the food chain. However, these capacities of soils are limited and vary according to the specific soil conditions.

1.1.3. *Gene reservoir*

A biological habitat and gene reserve with a large variety of organisms. Soils contain more species in number and quantity than all other above-ground biota together. Therefore, soils

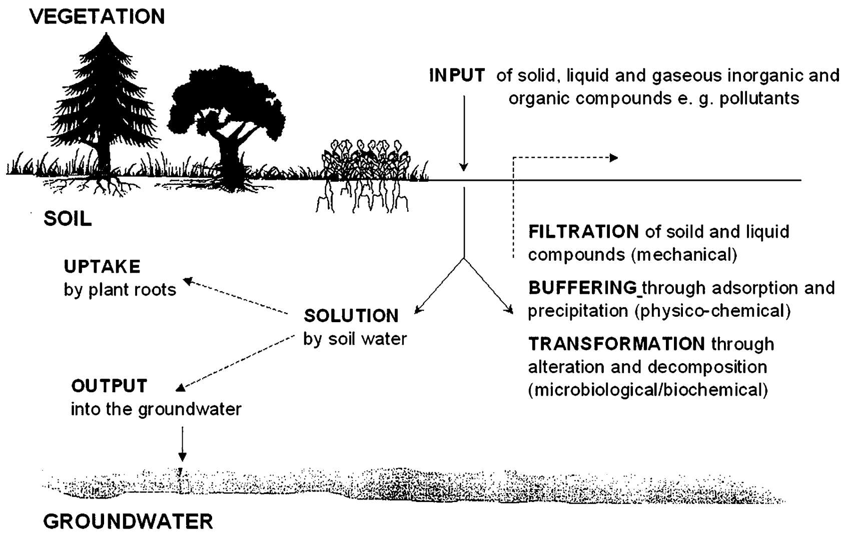

Figure 1. Soil as a filter, buffer and transformation system between atmosphere, biosphere and hydrosphere (acc. Blum 1996).

are the main basis of biodiversity. Human life is extremely dependent on this biodiversity, because we do not know if we will need new genes for maintaining human life from soils in the near or the remote future. Moreover, genes from the soil become increasingly important for many technological, especially biotechnological and bioengineering processes.

1.2. *Non-ecological functions*

In addition to the ecological functions, soils have three other functions, more linked to technical, industrial and socio-economic uses.

1.2.1. *Physical basis of human activities*

They are the physical basis for technical, industrial and socio-economic structures and their development, e.g. industrial premises, housing, transport, sports, recreation, dumping of refuse, etc. One of the main problems in this context is the exponential increase of urban and peri-urban areas, including transport facilities between them. This is not only true for Europe, but also for other continents, and especially for countries in development in Africa, Latin America and Asia.

1.2.2. *Source of raw materials*

Soils are a source of raw materials, e.g. clay, sand, gravel and minerals in general, as well as a source of energy and water. Raw materials are the basis for technical, industrial and socio-economic development.

1.2.3. *Geogenic and cultural heritage*

Last but not least, soils are important as a geogenic and cultural heritage, forming an essential part of the landscape in which we live, concealing and protecting paleontological and archaeological treasurers of high value for the understanding of our own history, and that of the earth.

In view of the soil as an absolutely limited resource, which cannot be extended or enlarged, the use of these six main functions of soil and land, which is often concomitant in the same area, becomes a key issue of sustainability. Under holistic aspects, soil or land use can be defined as the temporarily or spatially simultaneous use of all these functions, although they are not always complementary in a given area.

2. Sustainability of soil use

2.1. *Interaction and competition in the use of different soil functions*

For understanding the role of soil for society and the environment under the aspects of sustainable development, it is necessary to define the interactions and competitions which exist between the uses of soil functions and their uses in space and time. In this context, three different categories of interaction and competition can be distinguished.

2.1.1. *Soil use for physical infrastructure*
Exclusive competition between the use of soil for infrastructural development, as a source of raw materials and as a geogenic and cultural heritage on the one hand, and the use of soil for biomass production, filtering, buffering and transformation activities or as a gene reserve on the other hand. This becomes evident by the sealing of soils through urban and industrial development, e.g. the construction of industrial premises, houses, roads and sporting facilities, or when soils are used for the dumping of refuse, all this being known as the process of urbanisation and industrialisation, thus excluding all other uses of soil and land (see Figure 2). In this context, the exponential increase of urbanisation on a worldwide level is one of the main indicators for irreversible soil losses, with unsustainability in soil and land use in the long run. The process of sealing of soils is still very prominent in most of the European countries, and leads daily to severe soil losses.

2.1.2. *Soil use for agriculture and forestry*
A second category of competition exists through intensive interaction between infrastructural soil/land uses and agriculture and forestry. As shown by Figure 2, the scale of which indicates the intensity of interference, which significantly contributes to the problem of soil contamination and pollution, because all these linear and point sources are loading local soils with contaminants via three different pathways: through atmospheric deposition, on waterways and through terrestrial transport (see Figure 3).

Figure 3 illustrates the many possible interactions between infrastructural soil and land use on the one hand and agriculture and forestry on the other hand. This is especially true for densely populated areas in Europe and other densely populated regions of the world. In this context, it also seems necessary to point out that soils are the last but one sink for many inorganic and organic depositions, the last one being the bottom of the oceans. In Figure 3, different forms of loads can be distinguished: inorganic and organic depositions from traffic and transport and from urban and industrial activities. Most of these loads, such as severe acidification, pollution by heavy metals and other elements, pollution by xenobiotic organic compounds, severe salinisation and alcalinisation, as well as deposition of non-soil materials, are more or less irreversible, because soils act as a sink (Blum 1998b). Irreversibility is defined as the non-reversibility by natural forces or technical remediation measures

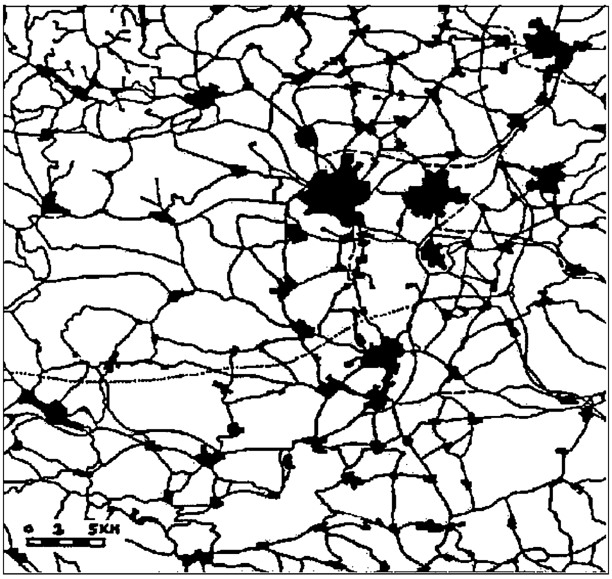

Figure 2. Sealing of soils and landscapes by urban and industrial development (Baar region in south-western Germany).

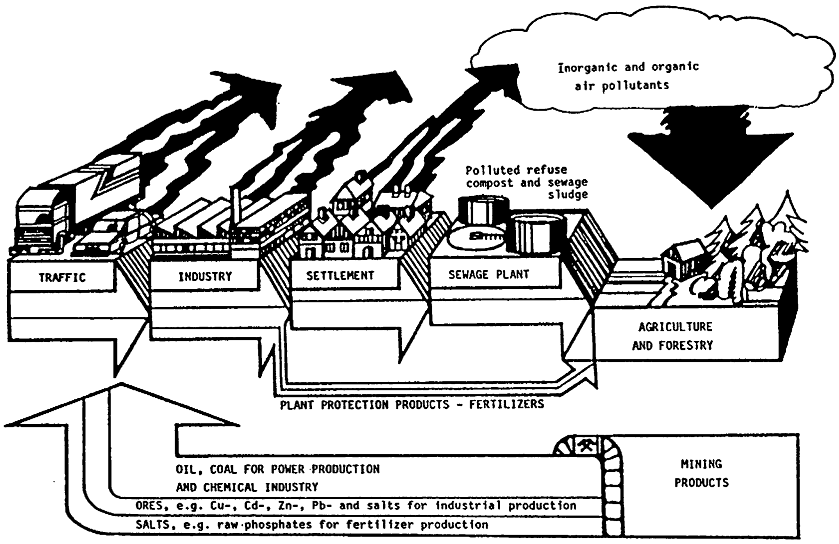

Figure 3. Soil contamination and pollution through excessive use of fossil energy and raw materials (acc. Blum 1998b).

within 100 years, a time span which corresponds to about 4 human generations.

Only few processes of soil degradation, such as superficial compaction or the contamination by biodegradable organics or by small amounts of heavy metals, can be regarded as reversible by technical measures or by natural remediation, e.g. bioturbation and bioaccumulation processes (Blum 2000). Some of the adverse effects of transport, urbanisation and industrialisation on agricultural and forest soils are exemplified in Figure 3.

2.1.3. *Ecological soil use*

A third form of competition also exists among the three ecological soil uses themselves, as shown in Figure 4. Waste and sewage sludge deposition on soils and dredged sediments as well as intensive use of fertilisers and pesticides in addition to the deposition of air pollutants (see Figure 3), may have a negative influence on the ground water and the food chain, surpassing the natural capacity of soils for mechanical filtering, chemical buffering and biochemical transformation. This is specifically true for high input agricultural systems. In this context, it should be remembered that agriculture and forestry do not only produce biomass above the ground but also influence the quality and quantity of the ground water production underneath, because each drop of rain falling on the land has to pass the soil before it becomes ground water.

Such problems are well-known for many parts of the world, where contamination of the ground water through nitrates, pesticides and other chemical compounds from the use of fertilisers, pesticides and the deposition of sewage sludge and waste compost were analysed. When the ground water is used as drinking water, the competition between the production of food and fibre above ground and the production of ground water underneath is a competition between the satisfaction of human basic needs.

In many areas of the world, especially in Europe, conventional agricultural production becomes increasingly controlled by quality standards for drinking water. It is easier to transport and sell food and fodder than to do the same with the necessary amount of drinking and household water.

3. Sustainable use of soil functions

The sustainable use of soils is only possible by a temporal and/or spatial (local or regional) harmonisation in the uses of the cited six soil functions, excluding or minimising irreversible uses, e.g. sealing, excavation, sedimentation, acidification, contamination or pollution, salinisation

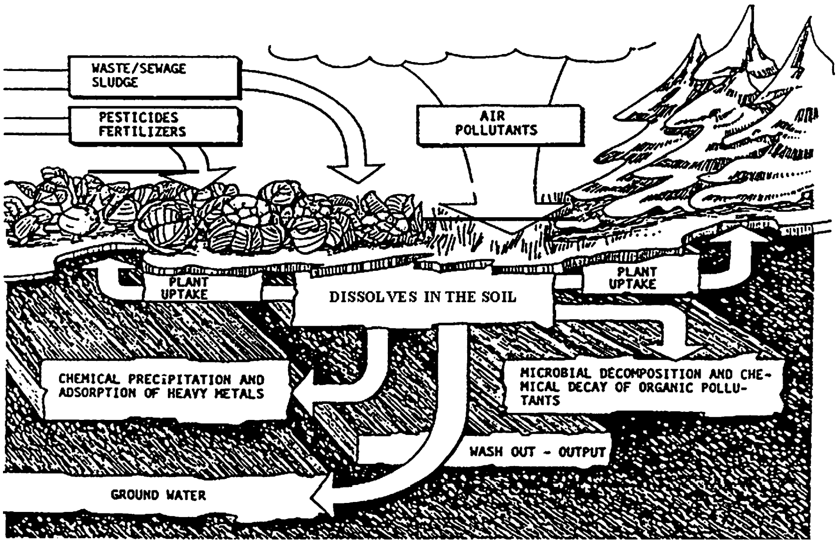

Figure 4. Competition between the production of biomass and groundwater and groundwater and the maintenance of biodiversity, due to pollutive depositions and the use of fertilizers and plant protection products (acc. Blum 1998a).

and others. This definition includes the dimensions of space and time. The final goal must be to provide multiple functions for the well-being of humans and for the environment.

The necessary harmonisation of the uses of the six soil functions is not a scientific but a political issue, which means that all people living in a given area or space should decide which soil functions they will use at a given time and/or at a given space (by a top-down or a bottom-up approach). Scientists only have the possibility to develop scenarios and to explain which causes and impacts may occur when different options are put into function.

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