Arable land at the border of Pulawy, Poland

Soils in and around our Cities

They deserve our Attention and Appreciation

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INTRODUCTION: SOILS ARE ESSENTIAL FOR THE ECOSYSTEM AND FORM THE BASIS OF LIFE

Soil, the thin skin of the Earth, is one of the most important compartments of the ecosystem and the basis of life. The genesis of soils depends on the parent rock material, climate, slope and time allowed for it to form. It takes a long time until soil one metre deep is formed through physical and chemical weathering and biotic processes. In Central Europe it takes around 100 years to produce 1 cm of soil. We can therefore say, in our human perception of time, that **soil is a non-renewable resource.** This non-renewable resource, endangered by sealing, erosion, compaction or pollution provides many services for us and the ecosystem. Soils with a variety of soil organisms are the big transformers ensuring cycling of nutrients, organic matter and water.

Profile of podzol soil

Currently 7 billion people live on our planet and nearly 100 % of our daily food is dependent on crop production on our soils. Because the global population continues to grow, the human population will become more and more dependent on soil availability and its fertility.

Currant plantation near urban residential area Bratislava – Rača, Slovakia

But not only fertile and productive soils play an important role and deserve protection. Soils with often extreme properties, low in nutrient status, wet, shallow or dry are indispensable reservoirs of rare plant and animal species and therefore essential for biodiversity.

Purity of groundwater and drinking water clearly depends on soils, acting as filters and a buffer for contaminant substances. Furthermore, without retention of precipitation water, the surface run-off would cause flooding after each major rainfall.

Soil is not only the life basis but a habitat for a multitude of soil organisms – from bacteria and fungi to earthworms and moles. They all need soil as a habitat and play a role in the functioning of the ecosystem. Not only the beautiful kingfisher or the majestic tiger deserve our attention. The humble earthworm, the hard worker in the dark, also needs and deserves protection and our respect.

Soil is a specific type of book full of information about its own history, the development of nature and landscape and sometimes human history. The Celts or Romans are still present through their marks left in the soil while the analysis of pollen collected in peat soils tells us about the climate and vegetation present thousands years ago.

We have to realize that the big global problems we have to deal with, such as climate change and energy supply, are closely connected to soil. Soils are enormous stores of carbon and, depending on soil management, can act as a sink but also as a source of carbon dioxide and other greenhouse gases.

One of the solutions potentially minimising the risk of global warming and reducing dependency on fossil fuels is the production of renewable organic raw materials. Biomass production, however, requires a certain availability of fertile soil not to compete with food provision.

On a small scale and particularly in urban areas, soils have a positive influence on microclimate. The evapotranspiration from soils and plants causes a cooling effect making urban life more comfortable, especially during a hot summer period.

Mitigation role of soil and plant cover for temperature extremes

In comparison to flowers, birds or butterflies, the soil under our feet seldom shows its beauty. However, under the surface, soils arisen out of the rock, formed by water, temperature, and soil organisms over a long time are works of art of nature with amazing colours and structures.

MAJOR SOIL FUNCTIONS

Production function

Production of biomass delivers food, fodder, renewable energy and raw materials.
This well-known soil function is the basis of human and animal life. This function differentiates soils from rocks. It is a function of a dynamic interaction of abiotic, biotic and socioeconomic factors. Its main feature is the

ability to provide suitable conditions for plant growth and ensure crop quality and quantity. Soil production capacity can be understood as its ability to collect, transform, store and transmit a sufficient amount of water and nutrients for plant growth. This function is dependent on soil's natural parameters such as texture and organic matter content, climatic conditions as well as agronomic practice. All these factors result in soil fertility. Even if nowadays the production function seems not to be the most important function in urban areas, the **production potential of soils should be kept at a high level,** especially in suburban zones.

Soils differ in their natural fertility according to soil type, texture, soil depth, its physical structure, content of available nutrients, water-air regime, soil reaction (pH), humus content and biological activity. Additionally soil contamination with organic contaminants (e.g. PCB or PAHs) or trace metals may limit the production function if they exist in excessive amounts.

Generally the most fertile and, therefore, most valuable in terms of production potential are deep soils with high water retention capacity, resistant to erosion, low content of skeleton in the top layer, substantial organic matter content, e.g. > 2%, soil reaction (pH) from 5.2 to 8.3, 1.1-1.5 g/cm^3 bulk density, proper soil texture, structure with rounded aggregates.

Such well-conditioned soils in urban areas occur sporadically since they have been under the strong influence of anthropogenic activities and subject to degradation processes. However, more productive soils can be found in sub-urban areas at the borders of urban agglomerations, which are prevailingly agriculturally used.

The existence of these areas has its rationale. Mostly, it is the fast accessibility of the crop market and unlimited sales opportunities in large metropolitan areas. In sub-urban areas it is necessary to conserve and maintain the soil productivity and soil availability for production.

Canola field near Pulawy, Poland

Retention function

From a physiological point of view soil water is an indispensable agent for plants and soil organisms. Water dissolves and supplies the roots with nutrients and transfers them through the plant tissues. The soil water is influenced by a complex of active strengths which can impact its movement and availability to plants and microorganisms. Distribution of soil water in relation to holding strengths can be divided into categories: adsorptive, capillary and gravitational soil water.

The retention function is defined as the capacity of soil to retain water in the soil profile or ability of soil to retain soil water against external strengths. Soil retention capacity can be expressed by, the so called, soil retention curve – a graphically presented relationship between soil moisture and negative soil water pressure potential (pF curve – the logarithm of strength necessary to drain the water from the soil). The pF value indicates the average level of energy that must be provided by plant roots to gather the required amount of soil water at a certain moisture.

There are several characteristics that shape the ability of soil to retain water: soil particle texture, slope, plant cover, soil structure, porosity, etc. Organic matter and clay increase the water storage capacity of soil. The mineral soils that are most effective in holding water are mainly loamy and clay soils with a favourable water-air regime, having rounded aggregate structure and a sufficient supply of soil organic mater. However, organic soils, like peat soils, exhibit the highest retention.

The supply of soil water and groundwater in cities has a generally downward trend due to the "drying effect of cities". The hydrological cycle in urban areas has different features than in rural areas and it is affected by often disturbed soil profiles, limited infiltration, accelerated evapotranspiration, crusting and compaction of soils, presence of impermeable layers, sewerage facilities and physical barriers. Covered areas produce intensive runoff whereas bare soils, as a result of crusting and compaction, do not absorb water as quickly.

On the other hand the covered soils dry more slowly after flooding.

An impermeable layer in the profile may cause water catchment in the profile and water logging.

Therefore, the role of soil as a medium for water retention and flow is of extraordinary importance in the urban area. **Water retention capacity of soils is a crucial factor for protection against flooding events in cities.**

The distribution of the urban sewage network becomes an important subject of urban planning in the cities. Lack of knowledge about the retention characteristics of soils in urban areas during urbanization planning may cause severe flooding events associated with lack of infiltration and limited water retention in soil.

Saturated retention potential of soil after heavy rain

Buffering/filtering soil functions

Soil acts as a natural filter to protect the quality of water, air and biota (including humans). Toxic compounds or excessive nutrients in soils can be degraded or made unavailable to the other environmental compartments.

Soil minerals, organic matter, and microbes are responsible for filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic harmful substances that enter soil with industrial and municipal by-products or through atmospheric deposition.
Soils can absorb contaminants from water, air and through their incorporation by humans. Some of these compounds (organic contaminants) are then degraded by microorganisms in the soil. Others are held safely in the soil, preventing secondary contamination of air and water. When the soil sorption system is overloaded, such as when heavy contamination occurs, or when the soil system becomes unstable, some contaminants can be released back to the air and water through erosion, desorption and leaching.
The soil acts as a natural filter. In this context, filtering means more than capture of solid particles. The soil filtering action, in fact, also means retaining chemicals or dissolved substances on the particle surface, transforming chemicals into less harmful forms through microbial biological processing, and retarding movement of substances in the soil profile.

Soil is a buffered system. This means that, when a factor of disturbance is applied to the soil, this latter tends to react, recovering its original status. This is particularly evident in the case of soil pH. The buffering function of soil is of crucial importance for quality of the environment. In fact, without this function, soil would not provide any protection to the groundwater.

Filtering and buffering functions of soils are ruled by their physical and chemical properties.
Among soil physical properties, depth, texture, and permeability determine the rate of groundwater recharge, as well as protection against groundwater contamination. Among chemical properties a key role in the filtering processes is played by cation (or anion) exchange capacity, pH, organic matter content, Fe and Mn oxides content. Microbial activity also plays a very important role in organic matter cycling and organic contaminants (bio)degradation.

Soil's ability to filter contaminants is limited. Contaminant attenuation in soils depends on its adsorption capacity and on water movement through the top layers of soil.

Deep, medium and fine-textured soils with good adsorption capacity are the most valuable soils in terms of filtering efficiency, whereas coarse-textured materials, with low organic matter and poor adsorption capacity are less valuable.

As explained above, the **filtering capacity of soils is crucial to protect the groundwater, plants, animals and humans against the harmful contaminants.** In the urban settlements this crucial function is often reduced, being sometimes irreversibly lost. In fact, the typical mixing of these soils with extraneous materials (bricks, debris from construction, etc.) strongly modifies its original physical-chemical properties, often leading to an increase in the coarse fraction, a reduction of organic matter and biomass activity and an increase in leaching of contaminants. Also, the fact that often soils are barren on the surface enhances contaminants dispersion through wind erosion of soil particles. Finally, due to the proximity to the contamination sources, these soils are often contaminated and the possibility of transfer of pollutants to the food chain is enhanced by the high population density in urban areas.

Provision of biodiversity

Biodiversity is understood as the degree of variation of life forms, from genes to species, within a given area. It is a basic indicator of the ecosystem's health.
The role of soil for the provision of biodiversity refers to two different scales: soil biodiversity combining all soil organisms and to the function of soil as a habitat for plant and animal species. Soil is one of the most diverse ecosystems on earth comprising fungi, bacteria, protozoa, nematodes, insects and even small mammals. The composition of soil organism populations depends on such soil properties as texture, organic matter, moisture and soil depth.
The role of soil organisms is complex: regulation of nutrient availability, decomposition and cycling of organic matter, improvement of soil structure and aeration, regulation of hydrological processes, nitrogen fixation, soil detoxification, etc.

Stork on arable field in Eastern Poland

Soil is also a medium for roots of terrestrial plants providing diversity of plant species. Many plant species growing in urban ecosystems are capable of adsorbing contaminants such as particulate matter and mitigating high temperatures.

Maintenance of biodiversity increases sustainability of the ecosystem. Soil living organisms are fundamental to the preservation of soil quality and other soil functions.

Urbanization introduces remarkable changes in the biodiversity. Soil sealing and other anthropogenic disturbances result in habitat loss for soil organisms, plant species and animals. Such pressures lead to considerable local extinction processes, elimination of a majority of native species and their displacement by non-native widespread species. This, in consequence, threatens the biological uniqueness of ecosystems. Decrease in soil biodiversity and the number of individuals leads to the inhibition or slowdown of organic matter and nutrient cycles.

Role of soils for global and local climate and air quality

The relevance of soils for climate can be considered in two different scales: as global and local impacts. Human activities leading to a release and an uptake of greenhouse gases alter their atmospheric concentration at a global level. At a local level, the mosaic of urban areas creates specific and instantaneous near-surface atmospheric changes which constitute the urban climate.

Earthworm burrowing soil

The soil-vegetation functional system plays a decisive role on both scales by exchanging greenhouse gases, energy and particulates with the atmosphere.

The soil related carbon dioxide exchange (CO_2) rate is a balance between carbon uptake by plants through photosynthesis and carbon release through the decomposition process.

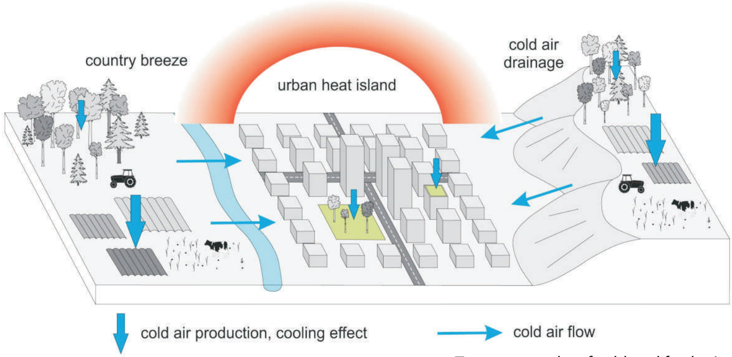
C-inputs to soil and C-outputs from soil show a dynamic equilibrium. This equilibrium can be disturbed by a variety of human activities.

Soil sealing and degradation of its profile lead to a reduction in the soil organic carbon pool and to the release of CO_2 and N_2O. Upland soils act as a permanent methane (CH_4) sink.

CH_4 diffuses into the soil matrix and is oxidized by a number of different microorganisms. Urban encroachments reduce the potential of the soil to act as a sink. Improvements in the full greenhouse gas balance of soils can be achieved by reducing the sources (CO_2 and N_2O) and by intensifying the gases' sequestration.

Furthermore, soils play a particular role at the level of the local urban climate. Differences in surface reflectivity, thermal conductivity, heat capacity, and water retention capability lead to characteristic surface and air temperature courses. In comparison to sealed surfaces plant covered soils warm up more slowly during the daytime due to evaporation, and cool

down faster during the night due to lower heat storage. Therefore, **high density of sealed areas in urban areas enhances the intensity of the urban heat island.** The consumption of soils in cold air production areas and in the ventilation paths lowers the cold air productivity and the intensity of city ventilation.
Another positive effect of plant covered soils results from the filtering capacity for atmospheric particulates, e.g. PM_{10}.
Plants increase the surface for deposition processes, and therefore support the reduction in urban atmospheric dust concentrations. Some of the particles which are deposited on plant surfaces are washed to the soil surface and inactivated.



Transport paths of cold and fresh air from the surrounding countryside into the settlement area (F. Gerst et al.)

THE BEAUTY OF SOILS

Variety of soil profiles

One might think that soil is only that brownish dirt, sticking on your shoes. But soils, arisen out of rock, formed by water, temperature, organisms and time are a work of art of nature with sometimes amazing colours and structures.
Soils are very different in their visual appearance – but can seldom show their beauty, usually being hidden under our feet. Most of us, unfortunately, can see the textures, layers and colours of soil, when we pass a construction site and look in the hole torn out of the ground by the excavator.

In all times, past and present, artists have used the "colours of the earth" as a raw material and an inspiration for their paintings. The prehistoric artists of the Stone Age used, for example, the soil material ochre for their rock- and cave-paintings.

A view over arable land is also exceptional. Not always colourful, and you might ask whether it is "beautiful" but it does promise prosperity and a secure life.
As John Steinbeck wrote in "Of Mice and Men" it assures us we can "live off the fat of the land". And we will only prosper as long as the land prospers.

Small works of art, painted by children using self-made colour from soil material (delivered by " regioplus Ingenieurgesell-schaft", Project: "Colours of earth")

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