Unit 6. Soil degradation

Soil pollution*

Soil is an upper layer of unconsolidated material at the earth's surface that can be plowed or dug into. It contains varying amounts of sand-, silt- and clay-size particles, and ever changing contents of fresh and decomposed organic matter.

Soil chemistry is derived in part from the parent rock from which it forms and in part from environment conditions where it evolves. The nutrients and other chemical elements and compounds in soil are important factors that determine its productivity.

A soil promotes vegetation growth when it contains sufficient contents of 16 essential plant nutrients (Table 5) and retains moisture at or close to the surface environment. Without sufficient essential macro- and micronutrients and moisture to sustain plant life, soil loses fertility. A plant deprived of any one of the essential elements in a growth environment will fail.

Sustainable productivity is predicated on multiple management strategies. One is to conserve the physical soil against loss by erosion. A second is to replace soil nutrients in amounts equal to that being used by crops and other vegetation. Another is to protect soils against an intrusion of pollutants that can damage a harvest. Chemical pollutants that intrude soils from natural or anthropogenic sources can cause a decrease in the quality and yield of cultivated products depending on the uptake and response of a crop to a pollutant. Lastly, it is necessary to protect a soil environment against other degradation factors such as salination or water logging. A healthy soil will sustain continuous vital activity of organisms (bacteria, worms, plant roots and others) which themselves work to promote growth of a diversity of plant life. This in turn bolsters animal life and agricultural activity.

Soil Degradation

The physical loss of soil, chemical damage to soil, and loss of soil fertility are gradual processes. They lower soil capacity as a growth medium to produce plants of suitable quantity and quality to satisfy the needs of existing and expanding populations.

Soil degradation represents a loss of a natural environment for normal cropping and for food animal production. This differs from land degradation that affects development sectors such as transportation, raw material resources, and building construction.

Table 5. Reasons for soil degradation.

Physical degradation – Erosion	Land clearing and overgrazing increases erosion by water and wind by destroying or decreasing a vegetative cover that functions

	to hold soils together and slow rainwater runoff. Compaction of soils by heavy equipment increases bulk density, increases resistance to rooting, affects soil structure and decreases porosity and permeability of soils and infiltration of rainwater or irrigation water causing greater runoff and water erosion. Crusting that resists water infiltration and prevents seedling emergence thus enhancing erosion by water runoff and wind Eroded soil can move any pollutants present (heavy metals, fertilizers, biocides) into other media in an ecosystem.
Chemical degradation - Nutrient and moisture loss, pollution	Depletion of soluble essential macro- and micro-nutrients by overcropping without refertilization and by removal, by leaching as water infiltrates through and moves out of soil system. Salination or precipitation of solutes from irrigation or rising water table and capillary action causes crusting on plant roots because of lack of an efficient drainage system or scheduled flushing to carry salts out of soil system. Pollution from sewage or industrial effluents and emissions containing harmful chemicals and/or potentially toxic metals and their adsorption by soil organic matter, clay minerals and Fe and Mn oxy/hydroxides; from overuse pesticides and fertilizers. Acidification from precipitation of acid rain and atmospheric deposition of pollutants. Laterization (decomposition of soil minerals with loss of cations and silica in solution leaving Al2O3.nH2O and Fe oxy/hydroxides as a hardened and dense surface crust), podsolization (strongly leached and bleached gray/white layer beneath the H and O horizons but above the B horizon), and large scale erosion. The accumulation of potentially toxic metals can build up but is liable to be suddenly released and mobilized into an ecosystem (e.g., by a lowered pH) and is considered by some as a "chemical time bomb". A release may also be stimulated by a change in land use, decomposition, exposure to air or oxygen-bearing water, erosion and discharge into an ecosystem, and drought and ablation by wind.
Biological degradation - Loss of binding strength and nutrient-moisture storage and transfer capacity	Organic matter loss means loss of storage capacity of soil for nutrients and moisture and hence their availability to growing plants; loss of organic matter soil-binding function decreases the resistance of soil to water erosion. Pollutant intrusion or changes in physical-chemical conditions in soils lessen the activity of microbiota that affects the balance of growth conditions and decreases productivity of a soil degradation.

Soil degradation is qualified as being slight, moderate or severe when the productive capacity is reduced by 10%, 10–50% and >50%, respectively. Soils are characterized as being at high risk or very high risk. Table 5 describes physical, chemical and biological processes that cause soil deterioration.

It is essential to protect soils against natural degradation (e.g., erosion) that reduces their productive capacity. They must be shielded as well from anthropogenic intrusions by chemical contaminants that diminish soil quality and from human activities that promote soil loss (e.g., vegetation stripping).

*Extracts from Siegel F.R.. Demands of Expanding Populations and Development Planning. Berlin Heidelberg: Springer-Verlag, 2008.

Task

1. Answer the questions according to the text above:

1.1. What are the main components of soils.
1.2. What the chemical composition of soils does depend on?
1.3. Which processes can occur in soils under the influence of external factor?
1.4. Give the definition of soil degradation.
1.5. What are the reasons of soil degradation?
1.6. Who to prevent soil degradation?
1.7 What are the functions of soil?

2. Read the text below and make a table or scheme, characterizing the soil functions and the impact of urbanization on them.

The Impact of Urbanization on Soils*

Soil is the productive layer of the earth's surface. It evolves with the biotic community based upon climatic conditions, local biota, topography, parent material, and time. Soil is a natural system with structure and specialized features. Because soils are productive, they are crucial to life on earth. This is well understood by farmers and those that work closely with soil. As the world is increasingly urbanized, however, people have lost contact with soil and with that they have lost an appreciation of how important soils are to their everyday lives.

This tendency is ironically counterpoised against increased dependency urban populations have on soils for food, for waste recycling, and as carbon sinks among other functions.

The question arises as to how to assess the impacts of living in cities on soils. In order to understand these impacts, we first need to understand the basic role of soils in our ecosystems. Brady and Weil (2002)[1] describe five functions of soils including: supporting the growth of higher plants, controlling water within the hydrologic system, mediating nutrient cycles, providing habitat for living organisms, and serving as an engineering medium. From these functions it is then possible to identify how urbanization might impact soils.

First, soils have a physical structure, temperature, and pH that help to provide support for higher plants. Second, soils control the cycling of essential nutrients and micronutrients, water movement, and they also act as a sink for wastes of all sorts. Finally, soils support biodiversity. These three characteristics therefore, can

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[1] Brady N.C. and Weil R.R. The Nature and properties of soils. – 13th Edition – Prentice Hall, NJ, 2002.

serve as a basis for an assessment of changes in soil; namely an impact assessment should identify the changes in physical structure, soil-related biochemistry, and/or soil biodiversity.

Identifying the focus of impact is not enough to undertake the review, however.

Soils cover most terrestrial ecosystems, and we therefore need to target the locations impacted by urban activities. Many previous studies examined the soils within urban borders. These studies restricted their perspective of the impacts of urbanization understandably, but artificially to the local scale. Cities and urbanization processes, however, affect soils both directly and indirectly outside city boundaries.

Increasingly, urban activities are seen to impact larger scales. Scale, in this sense translates into geographic extent or temporal duration of the process. Scale is often referred to as local, regional, or global. Local scale refers to particular phenomena, processes, or activities that are most evident at household, neighborhood, or community level. For example, in environmental terms, indoor air pollution and its impact is a local phenomenon because it is best observed and measured at that level.

While indoor air pollution statistics may be aggregated at the global level, understanding the processes that created it, its uneven distribution, and its impacts on human health are less obvious at regional or global scale. Alternatively, the environmental impact of carbon dioxide emissions is often referred to as a global-scale issue. This is because total global amounts of this gas have systemic impacts on the Earth's climate. Observing and measuring changes in this emission and its impacts are best performed at this scale, although there are also important regional and local impacts.

Urban development and economic growth have been associated with the changing scale of impacts. That is, cities' transition from one set of environmental challenges (including impacts) to another as they grow in wealth. This theory, entitled, urban transition theory, is powerful in its ability to disaggregate the types and dominance of environmental conditions associated with cities at different levels of income and how these conditions change in terms of their type, geographical, and temporal extent.

Human activity within cities changes the physical character of soils. Material inputs into cities have exceeded output for several years. This has meant several things, including the general rise of ground level in older districts as well as the infill of waterways, streams, and valleys in other parts of the city. With the constant changes and additions made to the urban ecosystem, it is no surprise that soils located within urban areas are unique.

The physical characteristics of soils include texture (particle size), bulk density, structure (shape of peds), plasticity, permeability, porosity, temperature, and moisture content.

At the regional level, urbanization has been associated with the advance of impervious surfaces that have sealed soil from the atmosphere and taken significant amounts of land from agricultural production. These changes have led to shifts in the hydrological cycle, as infiltration capacity is reduced, changing river and stream flow and sedimentation levels. Moreover, development in peri-urban areas has been associated with massive gully erosion. On the other hand, in developing countries access to markets (meaning the growth of towns and cities) can have an effect on soil quality, as farmers then can buy fertilizers and soil supplements. At the national and global level, urbanization and the accompanying changes in consumption patterns play a role in nutrient depletion of rural soils and accelerated erosion due to the expansion of urban areas. On the other hand, in some cases, rural–urban migration (particularly in developing countries) leads to land abandonment and forest regeneration.

*Extracts from Marcotullio P.J., Braimoh A.K., Onishi T. The Impact of Urbanization on Soils // Land Use and Soil Resources / Braimoh A.K., Vlek P.L.G. – pp. 201-250.