How soil compaction and erosion affect the environment

Under Stress

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The processes of soil compaction and erosion, while seemingly opposite in nature, in fact lead to similar consequences: significant soil impoverishment, lower ground water quality, and environmental pollution

The increasingly massive agricultural machines and tractors in use nowadays are seen as a sign of advanced agriculture and prosperity, yet they can greatly contribute to unfavorable changes in the soil structure by causing its compaction. The highest degrees of compaction are caused when heavy combines and transport trailers are driven over highly wet soil, usually during the autumn harvesting of root crops. Soil compaction is also exacerbated by rainfall. The resulting reduction in overall soil porosity has a significant impact - entailing the degradation of as much as 33 million hectares of soil in Europe.


Jerzy Rejman

Evaluating the intensity of erosion is no simple task, as the results depend on such factors as the scale and method of measurement used. Here: a plot for measuring surface runoff and water soil erosion in Bogucin, on the Lublin Upland

Soils of low clay content, with a poorly-developed aggregate structure, are particularly susceptible to compaction. The surface layers of such soils often have low water content while the layers below are very wet, increasing their susceptibility to compaction. Compaction is particularly evident in the "plough pan," a compacted subsoil layer caused by compression under tractor wheels running along furrows. Unfortunately, compaction in lower layers of the soil profile is usually an irreversible process, which neither deep mechanical tilling, nor freezing-thawing or wetting-drying processes, nor biological soil activity can fully repair.

One of the top threats

Significant soil compaction alters the physical, chemical, and biological conditions present in soil and induces a number of negative phenomena. It curbs root growth and limits plants' ability to uptake water and minerals. Unuptaken fertilizers or other chemicals linger longer in the soil and become leached out of it over longer periods, leading to environmental pollution and increased agricultural production costs. Moreover, greater wetness and limited oxygen access stimulate denitrifying bacteria to produce nitrous oxide, a greenhouse gas, and to emit it into the atmosphere, contributing to global warming and the disappearance of the ozone layer. Increased soil compaction also leads to higher atmospheric methane concentrations. Soil of compacted structure is moreover not easy to till, so the necessary use of machinery increases fuel consumption and the emission of other greenhouse gases like carbon dioxide and nitrogen oxides (NOx). Compacted soil cannot be infiltrated by water and cannot store rainfall, which causes water to run off and erode the soil surface. It is no wonder, therefore, that in 2002 the European Commission identified soil compaction as one of the top 8 threats faced by the environment. Of the recommended measures for curbing the phenomenon, the most effective are as follows: keeping vehicle movements to a minimum when soil wetness is high, maintaining low air pressure in tractor tires, and consistently using regular pathways.

In the process of erosion, in turn, soil particles are detached from the surface (e.g. by wind or water) and transported to sedimentation sites, which may be cultivated fields, reservoirs, or water flows. It is estimated that

Squeezed under the wheels of heavy agricultural machines, soil becomes nearly irreversibly compressed. Farming activity also increases soil erosion – i.e. the displacement of soil particles by wind or water. Both of these phenomena contribute to environmental pollution

29.7% of Poland's surface is threatened by water erosion, 28% by wind erosion; together both factors affect nearly 50% of the country's area. Researchers' attention has recently been drawn to newly recognized forms of erosion: the displacement of soil during tilling, and its removal from fields during the harvesting of root crops.

Erosion deteriorates a soil's properties, lowering the quality and quantity of humus and affecting the diversity of the granulometric composition. This lowers a soil's productivity, a direct measure of environmental impoverishment. In loess areas, in places where the tilled top layer is formed from the matrix rock (carbonate loess), the drop in harvests caused by erosion can even reach 40%! This is due to the reduced water content available to plants. Although the displaced material usually does settle in valleys, that does not compensate for the drop in harvests. Depending on the duration of agricultural use, soils altered by erosion may occupy 75-90% of a given drainage area.

Load-bearing rivers

Eroded soil particles generally contain more organic substances, fertilizer components (nitrates and phosphates) and chemical protection agents than soil *in situ*. Such material usually accumulates in depressions in the drainage area or enters water bodies directly, causing their pollution and eutrophication. The resulting excessive growth of aquatic plants and their subsequent decay upsets the normal functioning of ecosystems and causes a reduction in water quality; together with other water pollutants this threatens the quality of drinking water. Some of the eroded soil material and pollutants get transported into large rivers, which bear a huge "load" - the annual sediment mass measured at the mouth of the Vistula River in 1946-95 is estimated at 833,000 tons, with the largest share of sediment originating from the Carpathian foreland.

The environment is particularly threatened when soil erosion is accompanied by the intensification of agricultural production, including changes in land use and crop rotation, increased farm size, limited organic fertilization, and excessive liquid slurry at specialized farms.

Research carried out by the Institute of Agrophysics, Polish Academy of Sciences, has developed methods for continuously measuring plants' water use, taking account of the length and diameter of their roots and the soil compression and distortion caused by tractor wheels, depending on the wetness and density of the initial soil. We have analyzed individual erosion events, identifying the distance of soil displacement along a slope and the state of soil degradation. We have also identified the optimal and critical values of selected physical soil properties for plants. The results obtained and the methods so developed are of practical significance in evaluating and predicting the functioning of the root system and the crop yield in compressed or eroded soils. ■

Further reading:

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