PHYSICAL DEGRADATION OF SOILS, RISKS AND THREATS

Winfried E. H. Blum
Institute of Soil Research, University of Natural Resources and Applied Life Sciences (BOKU) Vienna, Vienna, Austria

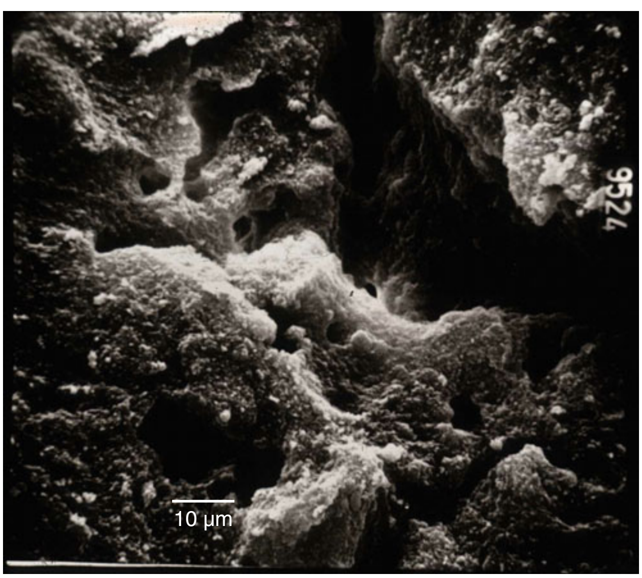
Definition

Physical soil degradation is one of the eight main risks and threats defined by the European Thematic Strategy for Soil Protection (COM(2002)179 final).

Physical degradation comprises very different processes and morphometric forms, mainly through the deformation of the inner soil structure by compaction, caused by tracking with heavy agricultural machinery, through vertical sheer stress caused by rotating parts of machines, e.g., wheels, as well as by chemical impacts such as salinization, especially alkalinization. Physical degradation also includes soil erosion by water and wind as well as the formation of crusts at the soil surface (soil crusting).

Physical degradation

The deformation of the inner soil structure, which comprises large (>50 μm diameter) and small macropores (50–10 μm diameter), medium pores (10–0.2 μm diameter), and fine pores (<0.2 μm diameter) (see Figure 1), occurs by heavy soil loading and results especially in the loss of soil macropores >50 μm diameter or even smaller macropores >10 μm diameter, under extreme conditions.



Physical Degradation of Soils, Risks and Threats, Figure 1 Look into a soil by electronic microscopy (observe scale of 10 μm), showing different types of pores, which are all interconnected (Blum, 2002).

Macropores are responsible for soil aeration and water conductivity and are also the living space of soil organisms, especially those which are not able to create own spaces in soil, like many earthworms. Therefore, the destruction of macropores, seldom medium pores (10–0.2 μm diameter), means low water (rainwater) conductivity, causing stagnant water phases in soils, with anaerobic conditions changing soil chemistry as well as soil biology. Under specific topographical conditions, compaction also causes soil erosion by water surface flow. Sheer stress causes similar results, although less compacting, but smearing and closing or blicking pores, especially in the top soil, between 0 and 20 cm soil depth. A special form of sheer stress combined with loading and compaction is the formation of the so-called plough horizons, a compacted zone below the ploughed top soil with problems for root penetration and often changes in redox potential through decreased water infiltration, causing stagnant water conditions after intensive rainfall.

Compaction at soil depths >50 cm are nearly irreversible, because no technical measures are available to restore soil macroporosity, except biological processes, e.g., through earthworm activities, which is normally a very slow process and depends on further edafic conditions.

Moreover, physical soil degradation occurs also at the soil surface through the destruction of crumby or blocky soil structures, mainly through the physical impact of rainwater, especially raindrops with high kinetic energy, called splash, destructing surface soil structures, causing smaller soil particles, which can be transported by water or wind (erosion) or may form crusts at the soil surface, especially under semiarid and arid climatic conditions. The physical degradation through splash by raindrops with high kinetic energy depends on the size of the raindrops, the wind velocity, and the type and stability of surface soil structures. Structure stability is highly influenced by soil organic matter. Through loss of soil organic matter in top soils, soil structures become instable and therefore prone to erosion, especially crumbs or small blocks at the soil surface. Soils with a high silt content are most endangered by wind and water erosion. Soil erosion causes losses of the most fertile part of the soil, additionally decreasing soil fertility through a decrease of the rooting depth and consequently of the availability of water and nutrients for plant growth.

In climatic regions with long-lasting dry periods, fine soil particles produced by rain splash at the soil surface can form crusts, which are in most cases very resistant against deformation by water and wind, also because of fungal growth compacting these surfaces, additionally. Crusting occurs very often in soils under a mediterranean type of climate or in semiarid or semihumid areas of the tropics and subtropics.

Conclusions

Physical soil degradation has negative impacts on nearly all soil characteristics and processes, e.g., space for plant roots and soil biota, soil temperature, transport of water, air, and nutrients as well as natural attenuation of organic and inorganic contaminants.

Bibliography

Blum, W. E. H., 2002. Soil pore space as communication channel between the geosphere, the atmosphere and the biosphere. In *17th World Congress of Soil Science*, Transactions No. 2014, Abstracts, Vol. V, 1942, IUSS, August 14–21, Bangkok/Thailand (CD-ROM).

Horn, R., Fleige, H., Peth, S., and Peng, X. (eds.), 2006. *Soil Management for Sustainability. Advances in GeoEcology 38*. Reiskirchen: Catena.

Cross-references

Aeration of Soils and Plants
Bulk Density of Soils and Impact on their Hydraulic Properties
Compaction of Soil
Claypan and its Environmental Effects
Field Water Capacity
Hydraulic Properties of Unsaturated Soils
Infiltration in Soils
Microbes and Soil Structure
Organic Matter, Effects on Soil Physical Properties and Processes
Oxidation–Reduction Reactions in the Environment
Physical Protection of Organic Carbon in Soil Aggregates
Plant Roots and Soil Structure
Soil Aggregates, Structure, and Stability
Soil Surface Sealing and Crusting
Soil Water Flow
Solute Transport in Soils
Subsoil Compaction
Surface Roughness, Effect on Water Transfer
Tillage, Impacts on Soil and Environment
Water Erosion: Environmental and Economical Hazard
Wind Erosion

PHYSICAL DIMENSIONS AND UNITS USE IN AGRICULTURE

Wojciech Skierucha[1], Marcin Widomski[2], Witold Stępniewski[2], Bogusław Usowicz[1]
[1]Institute of Agrophysics, Polish Academy of Sciences, Lublin, Poland
[2]Department of Land Surface Protection Engineering, Lublin University of Technology, Lublin, Poland

Definition

A unit and a number are factors expressing the value of a physical quantity.

Dimensions of a physical quantity are the powers to which the base units of a measurement system are raised to get one unit of the physical quantity.

Introduction

Real world should be described in terms of its biophysical and qualitative attributes, which are physical quantities. Agricultural objects and processes are interdisciplinary and they deal with nearly all physical, chemical, and biological aspects of real world. Therefore dimensions' and units' use in agriculture includes the respective physical quantities.

The majority of physical quantities that we actually deal with in science and also in our daily life can be expressed in terms of one or more base units.

International system of units (SI)

The most popular and scientifically recognized system of units is the International System of Units, known as the SI (from the French *Système International d'Unitès*). Use of SI is recommended by most scientific journals and in many it is now mandatory. Multiples and submultiples of units should be chosen to minimize the repetition of zeros before or after the decimal point. Several units related to SI (e.g., tonne and hectare) are convenient in speech as well as in writing but should be avoided in analysis to minimize the risk of numerical errors.

The fundamental part of the units in the system is called a set of base units describing base quantities and the other units describing remaining quantities are called derived units.

There are seven base quantities used in the SI system: length, mass, time, electric current, temperature, amount of substance, and luminous intensity. The base quantities are independent by definition. The corresponding base units are: the meter, the kilogram, the second, the ampere, the kelvin, the mole, and the candela. The definition of each base unit (The International System of Units (SI), 2006) of the SI is carefully drawn up so that it is unique and provides a sound theoretical basis upon which the most accurate and reproducible measurements can be made. The realization of the definition of a unit is the procedure by which the definition may be used to establish the value and associated uncertainty of a quantity of the same kind as the unit.

All derived quantities may be written in terms of base quantities by the equations of physics.

Table 1 presents base quantities and their corresponding symbols, symbols for dimension, units, and symbols for the

Physical Dimensions and Units Use in Agriculture, Table 1 Base quantities and dimensions used in the SI

Base quantity	Symbol for quantity	Symbol for dimension	Base unit	Symbol for base unit
Length	l, x, r	L	Meter	m
Mass	m	M	Kilogram	kg
Time, duration	t	T	Second	s
Electric current	I, i	I,	Ampere	A
Temperature	T	Θ	Kelvin	K
Amount of substance	n	N	Mole	M
Luminous intensity	I_v	J	Candela	cd

Physical Dimensions and Units Use in Agriculture, Table 2 Selected quantities as well as the corresponding applications, units, and dimensions in the agriculture use

Quantity	Application	Unit	Generally accepted unit	SI unit	SI dimension
Length	Soil depth	Meter	m	m	L^1
	Plant height				
	X-ray	Ångström	1 Å = 10^{-10} m		
Area	Pot area	Square centimeter	1 $cm^2 = 10^{-4}\ m^2$	m^2	L^2
	Leaf area	Square meter	m^2		
	Land area	Hectare	1 ha = $10^4\ m^2$		
	Specific surface area	Square meter per kilogram	$m^2 \cdot kg^{-1}$		L^2M^{-1}
Volume	Lab	Cubic meter	m^3	m^3	L^3
	Field				
Speed	Air	Meter per second	$m \cdot s^{-1}$	$m \cdot s^{-1}$	L^1T^{-1}
Total porosity	Soil, plant	Cubic meter voids per cubic meter soil	$m^3 \cdot m^{-3}$	$m^3 \cdot m^{-3}$	L^3L^{-3}
Air-filled porosity, differential porosity	Soil, plant	Cubic meter voids per cubic meter soil	$m^3 \cdot m^{-3}$	$m^3 \cdot m^{-3}$	L^3L^{-3}
	Soil				
Void ratio	Soil	Cubic meter voids per cubic meter solids	$m^3 \cdot m^{-3}$	$m^3 \cdot m^{-3}$	L^3L^{-3}
Concentration	Pollutant transport	Kilogram solute per cubic meter solution	$kg \cdot m^{-3}$	$kg \cdot m^{-3}$	$L^{-3}M^1$
	Fertilizers	Mole solute per cubic meter solution	$M \cdot m^{-3}$	$M \cdot m^{-3}$	$L^{-3}N^1$
	application	Cubic meter solute per cubic meter solution	$m^3 \cdot m^{-3}$	$m^3 \cdot m^{-3}$	L^3L^{-3}
Concentration of air components	Soil air	Cubic meter component per cubic meter air	$m^3 \cdot m^{-3}$	$m^3 \cdot m^{-3}$	L^3L^{-3}
	Atmosphere				
Molar fraction	Soil solution	Mole component per mole mixture	$M \cdot M^{-1}$	$M \cdot M^{-1}$	N^1N^{-1}
	Atmosphere				
Temperature	Soil	Kelvin	K	K	Θ^1
	Air				
	Water				
	Plant				
Force	Soil and plant mechanics	Newton	N	$kg \cdot m \cdot s^{-2}$	$L^1M^1T^{-2}$
Pressure	Soil	Pascal	1 Pa = 1 $N \cdot m^{-2}$	$kg \cdot s^{-2} \cdot m^{-1}$	$L^{-1}M^1T^{-2}$
Stress	Air	Newton per square meter	$N \cdot m^{-2}$		
Pressure equivalent of water potential	Water	Kilogram per square second meter	$kg \cdot s^{-2} \cdot m^{-1}$		
		Bar	1 bar = 10^5 Pa		
		Millimeter of mercury	1 mmHg ≈ 133.322 Pa		
Energy	Soil	Joule	1 J = 1 N·m	$m^2 \cdot kg \cdot s^{-2}$	$L^2M^1T^{-2}$
Work	Water	Newton meter	N·m		
Heat	Movement	Square meter kilogram per square second	$m^2 \cdot kg \cdot s^{-2}$		
	Air flow				
	Heat transport	Erg	1 erg = 10^{-7} J		
Power	Water movement	Watt	1 W = 1 $J \cdot s^{-1}$	$m^2 \cdot kg \cdot s^{-3}$	$L^2M^1T^{-3}$
	Air flow	Joule per second	$m^2 \cdot kg \cdot s^{-3}$		
		Square meter kilogram per cubic second			
Water content	Soil	Kilogram water per kilogram dry soil	$kg \cdot kg^{-1}$	$kg \cdot kg^{-1}$	M^1M^{-1}
		Cubic meter water per cubic meter soil	$m^3 \cdot m^{-3}$	$m^3 \cdot m^{-3}$	L^3L^{-3}
Water potential (matrix, gravitational, osmotic, total)	Soil	Joule per cubic meter water	$J \cdot m^{-3}$	$kg \cdot m^{-1} \cdot s^{-2}$	$L^{-1}M^1T^{-2}$
	Plant	Joule per kilogram water	1 $J \cdot kg^{-1} = 10^{-3}$ MPa $=10^{-2}$ bar	$m^2 \cdot s^{-2}$	L^2T^{-2}
	Laboratory	Joule per mole water	$J \cdot M^{-1}$	$kg \cdot m^2 \cdot M^{-1} \cdot s^{-2}$	$L^2M^1N^{-1}T^{-2}$