Manual on the Basic Set of Environment Statistics of the FDES 2013

Soil Characteristics Statistics

(Topic 1.1.4 Soil Characteristics of the Basic Set of Environment Statistics of the FDES 2013)

Elaborated by the Environment Statistics Section of the United Nations Statistics Division, in collaboration with the Expert Group on Environment Statistics

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Methodology sheet of the Basic Set of Environment Statistics of the FDES

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Contents

1. Statistics in Topic 1.1.4 Soil characteristics

Component 1: Environmental Conditions and Quality				
Subcomponent 1.1: Physical Conditions				
Topic 1.1.4 Soil characteristics				
Statistics and Related Information (**Bold Text - Core Set/Tier 1**; Regular Text - Tier 2; *Italicized Text - Tier 3*)		**Category of Measurement**	**Potential Aggregations and Scales**	**Methodological Guidance**
a.	Soil characterization		▪ By location ▪ By soil type ▪ National ▪ Sub-national	▪ FAO and the International Institute for Applied Systems Analysis (IIASA) Harmonized World Soil Database ▪ International Soil Reference and Information Centre (ISRIC) World Data Centre for Soils ▪ United Nations Convention to Combat Desertification (UNCCD) ▪ FAO Global Assessment of Human-induced Soil Degradation (GLASOD) ▪ FAO – Global Soil Partnership (GSP) [added after publication of FDES]
	1. Area by soil types	Area		
b.	Soil degradation			
	1. Area affected by soil erosion	Area		
	2. Area affected by desertification	Area		
	3. Area affected by salinization	Area		
	4. Area affected by waterlogging	Area		
	5. Area affected by acidification	Area		
	6. Area affected by compaction	Area		
c.	Nutrient content of soil, measured in levels of:		▪ By soil type ▪ By nutrient ▪ National ▪ Sub-national	
	1. Nitrogen (N)	Concentration		
	2. Phosphorous (P)	Concentration		
	3. Calcium (Ca)	Concentration		
	4. Magnesium (Mg)	Concentration		
	5. Potassium (K)	Concentration		
	6. Zinc (Zn)	Concentration		
	7. Other	Concentration		

2. Introduction/Relevance

Soil is a basic resource and a vital part of the natural environment in which most of the world's food is produced. In the same way, soil provides vital space for human beings, as well as essential important environmental services for the regulation and supply of water, climate regulation, conservation of biodiversity and cultural services. However, soils are under pressure due to population growth, increased food demand and competition for land uses. Approximately 33% of the world's soils are degraded and political leaders around the world are exploring ways to increase soil sustainability, including through the Sustainable Development Goals.[1]

In this context, soil provides the physical platform for the production and cycling of biological resources, is a source of nutrients and water for agricultural and forestry systems, provides a habitat for millions of organisms, plays an essential role in carbon sequestration, as well as playing an important role in environmental variability, ranging from buffering diurnal and seasonal changes in temperature and water supply to the storage of a wide range of chemical and biological agents. Increasingly, soils are under pressure, leading ultimately to soil degradation due to structural breakdown of the soil from erosion and compaction. Other problems arise from 'pollution' of the soil through excess application of chemical inputs such as fertilizers and pesticides, which along with other processes leads to salinization and acidification, and breakdown of the soil structure which can also cause loss of nutrients.

Anthropogenic practices are key drivers of soil degradation, including farming practices which disturb the soil and excess application of chemical inputs to the soil. Socio-economic drivers are also important as indirect drivers through abandonment of agricultural areas due to increased urbanization, changes to profitability of agriculture, etc. On the other hand, pressures to increase agricultural production can also lead to soil degradation through increased competition for land which pushes production onto marginal sites which are easily degraded. Climate change processes also have the potential to increase soil degradation through increased rainfall intensity and temperature changes.[2]

These drivers have been causing a number of threats to soil functions such as soil erosion, loss of soil organic carbon, nutrient imbalance, soil acidification, soil contamination, waterlogging, soil compaction, soil sealing, salinization and loss of soil biodiversity. These threats to the health of the soil are reflected in its decreased capacity to produce goods and provide services to society.

Soils are fundamental for life on Earth, but human pressures on this resource are reaching critical limits. A greater loss of productive soils will increase the volatility of food prices and potentially result in large increases in poverty which is avoidable. Careful soil management can increase food supplies and provide a valuable tool

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[1] FAO, *Soil World Alliance* webpage, http://www.fao.org/global-soil-partnership/about/why-the-partnership/en/ (accessed 29 September 2018)

[2] UNCCD (2017) Global Land Outlook, 1st edition, https://www.unccd.int/sites/default/files/documents/2017-09/GLO_Full_Report_low_res.pdf (accessed 29 September 2018)

for climate regulation and a way to safeguard ecosystem services.[3] Soils are also crucial to other aspects of a healthy environment such as maintaining the quality and quantity of water and flow regulation. Climate change mitigation depends on healthy soils which can stock carbon, thus supporting healthy forests and enhancing carbon sequestration.[4]

For countries that depend heavily on agriculture and forestry, knowledge of soils is also key to social and economic growth, and an understanding of the quality and resources of the soil is relevant in order to promote sustainable agriculture.[5] Soil degradation, manifested mainly in the form of soil erosion, is considered one of the fundamental causes of stagnation or decline in agricultural productivity in low-income countries, such as Africa South of the Sahara, a situation that, together with the loss of soil organic matter, acidification, salination and waterlogging contribute to the food crisis in this region. In Europe, soil degradation due to inadequate management practices, urbanization and changes in land uses jeopardize the key role of soil ecosystems as a basis for the provision of ecosystem services.[6]

The methodology sheet covers Topic 1.1.4 Soil characteristics which covers statistics on the character of soils, processes related to soil degradation and statistics on the nutrient content of soil, which when reduced, is also a type of degradation.

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[3] FAO (2015) *Status of the World's Soil Resources. Technical Summary*, http://www.fao.org/3/a-i5126e.pdf (accessed 29 September 2018)

[4] UNCCD (2017) *Global Land Outlook, 1st edition,* https://www.unccd.int/sites/default/files/documents/2017-09/GLO_Full_Report_low_res.pdf (accessed 29 September 2018)

[5] FAO *Soils Portal* webpage, http://www.fao.org/soils-portal/policies-governance/en/ (accessed 29 September 2018)

[6] FAO (2015) *Status of the World's Soil Resources. Technical Summary*, http://www.fao.org/3/a-i5126e.pdf (accessed 29 September 2018)

3. Definitions and description of the statistics

3A. Definition of the statistics

Soil is defined as a natural body consisting of layers (soil horizons) that are composed of weathered mineral materials, organic material, air and water.[7]

Soil is the end product of the combined influence of climate, topography, organisms (flora, fauna and human) on parent materials (original rocks and minerals) over time. As a result, soil differs from its parent material in texture, structure, consistency, colour, chemical, biological and physical characteristics.[8]

The FDES 2013 separates the soil statistics into 1.1.4.b Soil degradation and statistics on nutrients under 1.1.4.c Nutrient content of soil. However, depletion of soil nutrients is also considered soil degradation.

3A1. Soil characterization (FDES 1.1.4.a)

Area by soil types (FDES 1.1.4.a.1)

Area of the dominant soil, understood as the soil that occupies more than 50% of the soil cover.[9]

Remarks:

- This statistic may be obtained from soil maps.
- Soil classification systems can reflect dominant soils, codominant soils and associated soils, the latter two being soils which represents a lower percentage of the soil cover than dominant soils. Soil maps generally show the dominant soils but not codominant or associated soils.

3A2. Soil degradation (FDES 1.1.4.b)

A change in soil health resulting in a diminished capacity of ecosystems to provide goods and services for their beneficiaries. Degraded soils present a state of health that cannot provide the normal goods and services of the soil in their ecosystem.[10]

A related definition is the UNCCD definition of land degradation: "Land degradation means reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as:

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[7] FAO *Soils Portal key definitions* webpage, http://www.fao.org/soils-portal/about/all-definitions/en/ (accessed 29 September 2018)
[8] FAO *Soils Portal key definitions* webpage, http://www.fao.org/soils-portal/about/all-definitions/en/ (accessed 29 September 2018)
[9] FAO (2015) *World Reference Base for Soil Resources 2014*, http://www.fao.org/3/i3794en/I3794en.pdf (accessed 29 September 2018)
[10] FAO *Soils Portal soil degradation* webpage, http://www.fao.org/soils-portal/soil-degradation-restoration/en/ (accessed 29 September 2018)

(i) soil erosion caused by wind and/or water;
(ii) deterioration of the physical, chemical and biological or economic properties of soil; and
(iii) long-term loss of natural vegetation."[11]

Remarks:

- Of the complex factors leading to degradation, key processes of degradation are soil erosion and desertification.[12]
- Desertification is defined as land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities.[13]
- Land degradation is broader than soil erosion and soil degradation as it covers biological and water related changes which affect the environment.[14]

Area affected by soil erosion (FDES 1.1.4.b.1)
Soil area with an absolute loss of soil from the topsoil and soil nutrients.[15]

Remarks:

- Soil erosion is one aspect of soil degradation, other aspects include, e.g., salinization, compaction, etc.
- UNCCD recognizes soil erosion as a key factor in land degradation.[16]
- Information on soil erosion can be obtained from remote sensing data.

Area affected by desertification (FDES 1.1.4.b.2)
Desertification means land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities.[17] Area with irreversible change of land to a state such that it can no longer be recovered to its original use or land desertification in dryland areas,[18] and is reflected in the loss of its long-term capacity to supply goods and services to human populations.

Remarks:

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[11] UNCCD (1994) *United Nations Convention to Combat Desertification*, http://catalogue.unccd.int/936_UNCCD_Convention_ENG.pdf (accessed 29 September 2018)
[12] FAO *Soils Portal soil degradation* webpage, http://www.fao.org/soils-portal/soil-degradation-restoration/en/ (accessed 29 September 2018)
[13] United Nations (1994) Elaboration of an International Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa. A/AC.241/27, http://www.ifrc.org/docs/idrl/I223EN.pdf (accessed 29 September 2018)
[14] FAO *Soils Portal soil degradation* webpage, http://www.fao.org/soils-portal/soil-degradation-restoration/en/ (accessed 29 September 2018)
[15] FAO *Soils Portal soil degradation* webpage, http://www.fao.org/soils-portal/soil-degradation-restoration/en/ (accessed 29 September 2018)
[16] UNCCD (1994) *United Nations Convention to Combat Desertification*, http://catalogue.unccd.int/936_UNCCD_Convention_ENG.pdf (accessed 29 September 2018)
[17] UNCCD (1994) *United Nations Convention to Combat Desertification*, http://catalogue.unccd.int/936_UNCCD_Convention_ENG.pdf (accessed 29 September 2018)
[18] FAO *Soils Portal soil degradation* webpage, http://www.fao.org/soils-portal/soil-degradation-restoration/en/ (accessed 29 September 2018)

- Although this is a term used for arid zones, it is currently applied to all soils, as part of the degradation process.
- Desertification statistics can be categorized as slight, moderate, and severe.[19]

Affected area by salinization (FDES 1.1.4.b.3)

Soils are regarded as salt-affected, if they have salt concentrations above the thresholds of toxicity that include: 1) a concentration of salts in the soil solution of 3-5 g/l; 2) a sum of toxic salts measured in water extracts of 0,05-0,15%; 3) specific electrical conductivity of saturated soil-paste extracts of 2-4 mSm/cm.[20]

Remarks:

- The most common soluble salts are the chlorides and sulphates of sodium, calcium and magnesium. Nitrates may be present in appreciable quantities but only rarely.[21]
- Salinization leads to loss of soil fertility and impacts the soils ability to filter pollutants. It can affect plant growth by disrupting nitrogen absorption.[22]

Area affected by waterlogging (FDES 1.1.4.b.4)

Area of soil with high humidity and where oxygen in the pore space is insufficient for the roots of plants to breathe properly. Other gases (detrimental to the growth of roots), such as carbon dioxide and ethylene, can also be present.[23]

Remark:

- Many soils are naturally flooded, and this is only considered a threat when soils that were previously aerobic (for example, with adequate oxygen in the porous space) become flooded.

Area affected by acidification (FDES 1.1.4.b.5)

Area with a decrease in soil pH due to the build-up of hydrogen and aluminium ions in the soil, and the associated loss of basic cations such as calcium, magnesium, potassium and sodium due to leaching or product removal.[24]

Acidification can be natural or anthropogenic, it decreases the ability of the soil to support ecosystems such as forests.

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[19] UNEP/ISRIC (1991) *World Map of the Status of Human-induced Soil Degradation. (GLASOD)* cited in United Nations (1996) Indicators of Sustainable Development: Guidelines and Methodologies, 2nd edition, http://www.un.org/esa/sustdev/natlinfo/indicators/methodology_sheets/land/desertification.pdf (accessed 29 September 2018)

[20] FAO (2018) *Handbook for Saline soil management,* http://www.fao.org/3/i7318en/I7318EN.pdf (accessed 29 September 2018)

[21] FAO (1988) *Salt-Affected Soils and their Management* webpage, http://www.fao.org/docrep/x5871e/x5871e04.htm#TopOfPage (accessed 29 September 2018)

[22] FAO (2018) *Handbook for Saline soil management,* http://www.fao.org/3/i7318en/I7318EN.pdf (accessed 29 September 2018)

[23] FAO (2015) *Status of the World's Soil Resources. Technical Summary*, http://www.fao.org/3/a-i5126e.pdf (accessed 29 September 2018)

[24] FAO (2015) *Status of the World's Soil Resources. Technical Summary*, http://www.fao.org/3/a-i5126e.pdf (accessed 29 September 2018)

Area affected by compaction (FDES 1.1.4.b.6)

Area of soil surface whose porosity has been affected by the application of pressure to the surface thereof. The compaction prevents the functions of both, the superficial soil and subsoil, and inhibits the concentration of roots and the exchange of water and gases.[25]

Soil organic carbon

Soil organic carbon is not included in the FDES 2013. However, lack of soil organic carbon has been recognized under the Sustainable Development Goals as a type of soil degradation so is included here.

Soil organic carbon is an important element in soils, incorporated by the decomposition of organic matter. Soils are key to regulation of the emission of carbon dioxide and other greenhouse gases as they contain more carbon than all the vegetation on earth.[26]

Loss of soil organic carbon due to soil degradation is considered an important contributor to greenhouse gas accumulation and climate change; it is currently estimated that there has been a 59% loss in the availability of carbon in soil in the conversion of grasslands to crops.[27]

Carbon inputs to soil are determined by the amount and distribution of primary production, the life cycle of the vegetation, and exogenous organic matter additions (e.g., composts, manure). Thus, practices that increase net primary production (NPP) and/or return a greater portion of plant materials to the soil have the potential to increase soil carbon stocks.[28]

3A3. Nutrient content of soil (FDES 1.1.4.c)

The nutrients listed below are defined by their chemical composition, which is not redefined in this methodology sheet. However, under each a brief description is provided of their function for soil health. The nutrient information is derived from laboratory analysis of soil samples taken in the field which provide the specific distribution of these elements. Nutrient status in soil can be found in soil maps which include nutrient information or in the laboratory analysis reports of soil samples.

Nutrient content of soil, measured in levels of:

Nitrogen (FDES 1.1.4.c.1)

Nitrogen is an important nutrient for plants and therefore for soil fertility. However, soil fertility is dependent not on availability of nutrients, but on nitrogen fixation.[29]

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[25] FAO (2015) *Status of the World's Soil Resources. Technical Summary*, http://www.fao.org/3/a-i5126e.pdf (accessed 29 September 2018)

[26] FAO (2015) *Status of the World's Soil Resources. Technical Summary*, http://www.fao.org/3/a-i5126e.pdf (accessed 29 September 2018)

[27] FAO (2015) *Status of the World's Soil Resources. Technical Summary*, http://www.fao.org/3/a-i5126e.pdf (accessed 29 September 2018)

[28] IPCC (2000) *Special Reports Land Use, Land-Use Change and Forestry*, Geneva, Switzerland, http://www.ipcc.ch/ipccreports/sres/land_use/index.php?idp=163 (accessed 29 September 2018)

[29] FAO (2016) *Salination and sodification of soil* presentation, http://www.fao.org/3/a-i6471e.pdf (accessed 29 September 2018)

Nitrogen absorbed by soil in the form of nitrates (NO_3) and ammonium (NH_4), in addition to the addition of nitrogenated fertilizers, influences the acidity of the soil by stabilizing its pH at 6-7, a value that allows the maximum availability of nutrients.

Phosphorous (FDES 1.1.4.c.2)

Phosphorous is vital for the growth and health of plants, it assists in the conversion of energy from the sun and conversion of other chemicals such as nitrogen, into appropriate foods for plants. A deficiency of phosphorous will make plants look stunted and sick and produce low quality flowers and fruits, but with the correct amount of this element, will grow vigorously and mature earlier than plants that do not.

Phosphorous functions as one of the main players in photosynthesis, nutrient transport and energy transmission. Phosphorous also affects the structure of the plant at the cellular level.[30]

Calcium (FDES 1.1.4.c.3)

Calcium is an element that contributes to soil fertility, it is an essential element for soil microorganisms that transform crop residues into organic matter in the soil; its presence contributes to reduced soil salinity and improves water penetration, and in association with humic acid forms a characteristic structure that allows aeration of the soil. On the other hand, excessive presence of calcium, together with other elements, can lead to salinization of soils.

Magnesium (FDES 1.1.4.c.4)

Magnesium is an essential nutrient; its presence in excess in the soil can cause degradation in soil physical conditions and together with other elements can cause its salinization, while its presence can be affected by erosive processes.[31]

Potassium (FDES 1.1.4.c.5)

Potassium is one of the major plant macronutrients needed for plant growth and development. It is often applied in chemical fertilizers along with nitrogen and phosphorous.[32]

Zinc (FDES 1.1.4.c.6)

Zinc is an important trace element in soils and for plant growth. Issues affecting its availability are soil erosion and uptake is reduced with excess alkalinity. However, zinc toxicity may result if soils are acidified or if zinc fertilization occurs for long periods.[33]

Other (Soil pH) (FDES 1.1.4.c.7)

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[30] Servicios Agropecuarios de la Costa S.A. de C.V. (SACSA), *Importancia del fósforo por las plantas* (Importance of phosphorous for plants) webpage, http://www.gruposacsa.com.mx/importancia-del-fosforo-por-las-plantas/ (accessed 29 September 2018)

[31] Mikelsen, R., *Fuentes de Magnesio, International Plant Nutrition Institute webpage* (Magnesium Sources), http://www.ipni.net/publication/ia-lahp.nsf/0/47833649504C3064852579A0006A1A38/$FILE/3.%20Fuentes%20de%20Magnesio.pdf (accessed 29 September 2018)

[32] FAO *Soils Portal: Chemical properties* webpage, http://www.fao.org/soils-portal/soil-survey/soil-classification/numerical-systems/chemical-properties/en/ (accessed 29 September 2018)

[33] FAO (unknown) *Trace Elements in Soils and Agriculture, FAO Soils Bulletin 17*, http://www.fao.org/docrep/017/d4779e/d4779e.pdf (accessed 29 September 2018)

Soil pH is an important element of soil productivity which measures soil acidity or alkalinity. A pH of 7 is neutral, greater than 7 basic or alkaline and below 7 acidic. Soil organisms are hindered by high acidity, and most agricultural crops do best with mineral soils of pH 6.5.[34]

[34] FAO *Soils Portal: Chemical Properties* webpage, http://www.fao.org/soils-portal/soil-survey/soil-classification/numerical-systems/chemical-properties/en/ (accessed 29 September 2018)

4. International sources and recommendations

4A. Classifications and groupings

It should be noted that in addition to the international classifications listed below, national soil classifications are also widely used by other countries.

4A1. The World Reference Base for Soil Resources (WRB)[35]

The World Reference Base for Soil Resources (WRB) is an international standard for classification systems of soil groups approved by the International Union of Soil Sciences.[36] It provides soil groups and rules for creating map legends, showing how to characterize map units which are not homogenous soil types. Map units can consist of dominant, codominant or associated soils or combinations of these.

It has been used to generate legends for soil inventory maps. Statistics are derived from the soil maps generated by countries and international organizations. It is not intended to replace any national soil classification system, but rather to be a common denominator for international communication.

The WRB groups the soils as follows:

Histosols	Solonchaks	Plantosols	Gypsisols	Cambisols
Anthrosols	Gleysols	Stangosols	Calcisols	Arenosols
Technosols	Andosols	Chernozems	Retisols	Fluvisols
Cryosols	Podsols	Kastanozems	Acrisols	Regosols
Leptosols	Plintosols	Phaeozems	Lixisols	
Solonetz	Nitisols	Umbrisols	Alisols	
Vertisols	Ferralsols	Durisols	Luvisols	

4A2. USDA Soil Taxonomy, Soil Conservation Service of the United States Department of Agriculture

The USDA Soil Taxonomy, published in 1975 by the Soil Conservation Service of the United States Department of Agriculture, is a basic system of soil classification to elaborate and interpret soil surveys. A second edition

[35] FAO (2015) *World Reference Base for Soil Resources 2014*: international soil classification system for naming soils and creating legends for soil maps, World soil resources reports 106, http://www.fao.org/3/i3794en/I3794en.pdf (accessed 29 September 2018)
[36] FAO *Soils Portal World Reference Base for Soil Resources* webpage, http://www.fao.org/soils-portal/soil-survey/soil-classification/world-reference-base/en/ (accessed 29 September 2018)

has been published in 1999[37] and further revisions incorporated into the Keys to Soil Taxonomy[38] which provides the taxonomic keys necessary for the classification of soils in a form that can be used easily in the field. The system follows a hierarchical model that groups similar soils into very general categories.

Its basic principles were used in forming the World Reference Base and the FAO Soil Legend.[39] As it is a seminal work in the establishment of international standards, it is mentioned in the methodology sheet. The system is also internationally recognized, being used mainly in Latin America and Asia.

It classifies the soil into 12 Soil Orders (the highest group in the taxonomy):

Alfisols	Inceptisols
Andisols	Mollisols
Aridisols	Oxisols
Entisols	Spodosols
Gelisols	Ultisols
Histosols	Vertisols

4A3. Soil erosion

There is no official international classification of soil erosion. However, the FAO Local Level Assessment of Land Degradation and Sustainable Management[40] provides types and forms of erosion by wind and water, including degree of erosion.

This covers erosion by water:

- Erosion by raindrop impact (splash)
- Sheet erosion
- Linear erosion
- Mass movement

and erosion by wind, the major types below, with more detailed types:

- Deflation
- Accumulation

[37] United States Department of Agriculture, Natural Resources Conservation Service (1999) *Soil Taxonomy: a basic system of soil classification for making and interpreting soil surveys*, 2nd ed., https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_051232.pdf (accessed 29 September 2018)

[38] United States Department of Agriculture, Natural Resources Conservation Service (2014) *Keys to Soil Taxonomy*, 12th edition, https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/taxonomy/?cid=nrcs142p2_053580 (accessed 29 September 2018)

[39] FAO (2015) *World Reference Base for Soil Resources 2014*: international soil classification system for naming soils and creating legends for soil maps, World soil resources reports 106, http://www.fao.org/3/i3794en/I3794en.pdf (accessed 29 September 2018)

[40] FAO (2011) *Land Degradation and Assessment in Drylands: Manual for Local Level Assessment of Land Degradation and Sustainable Land Management: Part 2 Field Methodology and Tools*, LADA Project, http://www.fao.org/nr/kagera/tools-and-methods/lada-local-level-assessment-manuals/en/ (accessed 29 September 2018)

4B. Reference to international statistical recommendations, frameworks and standards

- FAO (2015) Status of the World's Soil Resources, provides regional assessments of soil change.[41]
- FAO Voluntary Guidelines for Sustainable Soil Management:[42] developed to provide a voluntary standard for sustainable soil management and to provide guidance on realizing this in practice.
- FAO (1996) Land Quality Indicators and Their Use in Sustainable Agriculture and Rural Development provides information on developing indicators of soil quality and their measurement.[43]
- FAO (2017) Soil Organic Carbon Mapping Cookbook[44] provides information on mapping of soil organic carbon.
- Guidance on how to present soil statistics can be found in the metadata for the international and regional databases discussed in section 4C.
- World Inventory of Soil Emission Potentials (WISE), World Soils and Terrain Digital Database (SOTER), and regional databases for Asia, Global Assessment of the Status of Human-induced Soil Degradation (GLASOD) and Regional Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia (ASSOD).
- United Nations Convention to Combat Desertification provides guidance on sustainable land management and land degradation neutrality.[45]

4C. Sources of global and regional environment statistics and indicators series

FAO/UNESCO Soil Map of the World

Presents soil statistics of different countries of the world starting from 1960 to 1980, presented globally and regionally at 1: 5 000 000 scale. Data for the map are provided by national institutions. As countries use national soil classification systems, data can be provided under other classifications such as soil taxonomy. Found at http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/faounesco-soil-map-of-the-world/en/.[46]

Global Soil Partnership SoilSTAT

SoilSTAT[47] is a system being developed by the Global Soil Partnership for monitoring, forecasting and reporting periodically on the status of global soil resources. This will be supported by the CountrySIS framework, a

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[41] FAO (2015) *Status of the World's Soil Resources*, http://www.fao.org/documents/card/en/c/c6814873-efc3-41db-b7d3-2081a10ede50/ (accessed 29 September 2018)

[42] FAO (2017) *Voluntary Guidelines for Sustainable Soil Management*, http://www.fao.org/3/a-bl813e.pdf (accessed 29 September 2018)

[43] FAO (1996) *Land Quality Indicators and Their Use in Sustainable Agriculture and Rural Development*, http://www.fao.org/docrep/W4745E/w4745e00.htm#Contents (accessed 29 September 2018)

[44] FAO (2017) *Soil Organic Carbon Mapping Cookbook*, http://www.fao.org/3/a-bs901e.pdf (accessed 29 September 2018)

[45] UNCCD *publications* webpage, https://www2.unccd.int/publications (accessed 29 September 2018)

[46] FAO (1971) *FAO/UNESCO Soil Map of the World* webpage, http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/faounesco-soil-map-of-the-world/en/ (accessed 29 September 2018)

[47] FAO SoilSTAT webpage, http://www.fao.org/land-water/databases-and-software/soilstat/en/ (accessed 29 September 2018)

framework to guide development of soil information systems by countries, which will help with harmonisation and integration with SoilSTAT.

Harmonized World Soil Database v 1.2[48]

The FAO Harmonized World Soil Database, http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/, developed in partnership with IIASA, ISRIC-World Soil Information, Institute of Soil Science, Chinese Academy of Sciences and the Joint Research Centre of the European Commission, is a 30 arc-second raster database covering terrain, land cover, soil quality, including nutrients, salinization. It updates the FAO/UNESCO Soil Map of the World with national and regional information including databases of SOTER, European Soil Data Centre (ESDAC), Soil Map of China, WISE. Legacy maps from scanned paper maps based on field survey data can be found at: http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/en/

International Soil Reference and Information Centre (ISRIC) Soil Data Hub

ISRIC is an independent foundation providing scientific information on soils. It is globally recognized and partners with FAO on several publications, including the World Reference Base for Soil Resources, http://www.isric.org/projects/world-inventory-soil-emission-potentials-wise.[49] Previously its database was known as ISIS: ISRIC Soil Information System. Its current data products include SoilGrids 250m and 1km outputs of ISRIC's automated global soil mapping system, as well as the World Soil Information Service (WoSIS) Soil Profile Database. SoilGrids provides modelled data on soil mapping; and WoSIS provides georeferenced point data of soil profiles, without adjustment.

World Inventory of Soil Emission Potentials (WISE)[50]

WISE was implemented by ISRIC between 1991-2016, http://www.isric.org/projects/world-inventory-soil-emission-potentials-wise. It is a global soil database, linked by means of GIS to the FAO-UNESCO Soil Map of the World.[51] It shows the carbon emissions potentials of soils and has been linked to the SOTER databases creating the SOTWIS products.

(World) Soils and Land of the World (SOTER)[52]

SOTER, http://www.isric.org/projects/soil-and-terrain-soter-database-programme, developed by FAO, ISRIC and UN Environment in 1986, provides terrain and soil data in GIS polygons at varying scales at continental, regional, national and district – generally above 1: 1 million. Also hosted are the SOTER-based soil parameter estimates (SOTWIS) products, which incorporate more standardized soil profile data.

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[48] FAO *Harmonized World Soil Database v 1.2* webpage, http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/ (accessed 29 September 2018)

[49] FAO (2015) *World Reference Base for Soil Resources 2014*: international soil classification system for naming soils and creating legends for soil maps, World soil resources reports 106, http://www.fao.org/3/i3794en/I3794en.pdf (accessed 29 September 2018)

[50] ISRIC, *World Inventory of Soil Emission Potentials (WISE)* webpage, http://www.isric.org/projects/world-inventory-soil-emission-potentials-wise (accessed 29 September 2018)

[51] FAO (1971) *FAO/UNESCO Soil Map of the World* webpage, http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/faounesco-soil-map-of-the-world/en/ (accessed 29 September 2018)

[52] FAO, UN Environment and ISRIC, *Soils and Land of the World database* webpage, http://www.isric.org/projects/soil-and-terrain-soter-database-programme (accessed 29 September 2018)

Global Soil Organic Carbon Map (GSOCmap V1.2.0)[53]

The Soil Organic Carbon map of the Global Soil Partnership, http://www.fao.org/global-soil-partnership/pillars-action/4-information-and-data/global-soil-organic-carbon-gsoc-map/en/, shows the current global soil organic carbon stocks in topsoil (0 – 30 cm). A Global Soil Salinity Map and Soil Erosion are planned.

United Nations Convention to Combat Desertification

UNCCD's reporting process http://www2.unccd.int/convention/2017-2018-unccd-reporting-process, provides data on countries progress in meeting the 2018-2030 Strategic Framework which aims to avoid, minimize and reverse desertification/land degradation and mitigate the effects of drought and to achieve land degradation neutrality.[54] It should be noted that the reporting indicators go beyond soils to reflect a broader range of conditions including ecosystem condition, conditions of affected populations, mitigation and adaptation activities to manage the effects of drought and resource mobilization. Objectives specific to this topic are:

- **Strategic objective 1:** To improve the condition of affected ecosystems: SO 1-3 Trends in carbon stocks above and below ground.
- **Strategic objective 4:** To generate global environmental benefits through effective implementation of the United Nations Convention to Combat Desertification: SO 4-1 Trends in carbon stocks above and below ground.

Assessment of Soil Degradation in South and Southeast Asia (ASSOD)

ASSOD[55] and Global Assessment of Soil Degradation (GLASOD), http://www.isric.org/projects/assessment-soil-degradation-south-and-southeast-asia-assod, developed from 1995 to 1997 by ISRIC is an assessment of soil degradation for South and Southeast Asia using the Global Assessment of Human-induced Soil Degradation (GLASOD)[56] methodology. It uses the physiography of the SOTER. Under the GLASOD project a world map of human-induced soil degradation was prepared from 1988 to 1991. It shows the soil degradation related to water erosion, wind erosion, chemical deterioration and physical deterioration, along with level of soil degradation.

European Union, Land Use and Cover Area Frame Survey (LUCAS)

LUCAS, https://esdac.jrc.ec.europa.eu/projects/lucas, http://ec.europa.eu/eurostat/web/lucas, includes a soil module based on field samples from the topsoil (the superficial 20 cm) for 10% of LUCAS sample points. It provides data on soil properties of coarse fragments, pH, organic carbon, carbonates, phosphorous, total nitrogen, extractable carbonate, cationic exchange capacity and heavy metals is available. The LUCAS survey has been carried out every three years since 2006; the soil module is available for 2009, 2012, 2015 and 2018.[57]

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[53] FAO *Global Soil Organic Carbon Map V1.0*, http://www.fao.org/global-soil-partnership/pillars-action/4-information-and-data/global-soil-organic-carbon-gsoc-map/en/ (accessed 29 September 2018)

[54] UNCCD (2017) *The Future Strategic Framework of the Convention*. ICCD/COP (13)/L.18, Conference of the Parties, Thirteenth session, https://www2.unccd.int/sites/default/files/inline-files/ICCD_COP(13)_L.18-1716078E.pdf (accessed 29 September 2018)

[55] ISRIC *ASSOD* webpage, http://www.isric.org/projects/assessment-soil-degradation-south-and-southeast-asia-assod (accessed 29 September 2018)

[56] ISRIC, *GLASOD methodology*, http://www.isric.org/projects/global-assessment-human-induced-soil-degradation-glasod (accessed 29 September 2018)

[57] European Commission, *LUCAS survey* webpage, http://ec.europa.eu/eurostat/web/lucas/methodology (accessed 29 September 2018)

Statistical Office of the European Union (Eurostat), Soil Statistics Data

Eurostat, http://ec.europa.eu/eurostat/web/environmental-data-centre-on-natural-resources/natural-resources/soil, provides data on soil types and human-induced water and wind erosion of soil by country, based on models supported by geological, climatic and land use information.[58]

[58] Eurostat, *Environmental Data Centre on Natural Resources, Soil* webpage, http://ec.europa.eu/eurostat/web/environmental-data-centre-on-natural-resources/natural-resources/soil (accessed 29 September 2018)

5. Data collection and sources of data

Statistical information on soils originates from the data sources produced by the national offices responsible for generating them, as well as that produced by academic institutions and researchers; the latter enriches the information produced by soil inventories.

Scope of the statistics

All soils in countries.

Statistical unit

Soils are generally grouped into *soil mapping units* which are areas which are coherent in terms of their soil components and are the basic unit of soil maps. They can contain one soil type or multiple soil types. It may be difficult to generate internationally comparable statistics as countries often use their own soil classification.

Measurement units

The measurement unit varies according to the nature of the data collection. Traditionally soil data have been collected using soil surveys where the measurement unit would be a sample point. Soil data obtained from remote sensing would not have measurement units, but the units correspond to the pixels and resolution of the images. Examples include soil erosion reported in tonnes/ha/year or area affected; soil nutrients reported in tonnes/kilograms of nutrient per hectare or kilometre of land. It is often difficult to obtain internationally harmonised units of measurements.

Sources and institutions

Data on soils are obtained from several sources:

- Remote sensing (land cover and land use)
- Soil surveys, with resulting thematic maps
- Administrative records
- Scientific studies

Some countries lack soil inventories, in which case the global datasets produced by FAO may be useful. The Global Soil Partnership (GSP) is working with countries through CountrySIS Framework to build national soil information systems as part of the GSPs federated Global Soil Information System (GLOSIS).

There is currently no harmonized system of soil information. FAO is working with member states to implement the World Reference Base for Soil Resources[59] with the support of the USDA Soil Taxonomy[60] to provide harmonized world-wide data on soils through Pillars 4 and 5 of the GSP (http://www.fao.org/3/a-

[59] FAO (2015) *World Reference Base for Soil Resources 2014*: international soil classification system for naming soils and creating legends for soil maps, World soil resources reports 106, http://www.fao.org/3/i3794en/I3794en.pdf (accessed 29 September 2018)

[60] United States Department of Agriculture, Natural Resources Conservation Service (1999) *Soil Taxonomy: a basic system of soil classification for making and interpreting soil surveys*, 2nd ed., https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_051232.pdf (accessed 29 September 2018)

bl102e.pdf and http://www.fao.org/3/a-bs756e.pdf). This would harmonize approaches to determine the main functional properties of soils, i.e., chemical, physical and biological characteristics of the soil; and to review existing indicators and evaluation procedures to develop harmonized criteria, baselines and thresholds. This will also support review of criteria for evaluation of soil degradation.

Data collection

Various information on data collection using traditional surveys and digital techniques, from international and national sources, can be found on the FAO Soils Portal.[61]

The UNCCCD reporting manual contains guidance on reporting on land degradation for the UNCCD processes and for the Sustainable Development Goals.[62] Techniques for measuring local level land degradation can be found under the Land Degradation and Assessment in Drylands (LADA) project of FAO.[63]

Aggregation

Temporal aspects

International soil data are compiled from a variety of national sources and the reference periods may vary. The periodicity varies by type of statistic. Datasets produced several years ago are still in use for statistics which change slowly such as soil type. Other examples include changes to soil nutrient concentrations have been reported over a four-year period; the UNCCD SDG 15.3.1 assesses change to soil organic carbon over a five or ten-year period (depending on type of country); soil erosion statistics have been reported over a five to seven-year period.

Temporal aspects are particularly important when addressing soil threats such as erosion, soil organic carbon loss, nutrient imbalance, soil acidification, soil contamination, waterlogging, soil compaction, soil sealing, salinization and loss of soil biodiversity.

Spatial aspects

The FDES 2013 includes potential aggregations by location, by soil type, by national and sub-national levels. Examples of map scales for products with national and sub-national level are 1:50,000 to 1:500,000. Those statistics measured by location may apply to local areas such as a watershed or community, e.g., type of erosion, and the area would be measured in an appropriate unit, i.e., square metres, hectares etc.

Note that some aspects, such as aggregation by soil type of international classifications may be difficult for countries which are using a national soil classification system.

[61] FAO *Soils Portal, Soil survey, digital soil mapping and traditional soil survey methodologies*, webpage http://www.fao.org/soils-portal/soil-survey/en/ (accessed 29 September 2018)

[62] UNCCD (2017) Reporting manual for the 2017-2018 UNCCD reporting processes, https://prais.unccd.int/sites/default/files/helper_documents/2-Manual_EN_1.pdf (accessed 29 September 2018)

[63] FAO (2011) *Land Degradation and Assessment in Drylands: Manual for Local Level Assessment of Land Degradation and Sustainable Land Management*, LADA Project, http://www.fao.org/nr/kagera/tools-and-methods/lada-local-level-assessment-manuals/en/ (accessed 29 September 2018)

6. Uses and dissemination

6A. Potential presentation/dissemination formats

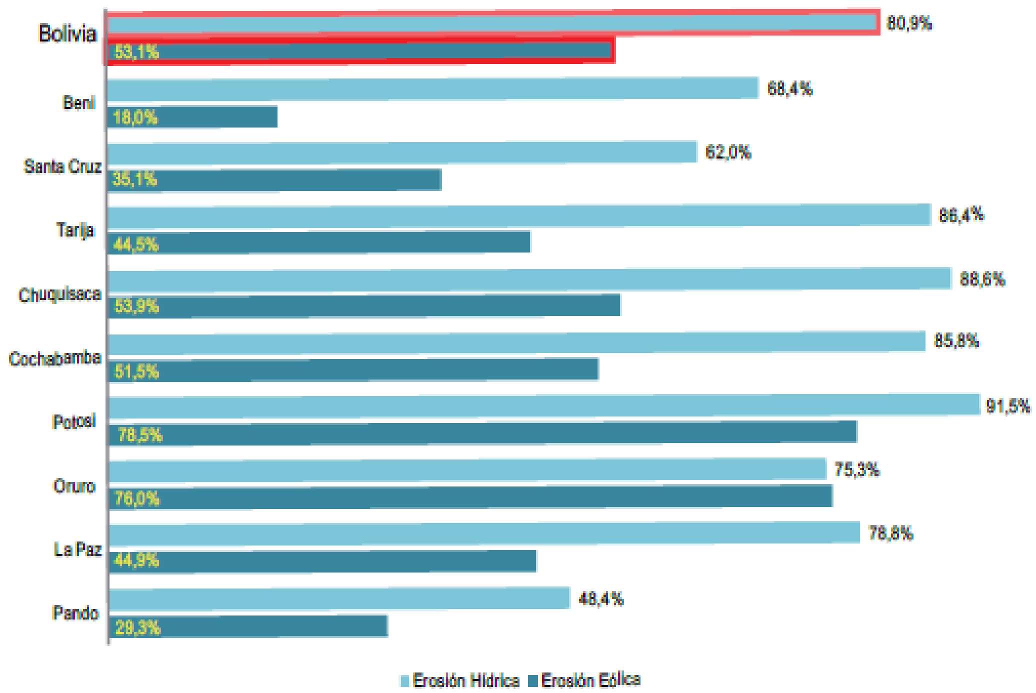
Figure 6.1 Water and wind erosion in the Republic of Argentina

	Moderate		Serious/Severe		Total	
	ha	%	ha	%	ha	%
Hydric (water) erosion	15 382 000	62	9 626 000	38	25 008 000	100
Aeolic (wind) erosion	7 020 000	33	14 390 000	67	21 410 000	100
Total	22 402 000	48	24 016 000	52	46 418 000	100

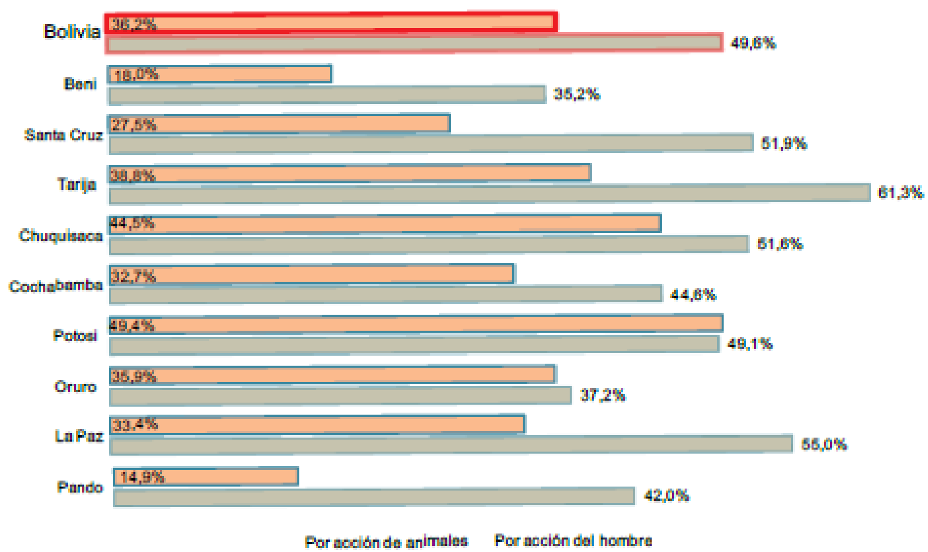
Source: FAO (1992) Erosion de suelos en America Latina: La erosion del suelo en la República Argentina, http://www.fao.org/docrep/t2351s/T2351S00.htm#Contents (accessed 29 September 2018)

Shows area affected by water and wind erosion at national level.

Figure 6.2 Bolivia, causes of soil erosion by department 2013



Fuente: Instituto Nacional de Estadística



Source: Estado Plurinancional de Bolivia (2014) Un Pincelazo a las estadísticas con base a datos de censos: Censo Nacional Agropecuario 2013. http://www.fao.org/fileadmin/templates/ess/ess_test_folder/World_Census_Agriculture/Country_info_2010/Reports/Reports_5/BOL_SPA_REP_2013.pdf (accessed 29 September 2018)

Shows levels of water and wind erosion, for each department, and the percentage of total erosion caused by animals and by human-intervention.

Figure 6.3. European Union, Estimated soil erosion by water - area eroded by more than 10 tons per hectare per year, 2000, 2010 and 2012

unit: Percentage

geo \ time	2000	2010	2012
EU (28 countries)	5.99	5.26	5.16
Belgium	0.70	0.41	0.41
Bulgaria	4.82	3.01	2.86
Czech Republic	2.77	1.34	1.26
Denmark	0.01	0.01	0.00
Germany	2.46	1.37	1.22
Estonia	0.01	0.00	0.00
Ireland	0.72	0.68	1.13
Greece	10.79	9.41	9.72
Spain	10.92	8.85	8.42
France	4.14	3.39	3.37
Croatia	7.78	6.95	6.89
Italy	25.83	24.61	24.58
Cyprus	8.54	6.12	6.18
Latvia	0.01	0.01	0.01
Lithuania	0.03	0.02	0.02
Luxembourg	3.60	2.68	2.67
Hungary	2.94	2.57	2.37
Malta	28.64	11.36	12.74
Netherlands	0.02	0.01	0.01
Austria	15.43	15.55	15.94

Source: Eurostat, soil erosion statistics webpage, http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=t2020_rn300&plugin=1 (accessed 29 September 2018)

Figure 6.4. Gross nutrient balance in agricultural land (Phosphorous, kilograms per hectare per year), 2001-2009 (selection of EU countries and years)

Gross nutrient balance on agricultural land
kilograms per hectare
The gross nutrient balance represents the total potential threat to the environment of ... more

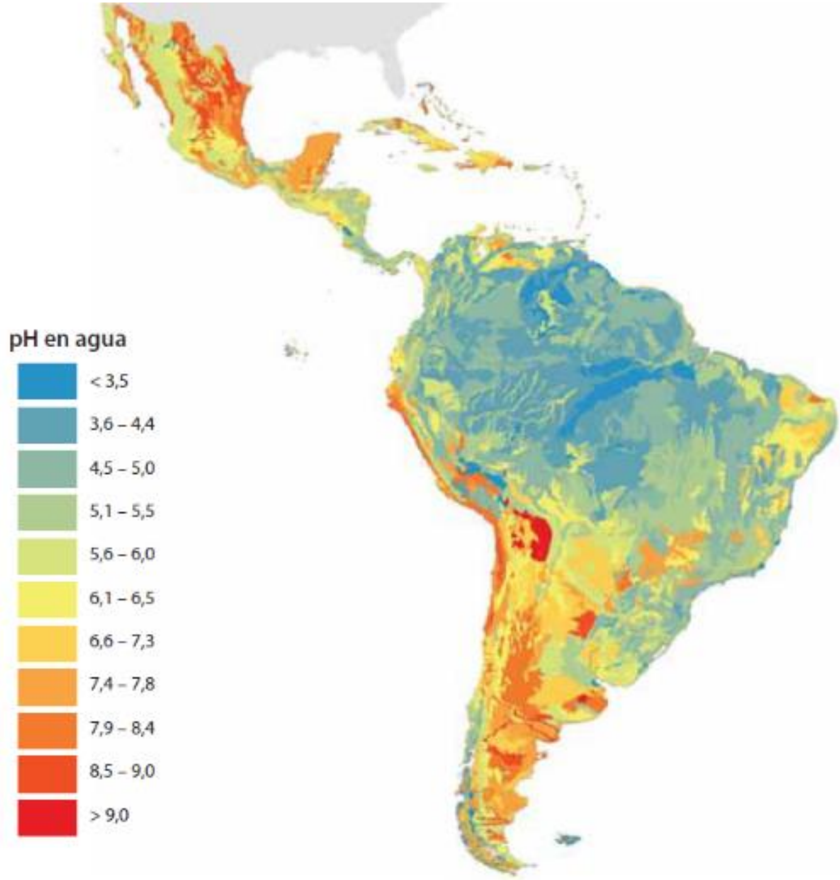
nutrient: Phosphorus

geo \ time	2002	2003	2004	2005	2006	2007	2008	2009
European Union (changing comp	:	:	3[e]	4[e]	4[e]	4[e]	2[e]	0[e]
EU (28 countries)	:	:	:	:	:	:	:	:
Belgium	15[e]	12[e]	11[e]	11[e]	10[e]	9[e]	4[e]	2[e]
Bulgaria	-3[e]	0[e]	-3[e]	-2[e]	-2[e]	0[e]	-4[e]	-4[e]
Czech Republic	2	4	0	0	1	2	0	-5
Denmark	14[e]	13[e]	13[e]	11[e]	12[e]	12[e]	7[e]	7[e]
Germany	2	5	-1	0	1	0	-1	-5
Estonia	:	:	-5	-7	-2	-7	-5	-6
Ireland	7	8	8	7	6	5	1	0
Greece	6[e]	7[e]	4[e]	3[e]	4[e]	4[e]	2[e]	3[e]
Spain	6[d]	6[d]	5[d]	6[d]	4[d]	5[d]	1[d]	3[d]
France	6	8	5	5	4	4	4	-2
Croatia	11	15	11	12	18	12	9	1
Italy	5[e]	6[e]	0[e]	0[e]	3[e]	2[e]	-3[e]	0[e]
Cyprus	35[e]	30[e]	29[e]	28[e]	28[e]	31[e]	33[e]	29[e]
Latvia	1[e]	1[e]	1[e]	2[e]	2[e]	2[e]	1[e]	1[e]
Lithuania	5[e]	6[e]	10[e]	13[e]	9[e]	4[e]	6[e]	-1[e]
Luxembourg	8[e]	7[e]	6[e]	7[e]	5[e]	6[e]	4[e]	4[e]

Source: Eurostat, soil statistics webpage, http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&pcode=t2020_rn310&language=en (accessed 29 September 2018)

Note: the full series reflects the EU 28 countries and years 2002-2016.

Figure 6.5. pH distribution of soils of Latin America and the Caribbean, 2014

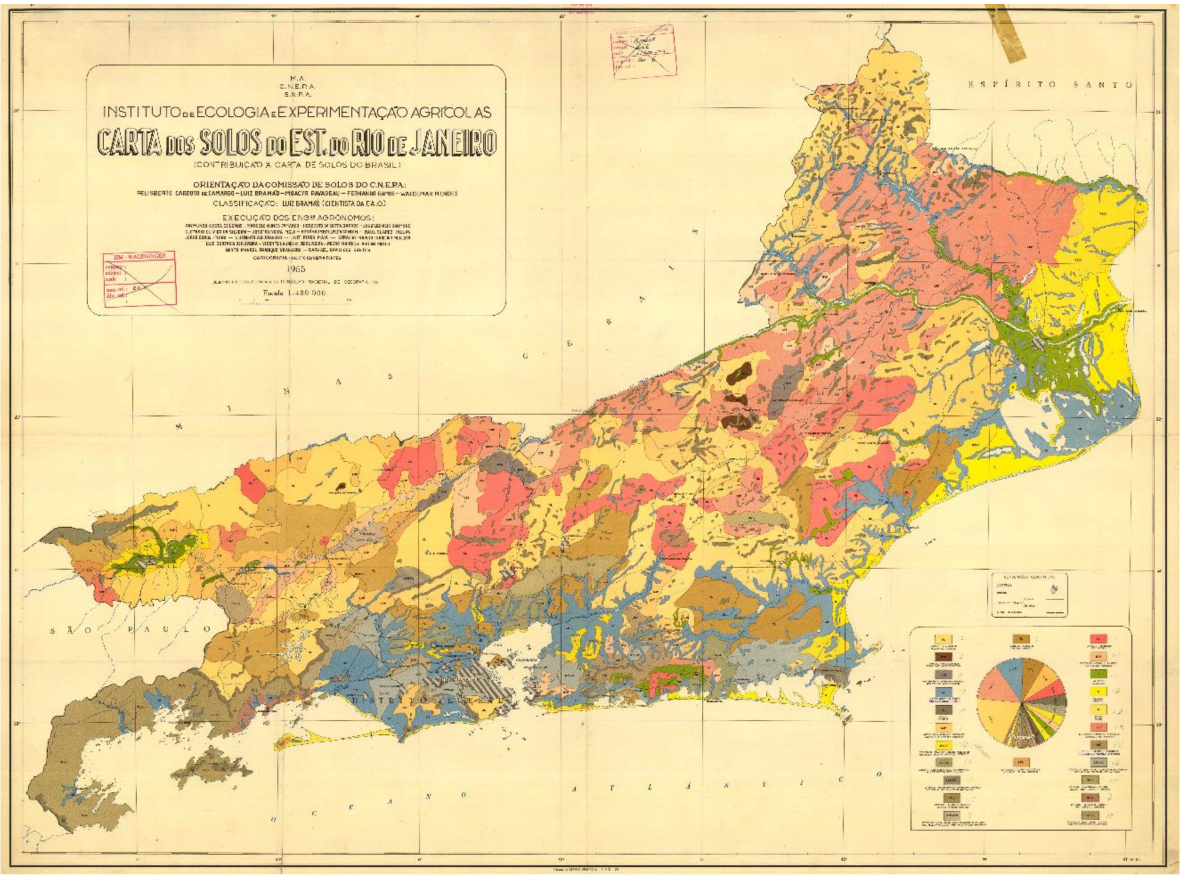


El pH es una designación numérica de la acidez o alcalinidad en el suelo (ver página 11). Un pH de 7 se considera un valor neutro, mientras que los valores inferiores son catalogados como ácidos y los superiores como alcalinos o básicos. Es un parámetro fundamental del suelo, ya que controla muchos procesos químicos, como aquellos relacionados con la disponibilidad de los nutrientes necesarios para los vegetales. El intervalo de pH óptimo para la mayoría de las plantas está entre 6 y 7,5, sin embargo muchas especies han desarrollado adaptaciones para crecer en suelos con valores fuera de este rango. Los suelos ácidos se encuentran fundamentalmente en las zonas con altas precipitaciones, donde los cationes básicos más móviles son lixiviados (lavados) del suelo, aumentando los niveles de los cationes Al^{3+} y H^{+}. Los suelos alcalinos se caracterizan por la presencia de sales solubles. La aplicación de cal a los suelos ácidos puede aumentar los valores de pH y permitir el cultivo de especies que de otra manera no se podrían cultivar. [SOTERLAC] (JRC)

Source: European Commission (2014) Soil Atlas of Latin America and the Caribbean, https://esdac.jrc.ec.europa.eu/Library/Maps/LatinAmerica_Atlas/Index.html (accessed 29 September 2018)

Shows the pH balance of soils in Latin America and the Caribbean.

Figure 6.6. Soil map of the state of Rio de Janeiro



Source: Brazil Government (1955) Institute of Ecology, https://esdac.jrc.ec.europa.eu/images/Eudasm/latinamerica/images/maps/download/br13015.jpg (accessed 29 September 2018)

An example of a traditional soil map using soil survey data.

Figure 6.7 Degradation of the soil resource in Mexico by level of degradation

Source: México (2013) National Forestry Commission

Shows soil degradation by categories of light, moderate, severe and extreme.

6B. SEEA accounts/tables that use these statistics

The Systsem of Environmental-Economic Accounting for Agriculture (SEEA AFF)[64] asset accounts for soil resources relate only to the top layers of soils. Quantities of soil extracted are not accounted for in these tables.

Table 5.17: Physical asset account for area of soil resources

Accounts for soil resources by soil type only for land used for agriculture and forestry and volumes to be extracted for use as a biological system. It covers opening and closing stocks, additions to stock from changes in land cover, changes in soil quality, and changes in soil environment; and reductions to stock from the same.

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[64] Food and Agriculture Organization of the United Nations, United Nations Statistics Division (2018) *System of Environmental-Economic Accounting for Agriculture, Forestry and Fisheries SEEA Agriculture*, White Cover version, http://www.fao.org/fileadmin/templates/ess/ess_test_folder/Publications/Agrienvironmental/SEEA_AFF_FINAL_Clean_03.pdf (accessed 29 September 2018)

Table 5.18: Physical asset account for volume of soil resources

The soil resources are classified by type of soil and by geographical region or land use/land cover type. Changes in volume for excavation are also recorded. The table aims to show changes due to erosion. It covers opening and closing stock, additions to stock from soil formation and deposition, upward reappraisals, reclassifications; and reductions in stock from extractions, soil erosion, catastrophic losses and downward reappraisals.

6C. Commonly used indicators that incorporate these statistics

A useful measure is that of the soil nutrient-balance which shows the difference between nutrients entering the soil and nutrients leaving the soil, often for the major nutrients of nitrogen, potassium and phosphorous. A negative balance shows declining soil fertility. It is measured in quantity of nutrient and in quantity of nutrient per hectare. The nutrient balance should be shown separately for soils of different fertility as the actual soil fertility as well as the nutrient balance will affect crop and vegetation growth.[65]

Scale issues are important as the most accurate balance is at field level. However, generalized or aggregate statistics are published for district or national scale which mask the underlying variation. Recommendations on presentation of nutrient balance data and appropriate uses for each scale are provided by FAO in the Assessment of Soil Nutrient Balance.[66]

Some indicators that are commonly used for soils:

- Area by soil type (as a proportion of the total surface area).
  Area by soil types (1.1.4.a.1) / Total land area

- Availability of soil nutrients (nitrogen, phosphorous, calcium, magnesium, potassium, carbon).
  For example, *Percentage Soil Organic Carbon*

- Eroded soil surface (as a proportion of the total area).
  Area affected by soil erosion (1.1.4.b.1) / Total land area

6D. SDG indicators that incorporate these statistics

2.4.1 Proportion of agricultural area under productive and sustainable agriculture

Indicator of Target 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.

The indicator is currently Tier III (as of 10 July 2018) and may consider various sub-indicators including rates of soil erosion and levels of soil organic carbon.

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[65] FAO (2001) *Assessment of soil nutrient balance: approaches and methodologies*, FAO Fertilizer and Plant Nutrition Bulletin 14, FAO: Rome, http://www.fao.org/fileadmin/templates/cpesap/C-RESAP_Info_package/Links/Module_5/Soil_nutrient_balance.pdf (accessed 29 September 2018)

[66] FAO (2001) *Assessment of soil nutrient balance: approaches and methodologies*, FAO Fertilizer and Plant Nutrition Bulletin 14, FAO: Rome, http://www.fao.org/fileadmin/templates/cpesap/C-RESAP_Info_package/Links/Module_5/Soil_nutrient_balance.pdf (accessed 29 September 2018)

15.3.1 Proportion of land that is degraded over total land area

Indicator of Target 15.3: By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.

The indicator is measured by three sub-indicators, land cover, land productivity and carbon stock.[67] The information from the UNCCD Reporting Process under the UNCCD 2018-2030 Strategic Framework will also be used to inform the SDG Indicator 15.3.1. The sub-indicator on carbon stock is pertinent to this methodology sheet.

The sub-indicator is measured taking soil organic carbon at a baseline period to assess whether it is degraded or not degraded; and it is assessed at each monitoring period to indicate whether conditions have changed to positive or improving, negative or declining, or stable or unchanging. Degraded land occurs where the sub-indicator is negative, or stable following a negative trend in the preceding time period.

[67] *SDG Metadata 15.3.1* webpage, https://unstats.un.org/sdgs/metadata/files/Metadata-15-03-01.pdf (accessed 29 September 2018)

F D E S

Manual on the Basic Set of Environment Statistics

2018