

ORIGINAL ARTICLE

Anthropogenic soils: general aspects and featuresCarmelo Dazzi^{1*}, Giuseppe Lo Papa¹¹Department of Agricultural and Forest Sciences, University of Palermo, Palermo, ItalyE-mail address of the corresponding author: carmelo.dazzi@unipa.it

Abstract - In recent decades man's role in soil formation has become a matter of great concern among soil scientists. Man is now considered a soil-forming factor and anthrosolization is recognised as a soil-forming process that consists of a collection of geomorphic and pedological processes resulting from human activities. These human activities include deep working, intensive fertilization, the addition of extraneous materials, irrigation with sediment-rich waters and wet cultivation. In this paper we review the influence of man as a soil forming factor stressing also some peculiar aspects linked to their classification.

Keywords - Anthrosols; man-soil relationship; Technosols.

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Introduction

The recognition of the man's role as the sixth pedogenetic factor [1] - [2] allows us to focus attention on the characterization and classification of soils deeply "modified" or even "built" by humans. In these soils, generally called "anthropogenic soils", it is not always easy to highlight the actions of disturbance due to human activities. Such actions, very often, affect biotic and abiotic soil functions in producing goods and services [3] - [4]. Due to the importance of the anthropogenic soils at worldwide level it is imperative that they must be defined and carefully characterised not only for land evaluation purposes, but also for land-planning and environmental protection.

For such reasons in many soil classification systems was introduced a new group of soil called Anthrosols [5] - [6] or Anthroposols [7] - [8] - [9], or Antropozem [10] or Anthropic soils [11].

In Soil Taxonomy [12] a new soil Order, which considers the "anthropogenic soils" will be introduced probably in the future. Several proposals have been made to define the classes of anthropogenic soils [13], however, until now a general consensus has not been reached.

Man's actions and anthropogenic soils

Because of the widely different kinds of human interventions and consequently of the broad range of soil conditions, also following Dudal [2], we could define seven major types of human induced 'anthropogenic soils':

1. Human induced changes of soil class
2. Human-induced diagnostic horizons
3. Human induced new parent materials
4. Human induced deep soil disturbance
5. Human induced change of landform
6. Human induced topsoil changes.
7. Human induced soil construction/reconstruction

Each soil type shows specific problems linked to the quality of the environment to which they belong and presents particular taxonomic implications.

Human induced changes of soil class

Soil management linked to land use practices may determine frequently changes in soil class. This can be slow or even very fast. In any case there is an evident modification of the diagnostic horizons. One of the most known examples are the Solonchaks developed from Cambisols in arid environments because of irrigation. Table 1 shows the analytical data of a Cambisol that, irrigated with saline water, has developed a surface horizon (salic horizon) showing an evident soluble salt accumulation and an electrical conductivity of 30 dS m⁻¹.

There are other examples of Solonetz developing from Cambisols in arid environment due to irrigation with saline water. Table 2 shows the analytical data of a Cambisols that has developed a deep natric horizon with ESP (Exchangeable Sodium Percentage) values ranging from 15 to 24.

Further examples of human induced changes of soil class concern the group of Gleysols that, artificially drained, become Cambisols (Figure 1 and 2). Even Regosols can derive from the truncation of Cambisols (or from other soil types) due to soil erosion.

Human-induced diagnostic horizons

Human activities determining the formation of new diagnostic horizons are mainly the long-term applications of organic matter or the wetland cultivation. In Soil Taxonomy (Soil Survey Staff, 2010) human induced enrichment of organic matter has been captured in the plaggen and anthropic epipedons. In the WRB [6] the organic matter enriched soils are split into plaggenic, terric and horticultural Anthrosols according to the practices involved.

The plaggenic horizon is defined as a mineral horizon of anthropic origin made from the addition of organic matter since medieval time or even before. Such name derives from the word "plaggen" that in the German agricultural tradition

indicated a sod of about 40 x 100 cm (and about 10 thick) formed by herbs and heather with a dense root system that was "collected" with a special iron-cutting tool and rolled. Added to the soils (even after having been used as bedding for animals), it allows for the cultivation of rye on sandy soils of low natural fertility. Probably this practice is 3000 years old reaching the maximum diffusion in the Middle Ages. Over the centuries this has led to the formation of a humic topsoil, 30-130 depth cm that, in Germany it is known as the "esch" horizon (eschhorizonte).

In the Netherlands "plaggen" indicated a sod of 25-30 cm from side to side and 3/5 cm thick that was used as

addition of animal and/or human waste or other organic residues (compost, vegetable waste). It is usually mixed and commonly presents artifacts.

Human induced new parent materials

Unconsolidated mineral or organic soil materials resulting largely from landfills, mine spoil, urban rubble, garbage dumps, dredging, produced by human activities generate fresh 'anthropogeomorphic' parent materials upon which soil forming factors can start acting anew [14]. Such type of 'anthropogenic soils' has received most attention and some names have been suggested [15] - [16] - [17] -

Table 1. Analytical data of a Cambisol that has developed a salic horizon due to irrigation with saline water.

Horizon	Depth cm	Sand	Silt g kg ⁻¹	Clay	pH in H ₂ O	C _{org} g kg ⁻¹	EC _e dS m ⁻¹	CEC cmol kg ⁻¹
Apz	0-18	760	55	185	7.4	80	30	12
Ap	18-60	745	65	190	7.2	50	10	12
2Bw	60-82	500	200	300	7.1	30	10	11
3Bw	82-105	670	150	180	7.7	10	8	11

Table 2. Analytical data of a Cambisol that has developed a natric horizon due to irrigation with saline water.

Horizon	Depth cm	Sand	Silt g kg ⁻¹	Clay	pH H ₂ O	C g kg ⁻¹	ESP %	CEC cmol kg ⁻¹
Apzn₁	0-20	777	59	164	7.5	40	24	13
Apzn₂	20-50	760	60	180	8.4	30	16	16
2Azn	50-80	400	220	380	8.4	40	15	28
2Bsszn	80-140	400	200	400	8.4	30	15	28

bedding for the animals and then applied to the soil as a soil amendment. The shift in the removal of the plaggen (to allow the reformation) was 5-15 years and to form 1 hectare of esch, people had to collect plaggen from 5-10 hectares. The application of the plaggen at the expense of the surrounding territories determined differences in altitude of 2 meters and marked broken slope. This practice was abolished by Dutch royal decree in 1798.

The terric horizon (as well as the plaggic) owes its genesis to the presence of less fertile soil and with low capability such as Arenosols, Podzols and Albeluvisols (sometimes also Fluvisols and Gleysols). It is an anthropogenic mineral horizon made by timeless addition of hearty material, compost, sludge, etc., while the ortic horizon is an anthropogenic mineral horizon made by prolonged cultivation and fertilization and/or continuous

[18] - [19]. In the WRB these soils were not retained as Anthrosols because of they have not been subjected, for a sufficiently period of time, to pedogenetic processes. They



Figure 1. A Gleysol with a relatively shallow water table.



Figure 2. A Gleysol that, artificially drained start to become a Cambisol.

are assigned to the Regosols (Entisols, according to Soil Taxonomy) and qualified at subgroup level in accordance with the origin of the anthropogeomorphic material.

Figure 3 shows a soil profile developed in 70 years on debris of sulfur mine. Table 3 shows the analytical data of this soil: there was a clear differentiation of the surface horizons from the parent material. This soil has been classified Haplic Regosols (transportic) according to the WRB system. The suffix indicates that such soil at the surface has a layer, 30 cm or more thick, with solid material that has been moved from a source area outside the

immediate vicinity of the soil by intentional human activity, usually with the aid of machinery, and without substantial reworking or displacement by natural forces.

Human induced deep soil disturbance

This type of anthropogenic soils refers to deep plowing, ripping, battlefields, trenches, excavations, pipelines, construction sites, cemeteries, broken hardened layers or pans. These soils show no diagnostic horizons or only fragments which are not arranged in any discernible manner. Soil Taxonomy [12] recognizes Arents for these types of



Figure 3. Haplic Regosols (transportic).

Table 3. Analytical data of a Cambisol that has developed a salic horizon due to irrigation with saline water.

Horizon	A	AC
Depth (cm)	0-8	8-25
Clay (g kg ⁻¹)	147	151
Silt (g kg ⁻¹)	309	299
Sand (g kg ⁻¹)	544	550
pH (H ₂ O)	7.4	7.3
CaCO ₃ (g kg ⁻¹)	171	100
C (g kg ⁻¹)	25	144
EC (dS m ⁻¹)	2.18	2.23
Gypsum (%)	1.74	1.67
CEC (cmol kg ⁻¹)	26	14
ESP	3	6

materials. The WRB [6] accommodates them in Aric subgroups.

An example of this kind of soils is shown in Figure 4. Its analytical data (Table 4), demonstrate that in the soil profile there are layers clearly distinguished within the same thickness of soil, evidencing its anthropogenic origin.

Human induced change of landform

Terracing is an agricultural technique with a long history that has transformed landscapes and soils in many parts of the world (Figure 5). Terracing involves segmentation of slopes which transform the landscape into stepped agro-ecosystems.

Slopes are reduced in angle and length, influencing hydrology, erosion and sedimentation in order to ensure soil and water conservation. On long and slightly sloping terraces, the original profile may still be present. However, on short range terraces the soil may be entirely reconstituted through a cut-and-fill process by which the lower part of the terrace surface horizons are buried while part of the pedon is

truncated in the upper part. Other changes in landform that need to be considered are mined areas, raised fields and levees. According to Sandor [20], the effect of terracing is quite different between the upland and hilly areas and the irrigated areas. The main differences (Table 5) depend not only on topography but also on soil management and influence the soil profiles as well as their chemical and biological features.

Human induced topsoil changes

The most evident and extensive changes of soil characteristics induced by humans are those affecting the topsoil as a result of activities such as tillage, deforestation, liming, irrigation, fertilisation, drainage, contamination by heavy metals or nuclides, pollution by acid aerial deposits or biocides. Topsoil fertility is of primary importance for soil management and crop production. However, the characteristics of the topsoil have not received a proper recognition in the current systems of soil classification because attention was mainly given to the subsoil, the more stable part of the soil profile over time. Therefore, the soil classification systems in many cases do not consider the differences in topsoil and, consequently, natural soils and agricultural soils can belong to the same soil taxa. For instance, changes in soil organic matter and increase of cations in topsoil do not allow separating these soils. Same situation for the topsoil changes due to liming or due to erosion (as a result of deforestation and forest fires) or the



Figure 4. Aric Regosols (eutric).

changes due to the mobility of heavy metals (as a result of acidification of the surface horizon) or due to the heavy-metal contamination resulting from industry or even the compaction resulting from the use of heavy machinery. Such consideration is the linchpin of many attempts to establish relations between soil taxa and productive responses of the soil.

Human induced soil construction/reconstruction

This category groups some particular soil types generated for the need/opportunity to "reconstitute" and/or "build ex novo" efficient soil systems, in either conventionally farming, urban or industrial environments, or in areas deeply transformed by events such as disasters or exceptional, natural or anthropogenic destructive phenomena.

We refer mainly to the different pedotechnique activities

that take into consideration the construction of soils in urban or farming areas or the environmental restoration of contaminated, post-industrial and degraded areas and also, in more serious cases, areas with abandoned military settlements.

Recently pedotechniques were applied also in farming areas, mainly to tailor soil suitable for vineyard in large

and objective classification of the soils that are both directly and indirectly influenced by human activities.

Many countries are updating their soil classification systems considering also the presence of the anthropogenic soils and trying to reconcile the purely genetic-evolutionary or predominantly morphological-quantitative considerations with the technical and practical needs. This will allow us to

Table 4. Analytical data of a Cambisol that has developed a salic horizon due to irrigation with saline water.

Horizon	Ap1	Ap2d	Ap3&B	Ap3&R	Ap4&B	Ap4&R
Depth (cm)	0-14	14-30	30-70	30-70	70-100	70-100
Clay (g kg ⁻¹)	240	270	170	340	150	300
Silt (g kg ⁻¹)	50	50	80	50	70	70
Sand (g kg ⁻¹)	710	680	750	610	780	630
pH (H ₂ O)	8.6	7.7	8.0	8.0	8.0	8.2
C (g kg ⁻¹)	40	30	30	20	30	20
EC (dS m ⁻¹)	166	432	770	760	770	117
CEC (cmol kg ⁻¹)	22	19	13	22	14	18

scale farming. Figure 6 shows an example of a soil anthro-chrono-sequence on marly-limestone substrata in an area characterized by large scale farming for vineyards cultivations in Sicily (Italy). The last soil in the sequence is



Figure 5. One of the most known and at the same time, ancient examples of terracing is in the Colca canyon in the south of Peru. It is considered the deepest canyon in the world and terraces date back to the Inca period (1400-1500 CE).

the tailored soils. With regard to the pedotechniques applied, we must stress that in a 22 year period (from 1982 to 2004), vineyard cultivation practices brought about an anthro-chrono-sequence of soils made up of: 1) the original Entic Haploxerolls (ST) / Calcaric Kastanozem (WRB); 2) a Haplic Xerarents (ST) / Aric Regosols (WRB), and 3) a Miscic Geofragmexerants (ST) or Geomiscic Anthrosols (WRB) [18].

We should stress that one of the effects of the expansion of tailored anthropogenic soils in large scale farming is an evident decrease of pedodiversity [21]. The loss of pedodiversity is in itself considered as a negative phenomenon disturbing the soil ecosystem that in the above reported study case can lead to other serious concerns such as erosion and/or chemical pollution.

Many and important practical reasons make urgent the introduction, in any soil classification system, of a detailed

obtain soil classification systems much more suitable either in scientific studies and soil mapping or in the evaluation procedures for soil management and planning.

There are works in progress by the ICOMANTH committee (International Committee for the Classification of Anthropogenic Soil) to indicate appropriate classes in Soil Taxonomy for soils whose main properties derived from human activity.

The most recent proposals from the ICOMANTH concern:

- The definition of Human Transported Materials (HTM) as any material (artifacts, organic materials, soil, rock, or sediment) moved horizontally into a pedon from a source area outside of that pedon by directed human activity, usually with the aid of machinery. HTM is a kind of parent material.

- The definition of Anthropogenic Features as an artificial feature on the land surface, having a characteristic shape and range in composition, composed of unconsolidated earthy, organic materials, artificial materials, or rock, that is the direct result of human manipulation or activities; can be either constructional (e.g., artificial levee) or destructional (quarry).

- The definition of Manufactured Layers as horizontal layers constructed by humans and placed on or in the soil. Examples include asphalt, concrete, plastic, geotextiles, and rubber. They are distinguished considering not only their features but also their influence on human health and their size. When these materials constitute one or more soil "horizons", the capital letter M is used, while the ^ symbol is used to indicate soil horizons consisting of HTM.

- The definition of Artifact: something created, modified, or transported from its source by humans usually for a practical purpose in habitation, manufacturing, excavation, or construction processes. Examples of artifacts include: processed wood products, liquid petroleum products, coal, combustion by-products, asphalt, fibers and fabrics, bricks, cinder blocks, concrete, plastic, glass, rubber, paper cardboard, iron and steel, altered metals and minerals, sanitary and medical waste, garbage and landfill waste

- The update of the definition of buried soils aiming at considering HTM such as cover material.

Anthropogenic soil in World Reference Base for Soil Resources (WRB)

One of the innovative features of the WRB [6] consists in recognizing the anthropic activity as a factor of soil formation. As a consequence, in this soil classification system there are two reference groups of anthropogenic soils: Anthrosols and Technosols. Both form in the WRB the conceptual group of "soil with strong anthropogenic

consult the WRB system may be immediately aware of these soils that have a significant diffusion and relevance in the environment.

Technosols (from greek "technikos", skillfully constructed) are soils dominated or heavily influenced by anthropogenic materials and include soils whose properties and pedogenesis are dominated by their "technical" origin.

They contain a significant amount of artifacts or are sealed by technic hard rock art (materials created by man,

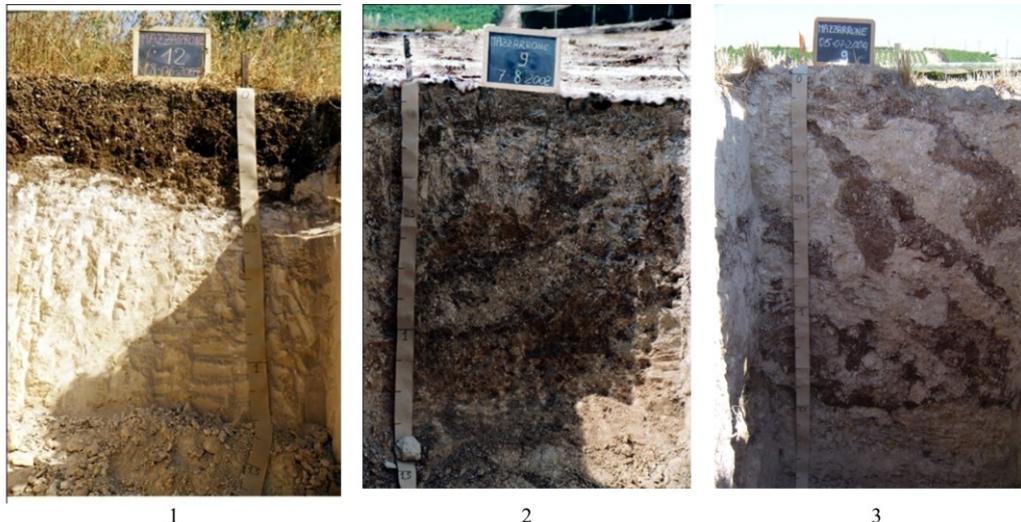


Figure 6. The anthro-chrono-sequence of soils on marly-limestone substrata in an area characterized by large scale farming for vineyards cultivations in Sicily: 1) Entic Haploxerolls (ST) / Calcaric Kastanozem (WRB); 2) Haplic Xerarents (ST) / Aric Regosols (WRB); 3) Miscic Geofragmexerants (ST) or Geomiscic Anthrosols (WRB) [18].

influence". The first are soils that do not have artifacts, and almost always, with a long and intense agricultural use; the second are soils containing many artifacts and, with an

having different properties from a natural rock). Within the Technosols group, are all types of materials constructed or derived from the anthropic activity. Pedogenesis in these

Table 5. General effects of terracing in upland and hilly areas and in irrigated areas. Differences between these two environments due to terracing are underlined (mod. from [20]).

Parameters	in upland and hilly areas	in irrigated areas
Topography	Slope breaking; colluviation;	Slope breaking, <u>levelled surfaces</u> ;
Management	Fertilization; irrigation;	Fertilization; irrigation; <u>submersion</u> ; <u>green manure</u>
Profile	Cumulization of A horizon; Buried horizon; plaggen, anthropic, agric horizon; Changes in texture, structure and porosity.	Cumulization of A horizon; <u>Plowpan formation</u> ; <u>Anthraquic conditions</u> ; agric horizon; Changes in texture, structure and porosity.
Chemistry	Increase in C, N, P; Changes in CEC; Changes in pH.	<u>Pseudogley processes</u> ; Changes in CEC; Changes in pH.
Biology	Changes in pedofauna; Changes in enzymatic activity.	<u>Anaerobic organisms</u> ; Changes in enzymatic activity

evident anthropogenic influence (Figure 7).

Technosols are at the beginning of the WRB keys of interpretation for the following reasons:

- to give immediate perception of a soil that should be treated with caution (for example, the toxic soil, that should be managed by experts);
- to represent a homogeneous group of soils consisting of particular materials;
- to ensure that politicians and policy-makers that

soils is strongly influenced by the constitutive material and from its arrangement.

Technosols may be found in all urban environments, in mining areas and landfill, in the areas of spilling oil, warehouses of coal fly ash and in all areas with such activities. They must be carefully managed because they may contain toxic substances from industrial processes. A layer of natural soil to allow the development of vegetation generally covers some of them, in particular those originated

in landfills. Generally, they do not have an evolved soil profile, although in old landfills we can highlight a natural pedogenesis, such as the translocation of clay.

Anthrosols (from greek "anthropos", man), are soils deeply modified by farming activity. They are found predominantly in areas of ancient farming tradition and, more recently as a product of intensive large-scale farming. The anthropogenic soils resulting from these activities (allowed by the use of powerful machines), determine most of the environmental problems, not only from the point of view of pedotechniques used for their "creation" but also in relation to their management. If the management of such soil is not carefully performed, several environmental problems can arise.

Man, now considered the sixth and most incisive factor of pedogenesis, will increasingly influence the soils of tomorrow (Dudal, 2005). It is therefore justified the



Figure 7. Technosols mainly made by artifacts.

proposal of a new era called "Anthropocene" [22], where humans play an incisive role, contributing to global change of the soil resource, considering that metapedogenesis, defined as the action of the man on the soil [23], in the last 2-3 decades have increasingly intensified, involving environments that year after year are becoming ever more vast.

Conclusions

The influence of man on soil formation is much deeper and more intense than we can perceive. For this reason, it is imperative that the anthropogenic processes are clearly recognized as a factor of soil formation. Characterization and classification of anthropogenic soils is a concern of debate in many international conferences. Anthropogenic processes may also not cause drastic changes in the soil morphology but may change some chemical, physical and biological properties that are significant for the soil management and for the quality of the total environment.

Soil science would be more credible if we will clearly recognize that a large part of the soilscapes were used and changed by man's activity. This awareness and knowledge, will allow us to predict the effects of new technologies applied to the soils and to increase the soil management and sustainability.

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