

The human factor of soil formation

DUDAL R. (1), **NACHTERGAELE F.O.** (2) and **PURNELL M.F.** (3)

(1) Soil Science, Institute for Land and Water Management, K.U.Leuven, Vital Decosterstraat 102, B-3000 Leuven, Belgium

(2) AGL, FAO. Viale delle Terme di Caracalla, 00100 Rome, Italy

(3) c/o AGL, FAO. Viale delle Terme di Caracalla, 00100 Rome, Italy

Abstract

Soils are natural bodies that have been formed by the interaction, over time, between climate, relief, parent material and living organisms. The latter soil-forming factor encompasses vegetation, fauna and human influence. Although soil management practices and other human interventions have been acknowledged as having an impact on soil formation, early soil classifications have not systematically catered for soils, which have been modified by man.

The human influence on soil formation is much more pronounced and extensive than originally perceived. Human interventions were either direct – through plowing, liming, manuring, fertilizing-or indirect through changing the natural soil forming factors-changing the vegetation by deforestation, changing the relief by leveling and terracing, changing the soil moisture regime through irrigation or drainage, changing the parent material through dumping or erosion. How are soil ‘improvement’ or ‘degradation’ reflected in soil classification? How and at which level does one distinguish ‘natural soils’ from ‘anthropogenic soils’?

The diversity of ‘anthropogenic soils’ has given rise to a proliferation of different names and units. In order to avoid a splintering of classes, it is attempted to identify the different types of man-made soils:

- a. Human induced changes of soil class
- b. Human-made diagnostic horizons
- c. Human induced new parent materials
- d. Human induced deep soil disturbance
- e. Human induced topsoil changes.

On this basis a more systematic characterization and subdivision of ‘anthropogenic soils’ could be envisaged.

Keywords: human influence, soil formation, soil classification

Introduction

Soils are natural bodies that have been formed by the interaction, over time, between climate, relief, parent material and living organisms. The latter soil forming factor encompasses vegetation, fauna and human influence. Although soil management practices and other human interventions have been acknowledged as having an impact on soil formation (Edelman, 1954; Bidwell and Hole, 1965; Yaalon and Yaron, 1966), early soil classifications have not systematically catered for soils which have been modified by human activities. The limited attention given to humans as a factor of soil

formation was understandable when population densities were low, and when agriculture was conducted at low levels of external inputs and with manual labour or draught animals. However, as these activities have gone on for several millennia their impact on the soilscape is far from negligible. Over the last decades, the drastic increase of population, the intensification of agriculture, the introduction of powerful equipment, the use of chemical inputs, the spread of industries and urban settlements, the development of infrastructures and of mining operations, have over large areas resulted in considerable and frequently profound changes of the soil cover.

The human influence on soil formation is much more pronounced and extensive than originally perceived when major soil classification systems were developed. Human interventions have constantly modified the soil resource in order to facilitate the growth of crops and the rearing of livestock. These interventions were either direct-through plowing, liming, manuring, fertilizing-or indirect through changing the natural soil forming factors-changing the vegetation by deforestation, changing the relief by levelling and terracing, changing the soil moisture regime through irrigation or drainage, changing the parent material through dumping or erosion. Are we a soil forming factor short?

The anthropic impact on soil formation is particularly marked in old agricultural areas such as western and central Europe, the Near East, the lowlands of South East Asia and China, but has influenced arable land all over the world, even in the tropics through slash and burn in shifting cultivation or by leveling termite mounds. While some interventions have been detrimental, for instance those leading to erosion, others have enhanced soil productivity for instance through liming and manuring. Hence it should be stressed that land transformations can be both positive or negative. The question arises how are soil 'improvement' or 'degradation' reflected in soil classification? How and at which level does one distinguish 'natural soils' from 'anthropogenic soils'.

Anthropogenic soils: what's in a name?

The term 'anthropogenic soils' is used here in a generic way. However, because of the widely different kinds of human interventions and the broad range of soil conditions that result from them, it would not be appropriate that they be considered in bulk in a classification system. Moreover, terms reflecting a soil forming process are no longer used in modern soil nomenclature. Lithogenic, climogenic or topogenic soils, connotative of a dominant soil-forming factor, are not distinguished as such in present day soil classification systems. Neither have former phytogenic 'forest soils' and 'prairie soils' been retained.

The diversity of 'anthropogenic soils' has given rise to a proliferation of different names and units: Agrozems, Anthrepts, Anthrosols, Anthrozems, Hortisols, Kultizems, Quasizems, Rigosols, Treposols, Urbanozems (Buondonno *et al.*, 1998). This rather unwieldy name giving is not conducive to enhancing the credibility and applicability of soil classification. In order to avoid a splintering of classes, it is attempted here to identify the different types of man-made soils on the basis of which a more systematic characterization and subdivision could be envisaged.

There appear to be five major types of 'anthropogenic soils':

- a. Human induced changes of soil class
- b. Human-made diagnostic horizons

- c. Human induced new parent materials
- d. Human induced deep soil disturbance
- e. Human induced topsoil changes

a) Human induced changes of soil class

Soils of which the diagnostic horizons have been modified by land use practices.

Examples are:

Solonchaks (Salids) developed from Cambisols (Cambids)* in arid environments as a result of irrigation

Plinthosols resulting from the emergence of plinthite near the surface, caused by human induced erosion of Plinthic Acrisols (Plinthudults)

Regosols (Orthents) arising from the total truncation of a Luvisol (Hapludalf) formed from deep loess

Anthraquic Nitisols (Anthraquic Kandiudults) which develop from Haplic Nitisols (Typic Kandiudults) subjected to surface waterlogging associated with long continued rice irrigation

Cambisols (Ochrepts) resulting from the artificial drainage of Gleysols (Aquepts)

Luvisols (Hapludalfs) developed from Albeluvisols (Fraglossudalfs) by many centuries of bioturbation associated with liming and manuring of arable land (Langohr and Pajares, 1983).

Although such soils are ‘anthropogenic’, and one should be fully aware that they are, their morphology is not basically different from that of ‘natural’ soils. Hence new classes or new names are not required. Their widespread occurrence reflects the importance of the ‘anthropogenic factor’ on the composition of the present soil cover.

b) Human-made diagnostic horizons

The formation of ‘new’ diagnostic horizons or features resulting from long term applications of organic matter or of wetland cultivation.

These soils have been grouped under the term ‘Anthrosols’ in the ‘World Reference Base for Soil Resources (FAO/ISRIC/ISSS, 1998; Kosse, 1990). In the USDA Soil Taxonomy (Soil Survey Staff, 1999) human induced enrichment of organic matter has been captured in the plaggen and anthropic epipedons. In the Soil Classification for England and Wales (Avery, 1980) these soils are grouped as ‘Man-made humus soils’, one of the ten major soil groups. In the German soil classification (DBG, 1985) they are distinguished as an order of ‘Anthropogenic soils’. The new Russian soil classification (Shishov *et al.*, 2001) distinguishes Agrozeems at order level. In the World Reference Base for Soil Resources the organic matter enriched soils are split into plaggic, terric and horticultural Anthrosols according to the practices involved. The wetland accumulations of silt are named irrigated Anthrosols, while the rice-irrigated surface waterlogged soils are included as hydric Anthrosols.

c) Human induced new parent materials

Unconsolidated mineral or organic soil materials resulting largely from landfills, mine spoil, urban rubble, garbage dumps, dredging, etc., produced by human activities, generate fresh parent materials upon which the common soil forming factors start acting anew.

* The nomenclature used is the one of the World Reference Base for Soil Resources (FAO/ISRIC/ISSS, 1998) with, in brackets, the equivalent in the USDA Soil Taxonomy (Soil Survey Staff, 1999).

It is this type of 'anthropogenic soils' that has received most attention and for which a number of names have been suggested: Spolents (Sencindiver *et al.*, 1978), Potisols (Fanning *et al.*, 1978), Depo-subgroups and Methanosols (Blume, 1989) the latter for organic wastes which break down anaerobically and cause the build-up of methane in landfills. In Russia (Shishov *et al.*, 2001) the 'Technogenic Superficial Formations' are being considered separately from the actual soil classification. The composition and origin of landfill materials are criteria for a detailed further subdivision. However, for interpretative purposes a site specific technical characterization will be needed. It has been suggested (Blume, 1989) that soils of sealed surfaces, under roads or buildings, also be recorded in order to provide statistical data as to the kinds and areas of soils which are lost to urban and industrial development.

In the World Reference Base for Soil Resources these soils were not retained as Anthrosols on account of not having been subject to pedogenetic processes for a sufficiently long period of time. They are assigned to the Regosols (Entisols) qualified at subgroup level in accordance with the origin of the geomorphic material (spolic, garbic, urbic).

d) Human induced deep soil disturbance

This type of anthropogenic soils includes terraces, deep plowing, battlefields, trenches, excavations, open mines, pipeline construction sites, cemeteries, broken hardened layers.. These soils show no diagnostic horizons or only fragments, which are not arranged in any discernible manner. The USDA Soil Taxonomy (Soil Survey Staff, 1998) recognizes Arenets for these types of materials. In Germany these soils are classified as Treposols and Rigosols (DBG, 1985). The World Reference Base for Soil Resources accommodates them as Aric subgroups. It is felt that, especially for the large extents of terraced soils (vineyards, irrigated slopes, olive groves), a more detailed characterization is required. Although the original soils may no longer be identified, terrace material still retains inherited textural and mineralogical properties.

e) Human induced topsoil changes

The most pervasive and extensive forms of human induced soil characteristics are the changes which affect the topsoil (20 – 30 cm) as a result of tillage, deforestation, liming, marling, fertilization, manuring, irrigation, drainage, erosion, mining of plant nutrients, fire, contamination by heavy metals, biocides, nuclides, acid aerial deposits. Topsoil is of prime importance for soil management, soil fertility and crop production. It is the layer where seeds germinate, where the bulk of plant roots develop, where biological activity is most intense, where a major part of applied plant nutrients are stored, where improved or degrading farming practices have their major impact. Yet, topsoil characteristics have not received a prominent place in current soil classification systems, in favour of subsurface horizons considered to be more stable over time. It was generally felt that 'transient properties' produced by plowing and normal agricultural practices should have the least possible effect on the placement of soil in a classification system. As a result soil survey interpretation is often flawed on account of differences in the topsoil of natural and cultivated soils that belong to the same class. This shortcoming may be the main cause of many frustrated attempts to establish relationships between soil taxa and the response to fertilizer applications.

There is a major difference in productive capacity between an acid 'natural' Podzol (Spodosol) and one, which has been improved through long-term manuring and fertilization. Yet the increased organic matter content and the improved base status of the topsoil do not allow separation of these soils in current soil classification systems. The same applies to considerable variations resulting, for example from liming, erosion of topsoil upon deforestation, destruction of organic matter through forest fires, increased mobility of heavy metals as a result of surficial acidification, Zn contamination through industrial wastes, pollution by biocides, compaction by heavy machinery, fertilizer and trace element applications, or topsoil 'conditioning' with polymers. On the one hand differences between soil classes are being reduced by the equalizing effect of 'good land husbandry' while on the other hand, differences are created within soil classes, as a result of different management practices and different exposures to external emissions and pollutants.

Anthropogenic soils revisited

'Man-made' or 'anthropogenic' soils have become a major component of the landscape. It is imperative that they be localized and characterized for purposes of land evaluation, land use planning and environmental protection. A number of proposals have been made to define soil classes and to coin names to accommodate 'anthropogenic' soils. However, no consensus has been reached as to which basic principles should apply in classifying them. A first principle which would be worth adhering to is that soils are defined on the basis of their morpho-analytical characteristics – of what they are – and not on account of their genesis – of how they have been formed.

Aware of the importance of a human factor of soil formation a number of soil classification systems have introduced a class of Anthrosols, Anthroposols, Anthropogenic or Man-made soils at the highest level of generalization (Avery, 1980; DBG, 1985; Baize *et al.*, 1992; Hewitt, 1992; Gong Zitong *et al.*, 1999; Isbell, 1996; FAO/ISRIC/ISSS, 1998). The advantage of an 'order' of Anthrosols is its visibility and its role as a signal, to both soil scientists and land users, that human activities seriously affect the soil resource base. The disadvantage is that such an order is extremely heterogeneous, covering plaggen improved soils as well as anthraquic irrigated soils. This kind of grouping may be stretching the range of variability within one 'order' too far. As an alternative there is the use of anthric or anthraquic subgroups within existing soil classes. When the anthraquic concept was launched (Dudal and Moormann, 1964) it was felt that the diagnostic features and the mineralogy of the horizons underlying the 'paddy layer' (Dudal, 1956; Jung and Eswaran, 1990) were sufficiently important to give them precedence at soil group level. Irrigation-sediments, if sufficiently thick, may well qualify as Fluvisols (Fluvents) and be identified through an 'anthric' qualifier.

On the basis of the five types of 'anthropogenic soils', distinguished above, a classification could be attempted as follows. The soils which have shifted to another class as a result of human influence (type a) could be accommodated within existing units, with an anthric qualifier where justified by observable characteristics. The 'Man-made humus' soils (type b), which have undergone long and continuous human influence, need to be recognized separately. Landfills and dumps (type c), terraces and deeply disturbed soils (type d), are a form of 'entisolization' (Dazzi, 1995) resulting from a one-off human intervention, and on which soil formation starts anew. Soils,

which show human induced changes in surface horizons (type e), could be characterized by a topsoil qualifier. Hence, only types b), c) and d) would require the separation of three different classes.

In order to overcome the gap between the interpretative value of soil classes and actual production potential it has been proposed to introduce a comprehensive characterization of topsoils (Purnell *et al.*, 1994) for the practical purpose of assessing and monitoring fertility status and guiding management practices. Topsoil characterization should, at an appropriate scale, become an adjunct to current soil classification and provide a way to link soil classes with soil management. It is proposed to identify main topsoil properties related to organic matter status, biological activity, physical, chemical and moisture conditions which allow to characterize topsoil over and above the diagnostic horizons and features required for defining a soil class. This approach could help overcome criticisms by other disciplines and by land users about shortcomings in the application value of taxonomic systems. A proposal was made recently (Krogh and Greve, 1999) to adopt a two-tier soil classification system, the first tier consisting of largely undisturbed soils while a second tier would accommodate significantly changed cultivated soils with anthric properties. Already in 1954 Edelman pleaded to clearly identify human influenced soils in addition to the 'natural soils' of genetically inspired soil classification systems.

Conclusion

Human influence on soil formation is much more profound and extensive than originally perceived. It is imperative that this influence be explicitly recognized as an independent anthropogenic factor. It is goal directed in contrast with the impact of other biotic and abiotic factors (Amundsen and Jenny, 1991). The effects and geographic distribution of the anthropogenic factor show great diversity, being linked to major differences in human interventions and to variations of land use in time and space.

A number of classification options will need to be considered in order to reach a balance between visibility, credibility and applicability to land use. Since soils need to be defined in terms of their own characteristics, rather than on the factors of their formation, additional research will be required to identify hard measurable evidence of human interventions. At international level the issue is being addressed by ICOMANTH, the USDA sponsored international committee on anthropogenic soils (Kimble *et al.*, 1999) and by the IUSS Working Group for the World Reference Base for Soil Resources (FAO/ISRIC/ISSS, 1998). Whatever solution is adopted it will be imperative that topsoil characteristics be given due attention in order to meet demands on soil management, soil improvement and soil rehabilitation. Soil science will become more credible if it clearly recognizes that most of the soils that we use have been, and are being changed by use and management. This awareness and knowledge will allow for predicting the effect of new technologies, for better or worse, and for enhancing sustainable soil management.

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