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Taxonomic and environmental implication of pedotechnique in large scale farming

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ABSTRACT

Human activities that involve deep modifications of the soils and a substantial deterioration of their features are numerous and very diverse. Such activities are considered as pedotechniques and, in large-scale farming, are used only under the boost of significant economic returns. In these last decades, the pedotechniques used to tailor soils suitable for table vine cultivation in the Acate valley (Sicily, Italy), not only led to objective difficulties in the classification of these deeply transformed soils but also, to several environmental hazards. In this work after considering the pedotechniques used in tailoring suitable soil for table vine cultivation, we propose to introduce Anthrosols as a new taxonomic soil Order in Soil Taxonomy stressing that a correct soil classification of these deeply modified soils allow for a correct understanding of their features and of the environmental hazards that their management could originate.

1. Introduction

Man, traditionally jealous keeper of soil's capability in supplying goods and services, in recent years has acquired an increasingly importance as a pedogenetic factor (Dudal, 2004). His influence on soils has become so effective and intense that in many systems of soil classification the need to introduce a new group of soils was felt. These are Anthrosols (CSTC, 2001; IUSS Working Group WRB, 2015) o Anthroposols (AFES, 1995; Isbell, 1996; Florea & Munteanu, 2000), o Antropozem (Němeček, 2001) o Anthropic soils (Hewitt, 1998). Human activities that involve deep modifications of the soils and a substantial deterioration of their features are numerous and very diverse. Some of these are very showy and occur for instance during the construction of structure and infrastructure. Others, less flashy but equally dangerous for pedodiversity conservation (Lo Papa, Palermo, & Dazzi, 2011; Lo Papa & Dazzi, 2013) and for the environmental resources safeguard, concern the creation of soil in burying wastes from various origins and nature, as happened along the slopes of Vesuvius (C. Buondonno, personal communication) in Italy.

Pedotechnique, is a term introduced in soil science in the 1980s (Fanning & Fanning, 1989), to indicate human activities affecting soil formation and soilscapes morphology. Pedotechnique can be considered as a new interdisciplinary branch of soil science, which tries to understand and integrate the effect of soil handling on the soil qualities (Van Ouwerkerk & Koolen, 1988) and classification (Dazzi, Lo Papa, & Palermo, 2009).

Man's activities in pedotechnique may vary widely. For instance in the selection and evaluation of suitable materials for "building soils" suitable for specific purposes, such as in the field of agronomy or for waste disposal, or in mining operations, in the artefacts production, etc.

Over time, the concept of pedotecnique was extended to all those human actions that link the soil to social, industrial and economic activities. In the 1990s, concepts and methods of pedotechnique were expanded (Fitzpatrick, 2009) to:

- environmental systems (desertification, soil and water quality, animal and human health);
- industrial systems (mines, quarries, new settlements);
- forensic system (the fight against crime and terrorism);
- conflictual systems (military operations, reclamation of minefields); and
- social systems (telecommunications, sports facilities, recreational areas).

In few words, pedotechnique methods were expanded to most of the human activities carried out with the soil or on the soil that, unfortunately, continues to be considered as a crypto-resource.

In agricultural management, pedotechnique is used only after the boost of significant economic returns, but in so doing, farmers often do not take into account a very important aim: i.e. satisfying

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human needs avoiding any undesirable environmental threat that might occur during the handling of earthy materials. Following such premises, in this work we wish to stress two particular aspects concerning the application of pedotechnique in large-scale farming for vine cultivation in Southern Italy: in particular: (i) those linked to the classification of these deeply disturbed soils and (ii) those linked to the environmental implications.

2. Study area

The study area we considered is located in the Acate river valley, in southeast Sicily, Italy (Fig. 1). Climate is Mediterranean, with maximum average monthly temperatures in August (25–26 °C) and minimum average monthly temperatures in January (10–11 °C). Average annual rainfall is around 450 mm. From a morphological point of view, the landscape is characterized by a gentle hilly morphology. Rock outcrops, dating back to Pleistocene and Holocene. They, consist of clay and sandy-clays, fossiliferous yellowish sandstones, fine quartzitic sands, weakly cemented sands, lacustrine and fluvial deposits and marly limestones. These environmental characteristics allowed for the development of soils with different evolution (Entisols, Inceptisols, Vertisols, Alfisols and Mollisols), but at present, most of them show anthropogenic features.

In this area during the late 1970's, vineyards spread copiously. Such huge land use change (Lo Papa et al., 2011) has allowed not only a significant increase in per capita income (up to 400% according to Lo Verde and Italian (1995)) and the almost complete disappearance of unemployment but, give rise also to several environmental hazards that, till now did not shown their dangerousness.

3. Materials and methods

To highlight pedotechniques used to tailor soils suitable for table vine cultivation in the Acate valley, we must premise that the motivating factor determining a huge land use change in the study area, was the farmers' certainty that high contents of calcium carbonate in soils increase the quality of the table vine.

Maps of land use change (from 1955 to 2010) (Lo Papa et al., 2011) highlighted:

1. that arable lands completely disappeared at the end of 1990s;
2. a huge development of trellis system vineyards at the beginning of 2000s;
3. a continuous increase in urbanized areas, reservoirs and artificial lakes; and
4. the huge decrease of woodlands and semi-natural areas.

Using former soil surveys and aerial photo interpretation, we had the possibility to survey the soils in two adjacent fields: a never cultivated field suitable as test area to survey the natural soils and a nearby area to survey the anthropic soils.

4. The pedotechnique used

Original soils showed A–C or A-Bw-C horizons in the profile; a loamy texture (clay content between 16.5% and 38.5%); a sub-angular blocky structure; $pH_{(1:5\ soil/water)}$ values range between 7.5 and 7.9. The amount of total carbonates in the soil solum ranges between 1.6% and 51%. Active carbonates (from 0.7% to 17.7%) and organic carbon (from 0.5% to 1.0%) in general decrease with depth. Interpretation of aerial photos and interviews from landowners indicate that the first intervention for planting trellis system vineyards on these soils was made in 1982 and consisted in ploughing them (about 90–100 cm depth) with a mouldboard one furrow plough, which provided complete overturning and deep stirring up of the soil horizons. After a first cultivation cycle, vineyards were explanted and the field surface was covered with a 50–70 cm layer of marly limestone, i.e. a soft rock made up of limestone and clay (approx. 70% and 30%, respectively). The surface moulding aimed at making a gentler slope and at increasing the amount of carbonates in the soils that as previously outlined, have a positive effect on the quality of the fruits because (R. Di Lorenzo, personal communication) of increase in both the crunchiness of the grapes (the vineyards are used to produce table grapes) and the soil albedo (with positive effects on the content of sugar in the fruits). After one year, the soils covered with the marly limestone (Human Transported Material – HTM) layer, were ploughed up to a depth of 100 cm with a mouldboard one-furrow plough, obtaining soils whose most striking feature is a double sequence of horizons at an oblique angle to the soil surface (Fig. 2a–c). Regarding the features of these soils, it should be noted that they show an anthropogenically disturbed deep profile (Fig. 2) with a loam to clay-loam texture and a fine and medium subangular and angular blocky structure. Furthermore the colour of the topsoil is consistently very light (from light grey, 10YR 7/2 to white, 2.5Y 8/2); the amount of carbonates, both total (from 41.5%

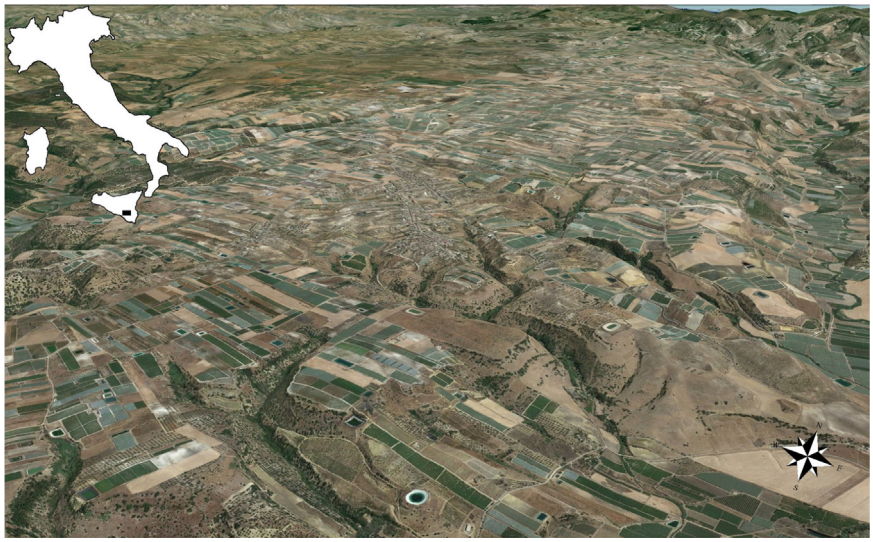

Fig. 1. 3D Satellite image of the Acate valley (29/07/2013). Vineyards fields are clearly visible.

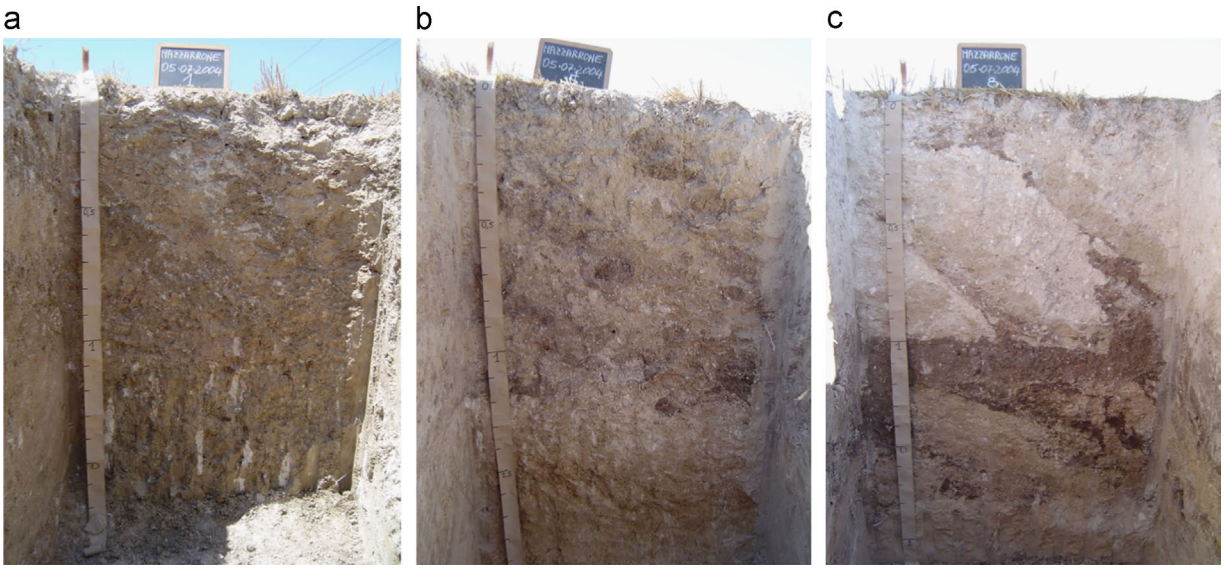

Fig. 2. Example of 3 pedons of soils tailored for table vine cultivation in large-scale farming in the Acate valley (southeast coast of Sicily, Italy).

Table 1
Definition of "Anthraltic (ST 2014-page 36a).

Anthraltic (modified from Gr. anthropos, human, and L. alterāre, to change). Soils that formed in 50 cm or more of human-altered material. This adjective is used primarily for human-altered material where ripping or deep ploughing has fractured and displaced diagnostic subsurface horizons that were root-limiting (e.g., duripans) and in excavated areas (e.g., borrow pits).

Table 2
Proposed nomenclature and meaning of the formative elements of the anthropogenic soils according to the Soil Taxonomy rules (modified from Dazzi & Monteleone, 2007).

Category	Order	Suborder	Great group	Subgroup
Name	Anthrosols (from Gr. anthropos, meaning "man")	Xer-Ant	Geofragme-Xer-Ant	Miscic Geofragmexerant
Formative element	**Ant**	**Xer** (from Gr. xeros, meaning "dry")	**Geofragme** (from Gr. geomai, meaning "to become heart" and from L. fragmenta, meaning "spoils")	**Miscic** (from L. miscere, meaning to mix)
Definition	Soils built or strongly influenced by human activity.	Anthrosols with a xeric moisture regime.	Anthrosols formed on or with mineral materials moved by man with earthmoving equipment.[a] Generally, landscapes are human reshaped.[b]	Anthrosols formed on or with mineral materials moved by earthmoving equipment[a] and deeply mixed by heavy machinery for farming purposes. Generally, landscapes are human reshaped.[b]

[a] Human transported materials (HTM) – any material (artifacts, organic materials, soil, rock or sediment) moved horizontally into a pedon from a source area outside of that pedon by directed (intentional) human activity, usually with the aid of machinery. HTM is a kind of parent material and should be recognized as such (ICOMANTH circular letter no. 5, 2004, page 2).
[b] Anthropogenic landform (ICOMANTH circular letter no. 6, 2005, page 2).

to 81.6%) and active (from 16.5% to 18.8%), is very high; the organic carbon content is consistently low, ranging between 0.1% and 0.7%, and decreases unevenly with depth.

5. Taxonomic aspects: reflections and proposals

Following the rules of the 12th edition of Soil Taxonomy (Soil Survey Staff, 2014), the soils deeply transformed by pedotechnique interventions would be classified as Anthraltic Xerorthents, i. e. "*other Xerorthents that have 50 cm or more of human altered material*" (ST, page 150a).

However, we must underline that the morpho-descriptive and the analytical features of the soils consequent to these pedotechnique activities, do not fit the Anthraltic definition (Table 1). In our study case the deep ploughing has "not" *fractured and displaced diagnostic subsurface horizons that were root-limiting (e.g., duripans) and in excavated areas (e.g., borrow pits).*

The sixth attribute of Soil Taxonomy, emphasizes that "*significant changes in the nature of the soil by humans cannot be ignored*" (Soil Survey Staff, 1999, page 16b). We totally agree with this idea and we believe that time has come for considering Anthrosols as a new Soil Order in Soil Taxonomy. Therefore, starting from previous reflections (Dazzi & Monteleone, 2007) and considering the features of the soils generated by pedotechnique, we suggest *Anthrosols* as a new soil taxonomy Order. In naming these soils at Order level, we could use "ant" as "formative element" (ant, from Greek anthropos=man). Moreover, considering that the pedo-climate of our study area is "Mediterranean", at suborder level we can name such soils as Xer-ants. Since they were made up of a mixture of marly limestone transported and deposited through earth excavations, covering a pre-existing deeply anthropo-turbated Mollisol, Geofragme-xer-ant could be the most suitable name at Great Group level (from Greek geomai=to become hearth, and from Latin fragmenta=spoils). Finally, since the surface was mixed to a depth of about 100 cm with the aid of

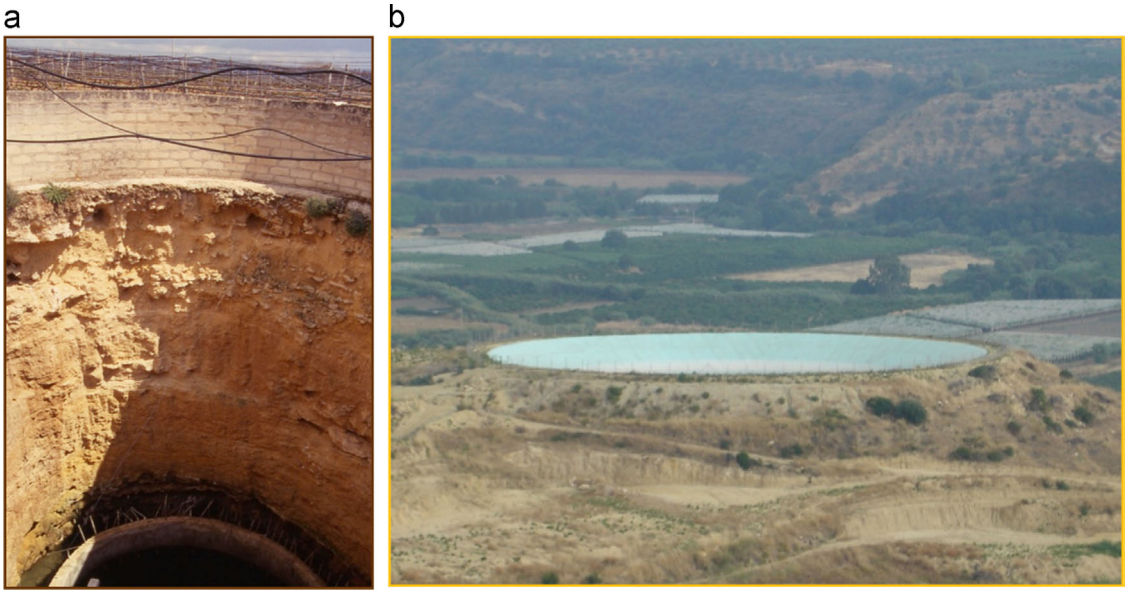

Fig. 3. The water pumping lead to 2–3 cm/year decrease of the water table (a). In many cases water is stored in reservoirs (b).

Fig. 4. The total lack of practices to mitigate water runoff, accelerate rill and gully erosion that reduces soil fertility and organic carbon stock.

heavy machinery, Miscic (from Latin miscere = to mix) could be the most suitable adjectives at Subgroup level.

Table 2 reports the proposed nomenclature and the meaning of the formative elements of the Anthrosols following the Soil Taxonomy rules.

6. Environmental aspects

In the Acate valley, pedotechnique, soil use and agricultural management has led to a considerable improvement in the economic conditions of the local population (Lo Verde, 1995). Anyway, farmers driven by the economic boost do not consider that the massive pressure on the soilscape, leads to other severe concerns. In particular:

- The water table level decreases 2–3 cm/year due to the pumping of the water to irrigate the vines (Dazzi & Monteleone, 2002) (Fig. 3a).

Fig. 5. Plastic films used to cover vineyards – even if law imposes recycling – are often abandoned in the environment and then burned releasing toxic compounds.

Fig. 6. To maintain grapes on the plants for a long period, farmers use massive quantities of pesticides that persist in the environment.

- The water pumping lead to a decrease of the quality of the table-water that, year after year become more and more saline (Fig. 3b).
- The total lack of agronomic practices to mitigate water runoff, accelerate rill and gully erosion even during medium intensity rainfalls (Fig. 4).
- Soil erosion reduces soil fertility and organic carbon stock but causes also downstream inundations and muddy floods.
- Plastic films used to cover vineyards – even if law imposes re-cycling – are often abandoned in the environment and burned releasing toxic compounds as, for example, dioxin (Fig. 5).
- To maintain grapes on the plants for a long period, farmers use massive quantities of pesticides (xenobiotic agents and heavy metals) which persist in the environment (Fig. 6).

7. Conclusions

In future years, the maintenance of well-being and human development will depend largely on the ability to ensure the sustainable use of soil resource, a task made complex by the changes of human activities that have an impact on the environment and, in particular, on soils.

The recognition of the man's role as the sixth factor of pedogenesis allows us to:

i) shift our focus on the classification of soils strongly "modified" or "built" by humans (generically known as "anthropogenic soils"); and
ii) detect human disruptive actions on the soils that often affect its ability to produce goods and services.

Due to the increasing spread and importance that anthropogenic soils are assuming, it is imperative that their properties are accurately surveyed, not only for evaluation purposes but also for landscape planning and environmental protection. We believe that the introduction of Anthrosols as a new Order for those soils whose features are due to strong man influence on soils, and the possibility to classify these Anthrosols following the Soil Taxonomy rules till Subgroup level, would provide sufficient information on the intrinsic properties of such soils and on their future evolution.

Finally, let us remind the sentence "*Nomina sunt consequentia rerum*" (Names are consequent on things, in English), affirmed by Justinian in his code *Institutiones* (VI cent. C.E.) to indicate that verbal language takes its origin from the things it denotes and that a well-known motto during the Roman period was "*nomen, omen*" i.e. "the meaning of the things is inside the name!"

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