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Soilscape Speaks Out; an Account of the Past, Present, and Future

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ABSTRACT Soil, a 3-dimensional component of the landscape, or simply a natural body in a soilscape with a given geopedological setting, was modeled by Jenny as S = f (Climate, Organism, Relief, Parent material, Time). To map such a complex body, the concept '*pedon'* –the smallest volume that can be recognized as a soil had to be defined. Classically, soil is known to function as *provider*, *controller*, *regulator*, *mechanical support*, and as a *filter* to protect the quality of water, air, and other resources. The intention of this paper is to argue, with the help of several examples of soilscape, in (semi-) arid regions of Tunisia, Morocco and Iran, some other functions of the soils, namely those of being an *archive* ('*history book of the landscape*'), *a guide (in soil management)*, and a '*predictor*' *(sensing soil health)*, in other words, soilscape speaks out: an account of the past, present and future.

Key words: *Geopedology, Paleoecology, Soil conservation, Soil degradation, Soil management, Soil (land) scape*

1 INTRODUCTION

Classically, soil is labeled with the functions: "1- it provides a physical matrix, chemical environment, and biological setting for water, nutrient, air, and heat exchange for living organisms; 2- Soil controls the distribution of rainfall or irrigation water to runoff, infiltration, storage, or deep drainage. Its regulation of water flow affects the movement of soluble materials, such as nitrate, nitrogen or pesticides; 3- Soil regulates biological activity and molecular exchanges among solid, liquid, and gaseous phases; 4- Soil acts as a filter to protect the quality of water, air, and other resources; 5- Soil provides mechanical support for living organisms and their structures. People and wildlife depend on this function (Buol *et al.*, 2011).

The intention of this paper is to discuss, with the help of a few examples of soilscape in (semi-) arid regions of Tunisia, Morocco and Iran. Some other functions of the soils, namely those of being a '*history book of the landscape*' (*archive*), *a guide (in soil management)*, and a '*predictor*' *(sensing soil health)* in other words, "soils speak out; an account of the past, present and future".

1.1 Theoretical Background

Soil is defined as "A natural body consisting of layers (or horizons) of mineral (and/or organic constituents) of variable thickness, which *differ* from the parent material in their morphological, physical, chemical, and mineralogical properties and their *biological* characteristics".

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To map such a complex body, the concept '*pedon'* –the smallest volume that can be recognized as "a soil" had to be defined (USDA, 1975). For mapping purposes, similar *pedons* are grouped to form *polypedons*, that is, the soil body, which will undoubtedly be associated with some degree of variability (Figure 1). A soil body is a representative specimen of a taxon in place on the natural terrain. The assemblage of soil bodies in a particular landscape is called a soilscape, connoting a continuum (Buol *et al.*, 2011). It is here, where geopedology (soil geomorphology) comes in to emphasize on the importance of studying "soils" (soilscape) and not only a "soil profile".

Analysis of the geopedologic setting in a given area makes it possible to interpret the pedologic and geomorphic features that should: 1) reveal past conditions (paleoecology), 2) having a guiding role in soil management (present conditions), or 3) predicting possible situations in the future.

1.1.1 Pedogenic-derived indicators:

Referring to the USDA Soil Taxonomy (1975) and the books on soil genesis, such as the one of Buol *et al.* (2011), the following information, important to the topic, can be extracted:

-Anthropic epipedon is known to have been formed during a long period of continued use of soil by men, being identified, among other things, by high level of phosphorus content.

-Plaggen epipedon is a man-made surface layer that has been produced by long-continued use of manuring.

-Argillic horizon, as far as known, results from the clay that is carried by water, moving from one section of the soil profile (eluvial horizon) to the lower section (illuvial horizon). In this process (lessivage), which takes hundreds of years, something must start the movement and something must stop it. This has been repeatedly, by different authors, related to alternating wet/dry climatic conditions.

-Agric horizon is an illuvial horizon that is formed under long-continued cultivation. When a soil is brought under cultivation, the vegetation and the soil fauna are changed drastically. After some time, the content of organic matter is not likely to be high, and the C/N ratio is low (<8).

-Petrocalcic horizon results from Calcic horizon, that has in time become plugged with carbonates and cemented into a hard, massive, and continuous horizon, fragments of which do not slake in water. The Petrocalcic horizon is a mark of advanced soil evolution.

Other pedogenic-based features: Pedon (a soil), diagnostic soil characteristics, such as abrupt textural change, COLE (coefficient of Linear Extensibility), and (Para-) Lithic contact; and such physico-chemical soil properties as particle size class, depth, pH, EC, etc, are all among the features used as indicators in soil survey interpretation for different purposes.

Figure 1 A view of soilscape

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1.1.2 Geomorphic-based indicators:

A glance at the erosion and sedimentation processes as explained by Birot (1965), King (1967), Sparks (1972), Selby (1990) and Gutierrez (2012) although different in some aspects, show the link between the climatic conditions and the piedmonts formation. A sloping surface formed at the foot of a mountain range or other elevated surfaces, such as plateau, is termed 'piedmont', literary meaning 'foot of mountain' (Zinck, 2013). Piedmonts can be of degradational origin, with widely extending rock-cut (erosion surfaces) or of accumulational origin, that is the result of deposition of transported materials, spread over a lower lying surface. It is noticed that piedmonts are either the end-product of the pedimentation process (also termed, mainly by French authors, 'glacis formation'), or of coalesced fans. Each of these cases exhibits features, such as particle size gradation, stratification, surface debris, stoniness/ rockiness, and drainage pattern that are used to distinguish between the different geoforms: erosional glacis (also referred to as pediment), accumulation glacis (also referred to as bajada and piedmont), alluvial fan, colluvial fan, alluvio-colluvial fan, and coalesced fans. A pediment, in arid or semi-arid regions, is a gently sloping erosion surface, underlain by bedrock, often covered by a thin, discontinuous veneer of soil and alluvium derived from upland areas. Pediments reflect a relative "static equilibrium" between erosion process that takes place mainly in elevated areas, and deposition of the resulted materials in an adjacent lower lying area. Pediment and alluvial fan formation is linked with climate change. Heavy rainfall that spreads over large surfaces can lead to 'sheet-wash' and glacis formation.

Besides, some other information, such as slope and the position of soils in the landscape (site) are regularly used in soil survey interpretations.

2 MATERIALS AND METHODS

Geopedologic approach to soil survey (Zinck, 2013) is the basis of all the case studies that are presented in this paper, all executed by the author. However, depending on the objective, other studies such as soil micromorphology, carbon dating, mineralogy (x-ray diffraction), GIS-based modeling, land evaluation, historic and archaeologic survey have also been carried out (Farshad, 1997, 2011, 2013).

Soil samples were collected not only for physic-chemical analyses but also for carbon dating and x-ray diffraction. Carbon dating was done at the Center for Isotope Research (CIO) in Groningen, The Netherlands. For x-ray diffraction, samples were sent to ISRIC, University of Wageningen, the Netherlands.

Regarding microscopic study (soil micromorphology), undisturbed samples were collected (using Kubiena boxes—mammoth size) from the topsoil, starting at 8 to 10 cm below the surface. The prepared thin sections were scanned, followed by georefencing the resulted raster maps (see 3.2.2), which could further be studied in ILWIS (GIS environment). The pasture soil, sampled at a depth between 8 to 18 cm, was taken as reference site. The traditionally managed soil was compared with the pasture soil and with the mechanized one. To check on the role of the parent material in causing compaction, two sites, under mechanized rainfed cereals, one on micaschist and another one on limestone-derived soils were sampled. The soil profiles, under mechanized farming, were sampled at a depth between 8 and 28 cm (Mc32void, in Table 1). The samples were collected with a small overlap, using Kubiena boxes of 15 x 8 x 3 cm.

Following the principles of the 'communication theory' (Dexter, 1976), a simple computer program, written in FORTRAN took care of scanning a binary raster image along horizontal (H) and vertical lines (V), and pixel counting (Table 1). The number of 1's and 0's along each line are counted, where the value 1 represents the occurrence of pores, while the probabilities of 1 being followed by 1 or 1 being followed by 0, etc. are calculated. A comparison was made between the pore space (surface area) in a thin section prepared from a soil managed traditionally and

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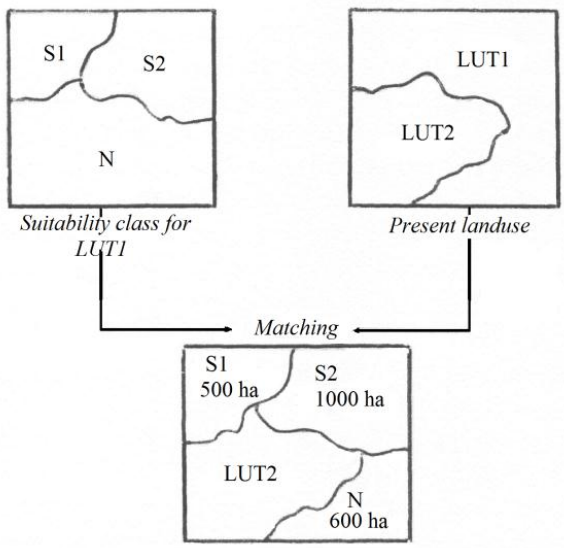
that in a soil under mechanized agriculture (Tradvoid, Mc21void and Mc22void). These soils were then compared with a soil under pasture (Pastvoid).

In line with the FAO land evaluation terminology (actual and potential land suitability), Sokouti and Farshad (1999) introduced an Index--LUCI ('Land-Use Compatibility Index), an index which should be simple so that agricultural extension staff can explain to farmers (Figure 2). The index was used to demonstrate the result of matching between 'land suitability classes' on a suitability map and the way these units were currently used. If the LUT (= demand) is satisfied by the supplier (= the land), the land map unit (LMU) is assigned S1, in which case its suitability coefficient was assigned 1. Following this convention, S2, S3 and N (not suitable) were assigned 0.67, 0.33 and 0.1. To obtain an LUCI for each LMU, each coefficient was multiplied by the extent (surface area) of the land use, and then divided by the total surface area of the related LMU. The final compatibility index for a given LUT was sum of the coefficients of all LMUs, where the LUT (under consideration) is practiced.

Table 1 Porosity Index (Farshad, *et al.*, 2005)

	Pastvoid Under pasture		**Tradvoid Under traditional management**		**Mc21void Semi-mechanized 8-18 cm depth**		**Mc22void Semi-mechanized 18-28 cm depth**		**Mc32void Mechanized 18-28 cm depth**	
Readings of	V	H	V	H	V	H	V	H	V	H
SCANIMAG	0.69	0.52	0.74	0.55	0.33	0.38	0.80	0.37	0.34	0.25
Average	0.62		0.64		0.35		0.58		0.29	



The compatibility coefficient can be written as: cx= ax*Si/A, where cx=compatibility coeff. of LMUx for LUTi; ax= surface area of LUTi; Si=suitability coeff. of LMUx for LUTi and A=surface area of LMUx.
The compatibility index is then calculated by
Cx=Σ cx, where: Cx=LUCI of LMUx and Σ cx=total compatibility coeffs. of LMUx for all LUTs.

Figure 2 Land Use Compatibility Index (LUCI) calculation

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By applying the geopedologic approach, surveyor is guided to set up a scientific framework for soil resource inventory and its interpretation/ evaluation for various uses and purposes, by means of modeling the occurrence of soils in landscape, a process which is based on (mental) integration of knowledge on climate, geology, geomorphology, sedimentalogy, hydrology, vegetation, and pedology. A geopedologic map is a soil map, which includes much facts and understandings about the landscape.

2.1 Description of the Case-Study Areas

2.1.1 Sbeitla - Kaserine, Tunisia (around 35◦ 14' N 9◦ 16 E)

The area, about 250 km south-west of Tunis, is characterized by an arid climate in the plains (±290 mm annual rainfall) and a semi-arid type in the surrounding mountains (400 to 450 mm annual rainfall). The mean temperature in January is 9◦C and in July is 26◦C. Aridic and Xeric moisture regimes were applied to classify the soils of the plains (glacis) and those of the mountain areas, respectively.

Geologically, the area is composed of a series of narrow anticlines and comparatively wider synclines. Many local faults and fractures occur. Lithologically, the anticlines are composed primarily of limestone, dolomites, marls and clay, marly limestone and sandstones. The Quaternary deposits occur mainly in the in-filled synclines. The three landscapes distinguished are mountains, piedmont (glacis and fans) and the valleys. Landuse consists of cereals, fodder, legumes, trees (olive and almond), and pasture (outher observation during the fieldwork).

2.1.2 AinBendar/Hannath, Morocco (around 33◦ 58' N 6◦ 51' W)

The study area is located about 10 km south-east of Rabat, with a rolling to hilly topography, a part of the lower central plateau Atlantic Meseta. The climate is mediterranean and subtropical, with a mean annual rainfall about 350 mm. Soil moisture regime and soil temperature regime (USDA, 1975) for Rabat and the surroundings, including the study area are (dry) *Xeric* and *Thermic*, respectively. The dominant soils, that were observed during our fieldwork, are Inceptisols and Entisols, but Argillic-bearing soils (Alfisols and Ultisols) were seen too.

Besides the scattered cork oak forests and Eucalyptus plantations, land use consists of wheat, barley , maize, beans, some vegetables and orchards, not to forget pasturalism; excessive grazing by the livestock.

Due to the increasing population pressure (both human and livestock) the region has been undergoing major land use changes, such as the trend towards replacing natural forests with exotic species (Eucalyptus sp. :http://www.cabi.org/isc/abstract/19960612070) eucalyptus), and intensification of traditional landuse with corresponding reduction of fallow periods and overgrazing in natural areas, despite the low production of vegetation and readily erodible soils (Shruti *et al.*, 2011). The reduction of organic matter and vegetation cover also results in soil compaction and higher overland flow generation in the overgrazed areas, increasing chances of erosion.

2.1.3 Iran

- Hamadan Province (around 34◦ 47' N 48◦ 50' E)

geopedologic surveys that are executed by the author in several areas, including Hamadan-Bahar, Sharra, Komidjan, Azna (Arak), and Malayer, are the basis of this investigation. The Hamadan-Bahar (at the foot of the Alvand Mount), about 400 km south-west of Tehran, has been inhabited during the Medes kingdom (625-336 BC). Mountain, hill-land, piedmont and valley are the major geopedologic units distinguished in the study areas (Farshad, 1997; Farzaneh, 2011). Climate is of a Mediterranean

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type, with an average annual precipitation of about 300 mm. The mean monthly temperature in Hamadan varies between -5 °C in January and 24°C in June, with an annual mean of 10°C. The average annual evaporation from a class a pan is around 1900 mm. The soil moisture regime is (dry) xeric, and the temperature regime is mesic. The dominant soils are classified in Inceptisols and Entisols, but Argillic bearing soils (Calcixeralfs and Natrixeralfs, in the Sharra valley) occur too. The dominant crops produced were alfaflfa, cereals and legumes. Pasturalism is an important agricultural sector (own observation, cross-checked against the agricultural statistics issued by DSI (the Dept. of Statistics and Information of Hamadan Province) reports).

- Urmieh (Shahr-Chay) plain (around 37◦ 19’ N 44◦ 55’ E)

Urmieh, capital of West Azerbaijan Province, is situated at an altitude of 1,330 m above sea level, and is located along the Shahr-Chay River. Lake Urmieh lies to the east of the Urmieh city, with the mountains to the west, on Iran-Turkish border. Climate is characterized by cold and moist winter and mild summer; mean annual rainfall of about 590 mm; a mean annual temperature of 9◦C with a mean annual evaporation of about 920 mm. Geopedologiaclly, mountains, hills and piedmont, plateau and valley are distinguished. Soils are classified in Inceptisols, with some Alfisols that occur in the plateau. Besides farming (mainly wheat, beans, tobacco, fruits) pasturalism is an important sector (Sokouti, 1997).

3 RESULTS

It is attempted to present the results in the order of past, present and future, as appearing in the title.

3.1 Past; paleoecology

3.1.1 The case of Sbeitla, Tunisia:

Erosional glacis – adjacent to the mountain front- is extended by an accumulation glacis (Figure 3; Sbeitla, Tunisia). A fan, visible in the air photo, distinguishes itself from the glacis by being associated with a distributary (dichotomic) drainage pattern.

Three major geomorphic units are distinguished: the mountains, the glacis and the valleys. The glacis, the formation of which is related to changes in climate (Farshad, 1988) is further subdivided into high, middle and low (Figure 4). The highest glacis (Pleistocene) is at the foot of the mountain, or occurring as buttes and table-lands. In places right at the foot of the mountain the glacis is covered by alluvio-colluvial fan deposits. The lowest glacis (Holocene) are of a depositional nature in places grade into the terraces of the wadies.

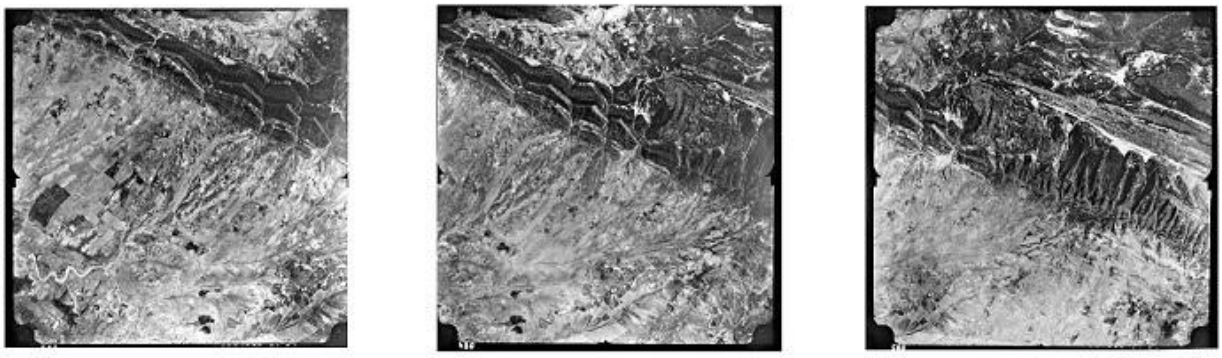

Figure 3 Aerial photographs depicting the glacis of Sbeitla, Tunisia. Panchromatic B and W with Approx. Scale 1:25000; after Farshad, 1988.

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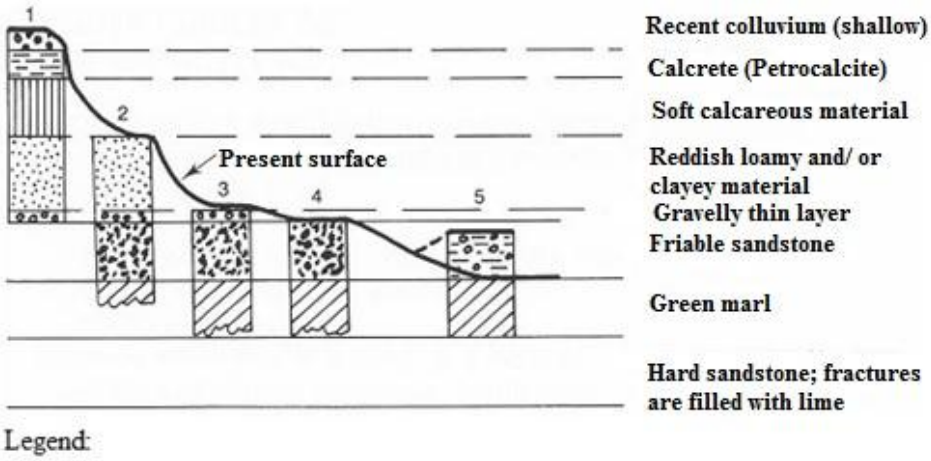

1= Typic Paleorthids and/or Typic Calciorthids; 2= Typic Camborthids and/or Typic Calciorthods; 3 and 4 = Typic Torriorthents; 5= Aquic Torriorthents, Vertic Torriorthents, dark coloured soils (mainly in the old valley floors)

Figure 4 Schematic presentation of the glacis surfaces on different lithologic substrata (After Farshad, 1988). The complete geologic column (section) can be observed in the Roman town of Sbeitla

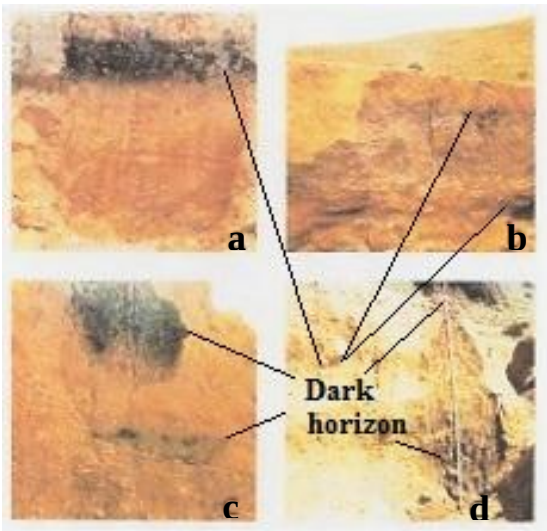

Figure 5 Dark colored soils: **a** = in the old Roman town, **b** = Wadi's wall, **c** and **d** (bisequm) = in the mountains

Analysis of the collected geopedological data and the conclusion drawn from the occurrence of the dark coloured soils reveal that the region has enjoyed a wetter climate. The geopedological setting, very much relied on soil morphology, and the routine analyses of the collected samples support the idea of changes in climate (Figure 5). According to the geo-chronologic table of the Quaternary in North Africa (Durand, 1959), the climate has changed several times since the end of the Tertiary (Farshad, 1988). Apart from the natural events, several man-made events are striking and at the same time show that the area was heavily forested. In the course of some

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very fierce battles between Carthesians, Romans, Vandals, Arabs, and Turks, the heavily forested parts were set on fire and burned to ashes.

3.1.2 The case of AinBendar/Hannath, Morocco:

Understanding of the geomorphic and pedogenic processes (Geopedological setting) in the study area (own fieldwork; Shruti *et al.*, 2011) in Ain Bendar/Hannath, in Morocco helped conclude important points about the gully formation. Geomorphology of the study area can be explained in one word, that is, "pediplanation". The process must have begun with a change in erosion base level which led to the formation of glacis (Figures 6 and 7).

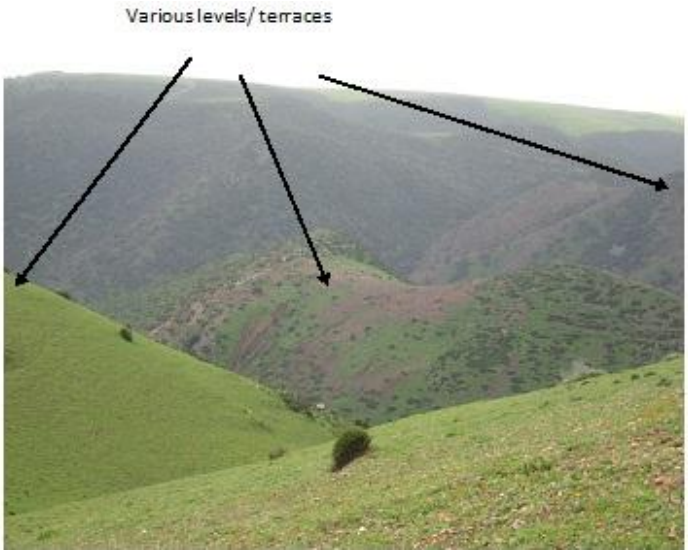

Figure 6 Various levels of erosional terraces (glacis)

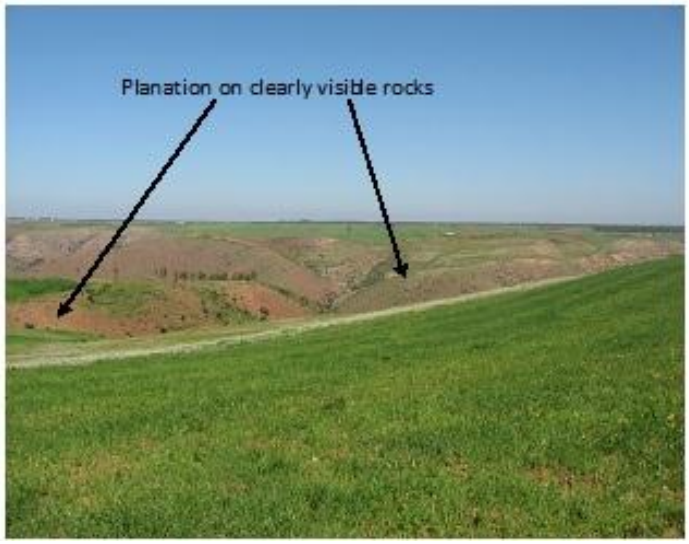

Figure 7 Erosional and accumulation glacis terraces

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The sheet-wash, that truncates extensive surfaces with different lithology, and that leads to the formation of erosional glacis, produces materials which move and deposit downslope to form the accumulation glacis (Figure 8).

Occurrence of the *Ultisols* (characterized by an Argillic horizon and low base saturation percent in subsoil), *Plinthite*, and *Ironstone* implies a wetter and probably hotter climatic condition (Figure 9).

Figure 8 Accumulation glacis, wherein Ultisols occur

Figure 9 Ironstone (left picture) used in the construction of several monumental buildings (right)

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3.1.3 The case of Hamadan, Iran:

In previous researches, (Farshad, 2013; Poch and Kovda, 2013), the role of geopedological setting in reporting historical changes in climate and agroecology in northwestern Iran was demonstrated, following the line of research in "global warming" that is often claimed to be the cause of climate change, which is often held responsible for water shortage. Let geopedology represents the complex process of soil formation; a dynamic interaction between the atmosphere, biosphere, lithosphere, and the hydrosphere. In a multidisciplinary sustainability - oriented study, geopedologic data were analyzed and cross-referenced with some historic and archaeological information to reconstruct paleoecologic conditions in several time periods, since upper Pleistocene. The geopedologic setting revealed that once upon a time the area was subject to cycles of erosion and sedimentation; glacis formation (Farshad, 2006). Besides the glacis formation, karstic springs, almost all are dried out, where travertine is formed is an important feature in extracting information about the past. The occurrence of a subsurface layer of travertine (dated 27,000 yr BP) coated by a thin organic layer (Figure 10) that is dated 13,000 yr BP, implies a humid environment.

The layer of travertine (yellowish brown in color, dated 27,000 yr BP) coated by a thin organic layer (dark brown and black in color) is dated 13,000 yr BP.

A climate characterized by the alternation of wet and dry periods is also supported by the occurrence of Argillic and Petrocalcic horizons. On the other side, cultivating crops such as rice, tobacco and cotton, which is not possible these days, implies relatively wetter conditions. The conclusion of the research published in Farshad (1997) (ISBN 90 6164 142 X) is that aridification has never been as degrading as it is today, mainly due to the over-exploiting of the non-renewable fossil groundwater.

Figure 10 Microgram of the coated travertine specimen (shown in thin section)

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3.2 Present; soil management

3.2.1 The case of Malayer, Iran

The soil, reported in Farshad (1978) as Typic Halaquepts (Figure 11) could be traditionally managed for decades to grow barley, a crop with superficial rooting system that tolerates salinity. The same area when plowed deep, using tractors, turned into wasteland.

In this connection, soil is looked at holistically, that is, to consider the soil as one of the main components of the 'land'. Land comprises the physical environment, including climate, relief, soils, hydrology and vegetation, to the extent that these influence potential for land use (FAO, 1976). Two soils that are similar in physico-chemical characteristics, but occur in different positions in landscape may not be manageable in the same way. Variation in geopedologic setting (soils and landforms) is often the main cause of differences between land map units within a given area. Here, land suitability evaluation (FAO, 1976 and 1993) comes up to speak out; putting land in different suitability classes for various land utilization types (LUT). LUT being defined, in short, as the 'produce' (e.g., crop) plus the 'management', including capital intensity, labor intensity, farm power, level of technical know-how, farm size, land tenure, etc. FAO methodology speaks of actual and potential suitability, being decisive in management. 'Potential land suitability refers to the suitability, for a defined use, of land units in their condition at some future date, after specified major improvements have been completed where necessary (FAO, 1976)'.

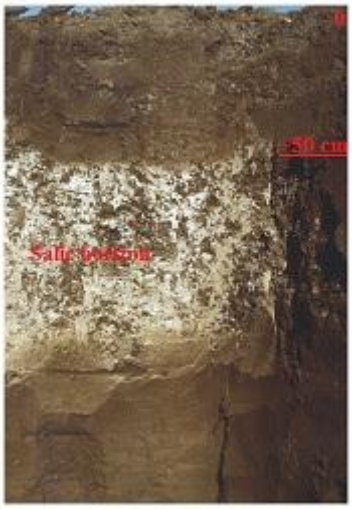

Figure 11 A soil with Salic horizon

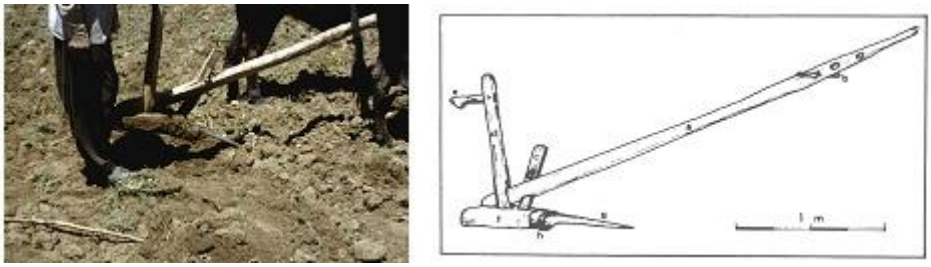

Figure 12 Wooden plow (called *khish* in Persian)

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3.2.2 The case of Hamadan-Komidjan, Iran

Farshad *et al.*, (2005) demonstrate (Figure 13) how mismanagement can lead to compaction and ultimately to yield reduction (Figure 15). In order to understand to what extent the soil has been affected by traditional and mechanized practices, and to check the effect of converting the initially dry-farmed land into irrigated cultivation, an integrated approach, i.e., application of image processing techniques (field of remote sensing) to micromorphology (Farshad, 1994; Stoops 2003) was employed (Figure 14, Table 1). The soils managed traditionally (Tradvoid) are the best aerated ones, whereas the mechanized soil (Mc21void, 8 - 18 cm depth) is the most compacted one. The reason why Pastvoid is not the best aerated soil lies most probably on the fact that these soils are grazed, trampled by animals, for centuries. In this connection, parent material plays a role too. Under any pressure (e.g., use of machinery), the soils formed on micaschists can easily become compacted, due to the gliding effect of mica. This led to study a sample collected from a soil formed in calcareous material.

Figure 13 Manual harvesting (left), mechanized (right)

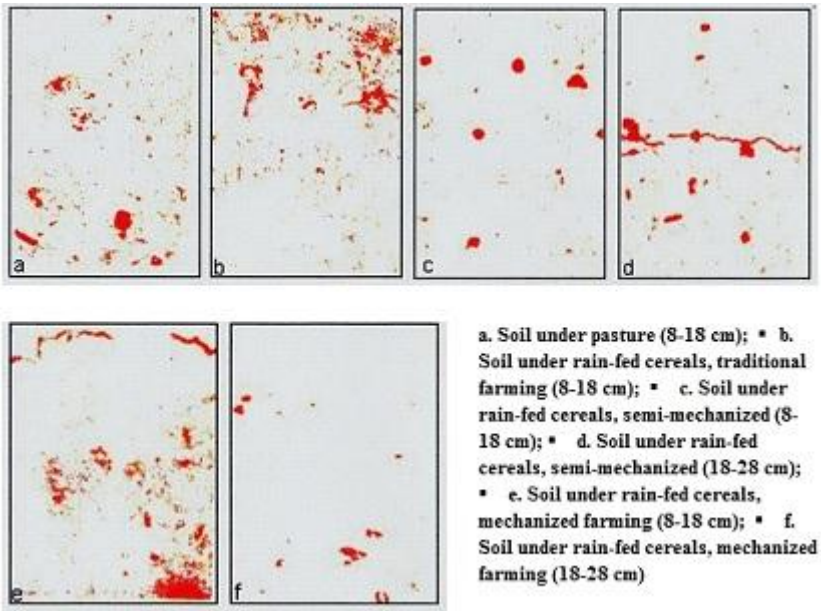

Figure 14 Thin sections of the soils under different management (all rain-fed; traditional, semi-mechanized and mechanized farming); red points depicts pores (Farshad *et al.*, 2005)

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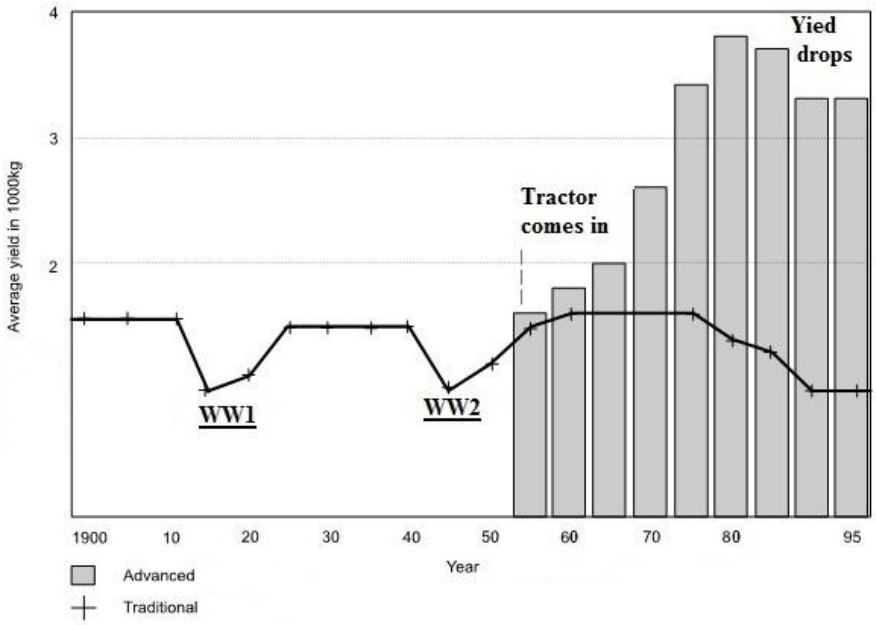

Figure 15 Yield reduction (*WW1= World War I and WW2= World War II*)

3.2.3 The case of Morocco

Often geomorphology plays basic role in natural sciences-based studies. In soil erosion studies however soil forms the base, and very much dependant on the cause, whether natural and/or accelerated (under human influence), geomorphology is of valuable help to explain the ‘’cause and effect’’ process. In other words, understanding geopedological setting of the area under study would ease the modelling of erosion.

Gully formation is considered as a natural geologic process that can be greatly accelerated by human activities. Proper recognition of gully forming factors and the causes of acceleration is a hot issue in environmental sciences (Shruti *et al.*, 2011), considering that gully erosion is one of the indicators employed to evaluate geomorphic hazards.

Naturally, gully erosion is associated with “pediplanation” (Birot, 1965; Penck (cited by Sparks, 1972) and later on, King, 1967; Gutierrez, 2012). The process begins with a change in erosion base level followed by lateral retreat of slopes, that is, formation of pediments and pediplain. Theoretically, change in the erosion base level is either resulted from climate change or as a consequence of tectonics (Figures 16 and 17). Topographically, catena and/or toposequences will be formed where the Rhue model (Zinck, 2013) can be of use to come to geoforms, that is, summit, shoulder, backslope, footslope and toe-slope facets.

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Figure 16 The main gully; banked by two different soils (at order level)

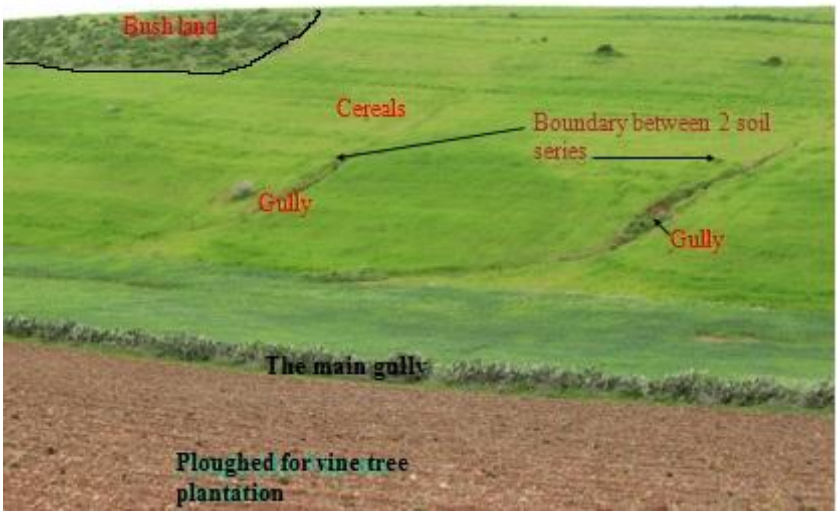

Figure 17 Gullies running perpendicular to the main one, each banked by two different soil series

Very remarkable is that the position of the gullies (Figure 16) corresponds with the pedons' boundaries (Figures 18 and 19), that is, a weak point (/line) between two bodies.

3.3 Future; prediction

The first paragraph of the first chapter of the Soil Survey Manual (USDA, 1993) reads "A soil survey describes the characteristics of the soils in a given area, classifies the soils according to a standard system of classification, plots the boundaries of the soils on a map, and *makes predictions about the behavior of soils*." Using the land evaluation-oriented Index--LUCI ('Land-Use Compatibility Index), an index which can easily be used by agricultural

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extension staff to explain to farmers (Figure 2), the result of matching between 'land suitability classes' on a suitability map and the way these units were currently used is demonstrated.

Classes which were set up for the case of Urmieh were: suitable= rating 0.6, warning= 0.3-0.6, and unsuitable when the rating was <0.3.

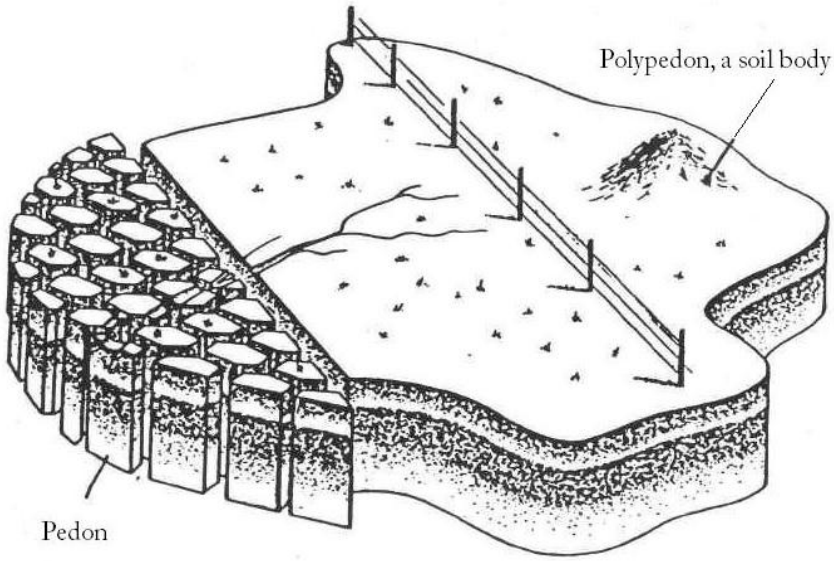

Figure 18 A schematic view of pedon/Polypedon

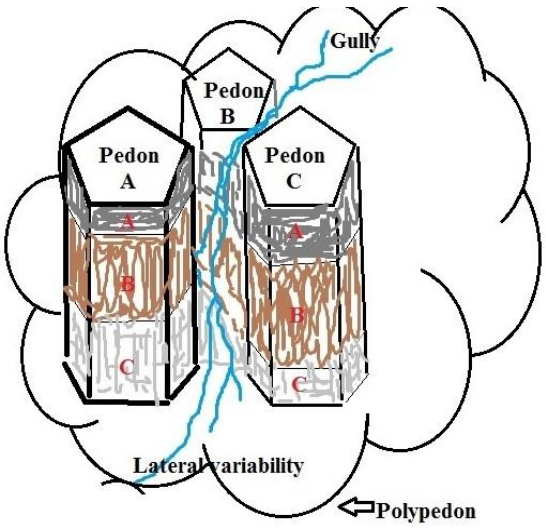

Figure 19 Pedons boundaries (compare pedons A, B and C; with attention to the thickness of horizons)

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4 CONCLUSION

Classically, soil is known to function as *provider*, *controller*, *regulator*, *mechanical support*, and as a *filter* to protect the quality of water, air, and other resources. Through analyzing a few soilscapes, in the (semi-) arid regions of Tunisia, Morocco and Iran, three additional functions of the soil, being the history book of the landscape (archive), a guide, and a predictor are argued. Studying soilscape is beneficial to paleoecology, soil management and soil health, that is to say: soilscape speaks out; an account of the past, present and future.

Regarding the 'account of the past' our understanding of soilscape genesis (e.g., horizonation, pediplanation) help us describe paleoecology.

The role that soilscape plays as a *guide* is argued using such information as particle size class, depth, pH, EC, and the position in landscape (Site) that are collected in a soil survey to apply in the development of land-use plans and the way soils have to be managed.

Finally, the role that soilscape plays as a predictor (an account of the future) is explained referring to such pedogenic-based features as Pedon (a soil) and diagnostic soil characteristics, such as abrupt textural change, COLE (coefficient of Linear Extensibility), and (Para-) Lithic contact, etc.; and those of geomorphic-based, such as slope and position in the landscape. In this connection, soil mismanagement is also a guiding feature.

To conclude: Listen to what soils ('soilscape') say, before it is too late. Coming generations also have the right to enjoy a healthy environment. Prevention is better than cure: better to try to keep a bad thing from happening than fixing the bad thing once it has happened (Figure 20).

Figure 20 Badland formation

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زمین‌نمای خاک: نمایه‌ای از گذشته، حال و آینده

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چکیده خاک یک مولفه سه بعدی از سیمای سرزمین است. به‌عبارت ساده یک پیکره طبیعی در زمین‌نمای خاک با مشخصات زمین خاک‌شناسی بوده که توسط Jemy آن را تابع پنج عامل اقلیم، موجودات زنده، پستی و بلندی، مواد مادری و زمان معرفی نموده است. برای مطالعه چنین پیکره‌ای پیچیده، مفهومی بنام پدون که کوچک‌ترین واحد قابل مطالعه محسوب می‌شود تدوین و تعریف شد. تا به‌حال کارکردهای خاک تحت عنوان‌های تهیه کننده، کنترل‌کننده، تنظیم‌کننده، حمایت‌کننده مکانیکی و فیلتر حفاظت‌کننده کیفیت آب و خاک و سایر منابع مطرح شده است. در این مقاله سعی بر این است که با ذکر نمونه‌هایی از زمین‌نماهای خاک در مناطق نیمه خشک تونس، مراکش و ایران چند کاربرد دیگر خاک از قبیل آرشیو (کتاب تاریخی زمین‌نمای)، یک راهنما (در مدیریت اراضی) و یک تخمین‌گر (سنجش سلامت خاک) نام برده و به‌عبارت دیگر، زمین‌نمای خاک در رابطه با شرایط گذشته، حال و آینده خاک تشریح شود.

کلمات کلیدی: پالئواکولوژی، تخریب خاک، حفاظت خاک، زمین نمای خاک، ژئوپدولوژی

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