THE IMPACT OF SOIL FERTILITY ON THE CHARACTERISTICS OF THE RURAL LANDSCAPE FOR ITS PROTECTION

Canio Manniello[1], Dina Statuto[1], Andrea Di Pasquale[2], Giuseppe Cillis[1], Pietro Picuno[1]
[1] SAFE School of Agriculture, Forestry, Food and Environmental Sciences, University of Basilicata, via dell'Ateneo Lucano 10, 85100 Potenza, Italy
[2] INNOVA Consorzio per l'Informatica e la Telematica srl, III Trav. G.B. Pirelli, snc – Z.I. La Martella – 75100 Matera, Italy

Abstract
The optimization of land use, entailing the integration of land, water and soil management, encompasses complex decisions, which ask for some appropriate socio-economic and ecological priorities. Soil represents a fundamental resource, which plays a key role in ecosystems, since it governs all the mechanisms at the basis of vegetal growth and of all components of the total environment concurring to the formation of a rural landscape. Therefore, the characteristics of soil fertility should be taken in the highest consideration when the analysis of a rural landscape is performed, to preserve pedo-diversity and its spatial variability. In this paper, a peculiar feature of the soils - such as the availability of organic matter and soil fertility - has been considered with reference to the Basilicata Region (Southern Italy). An ecological index has been also quantified there, to examine the complexity and fragmentation of relevant rural landscapes. The combined assessment of these two parameters has allowed to highlight the characteristics that generally do not appear immediately in the perception of a certain landscape, enabling the evaluation of the actual fragility of typical scenarios of the study area, hence paving the way to the formulation of new landscape protection policies.

Key words: Land & Soil, Fertility maps, Geographical Information Systems, Sharpe Index, Landscape protection

Introduction

The environmental changes occurred during the last decades, mainly caused by the concurrent actions of human activities and natural forces, have resulted in continuous interactions with the surrounding context (Statuto et al., 2017). A landscape can be considered as a dynamic open system, in which economic, social and biophysical factors interact among themselves, defining its current structure (Neubert and Walz, 2002; Statuto et al., 2016) and transforming it into a valuable heritage, having a cultural value as well (Statuto and Picuno, 2017; Statuto at al., 2013).
The long-standing historical relationships that traditional communities have established with their environments, provided a rich diversity of soils. A soil is, then, the result of the complex interaction among specific regional environmental factors and managing strategies. Distinctive landscapes are thereby generally formed by particular soil modeling processes. Land use for agricultural purposes is leading to unprecedented changes in the rural landscape, ecosystems and the environment. Rural landscapes are changing due to the intensification of agriculture, which exploits the soil and changes its state and its natural functions, bringing with it some undesired environmental problems such as climate change, loss of biodiversity and pollution of water, soil and air (European Environment Agency, 1999).
When soils are subjected to human impacts, they influence the value of the cultural landscape (European Policy Brief, 2016). The re-working of soils is the most tangible mean by which human activity has impacted on the landscape, creating field boundaries, spaces, paths and settlements. Behind the complexity of cultural landscapes, there are high levels of soil diversity (i.e. pedo-diversity) within regions, that demonstrate a great spatial variability of soil properties. This variability is not accidental, but rather structured by the activities of past communities. Therefore, pedo-diversity can be intended as the identification of specific cultural signatures present in the soil of local landscapes. In this paper, a peculiar feature of the soils - such as the availability of organic matter and soil fertility - has been considered to elaborate an ecological index enabling to examine the complexity and the fragmentation of a rural landscape.

Materials and Methods

The study area consists of the total territory of the Basilicata region (Southern Italy). It has a total geographical area of 10073.11 ha (Urbistat, 2019), predominantly covered by rural land, with a quite low density of average regional population (56.3 inhabitants/km^2) (RSDI, 2019). The area used for agriculture is 472,833 ha (accounting for 46.9% of the regional surface area), of which 58.6% is used

for arable crops and 11.7% for woody crops. The 29.7% remaining surface area is characterized by permanent grassland, especially located in mountain areas (RSDI, 2019). In this region, soil is a fundamental component of agriculture, since it forms the basis of all chemical and physical processes. In recent decades, a persisting inadequate substitution of soil nutrients has led to the lack of organic matter and consequent low level of soil fertility (Fig. 1) (Manniello et al., 2020/a), only partly balanced by the reuse of agricultural residues (Manniello et al., 2020/b).

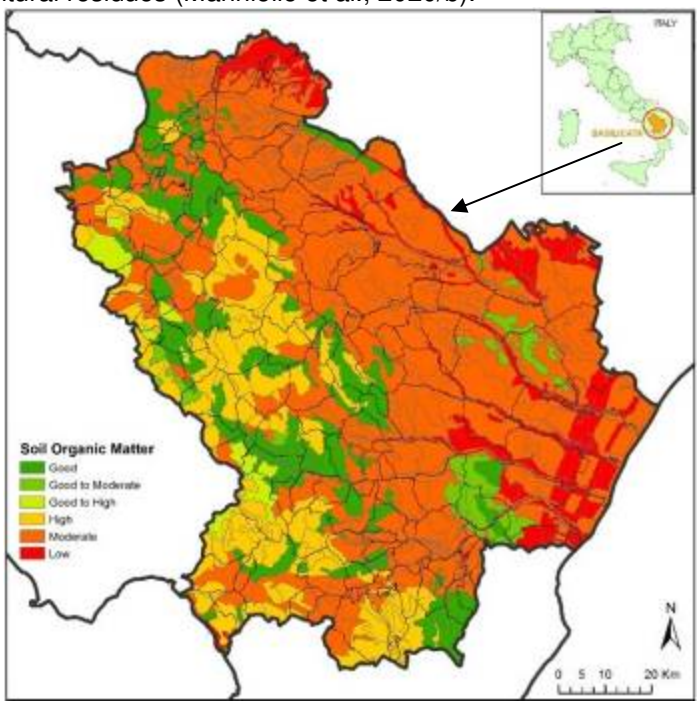

Fig. 1: Map of the concentration of soil organic matter in Basilicata Region.

Using a Geographical Information System (Quantum GIS-v.3.10) and considering the specificities of the study area, an ecological index has been calculated in order to examine complexity and fragmentation of the rural landscape. Through the *Sharpe Index* (Hulshoff, 1995) it is possible to highlight the significance of certain processes concerning land use transformations that have occurred in an historical period in a study area. The Sharpe Index is applied to individual types of land use classes. It may assume positive or negative values (Rete Rurale Nazionale, 2016). The Sharpe Index (S.I.) is thus calculated as:

$$S.I. = \frac{\left(\frac{(pk_2 - pk_1)}{(t_2 - t_1)}\right)}{S}$$

Where *"pk_1"* is the area of the single land use class at year t_1 expressed in hectares; *"pk_2"* is the surface of the single land use class in year t_2 ($t_2 > t_1$) expressed in hectares; "*S*" is the total surface of the study area expressed in km^2.

Results and discussion

The land use categories of the study area in the years 1990 and 2018 (Copernicus, 2020) are reported in Figure 2.

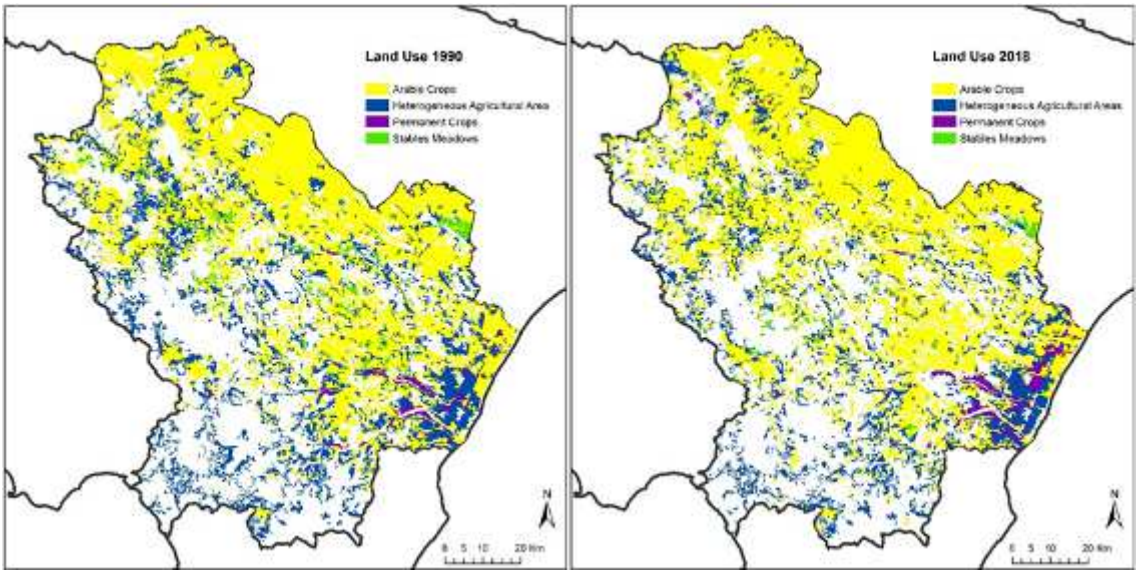

Fig. 2: Land Use Categories in the year 1990 (left) and in 2018 (right).

On the basis of the "Agricultural Area Used" (Corine Land Cover level 2), the Sharpe Index has been calculated for each land use, to provide a comparison between the two different periods. When this Index has assumed a positive value, then the land use has recorded an increase in surface area in the reference period. On the contrary, if the index has assumed a negative value, the land use has recorded a decrease in its surface area. The results of this comparison are showed in Figure 3, in which the land uses responsible for the most significant changes are reported in a bar chart form. As a final result, it is clear that, in the case of Basilicata region, the most meaningful changes are due to the increase in the area used for arable and permanent crops, that has been balanced by a decrease in permanent grassland and heterogeneous agricultural areas.

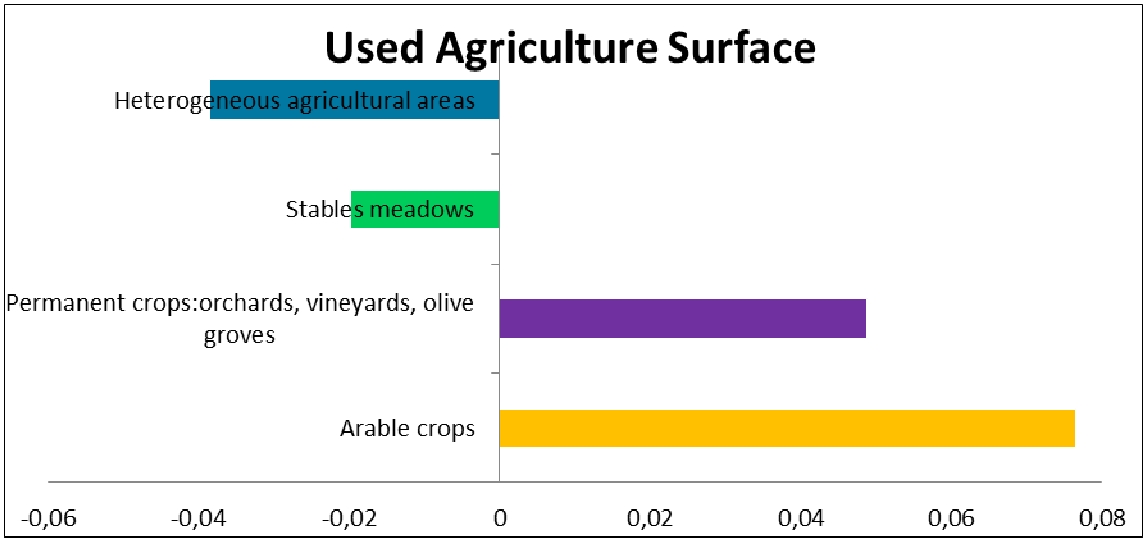

Fig. 3: Application of the Sharpe Index to the “Agricultural Area Used” of the Basilicata Region.

This increase in the areas intended for arable and permanent crops (orchards, vineyards, olive groves), inevitably presupposes an intensification of agricultural activities in the considered period and a consequent increase in the tillage of the soil. This agricultural practice modified the soil pedological profile, its structure and spatial variability, causing at the same time a reduction of the organic matter content. These activities, like most intensive agricultural practices, require indeed continuous removal of nutrients from the soil, especially in relation to the agronomic techniques used. The arable crops, with their continuous processing, change the soil structure, progressively subtracting nutrients to the plant root systems. In the same way, permanent crops, in order to grow and perform their vital functions, need nutrients constantly, depleting the soil. As a consequence, without the necessary balancing and return to the soil of the substances removed from agricultural activities - which would close the cycle of organic matter - the soil no longer performs its vital functions correctly, as it

significantly reduces its physical, chemical and biological fertility, with consequent increase in erosion, causing alterations to the local ecosystems and to the whole rural landscape. Suitable planning interventions are therefore absolutely necessary, in order to restore proper conditions for safeguarding soil health and protecting the relevant landscape. For such an appropriate planning approach, the use of a powerful tool like a GIS - in which concentration of soil organic matter and land use transformations may be correlated – may reveal decisive.

Conclusion

Soil health is an excellent "indicator" of the quality of the landscape, which performs the fundamental function of maintaining landscape biodiversity. In the study area, which is considered a territory with a high rural – i.e., both natural and agricultural - landscape value, the content of organic matter present in the soils, and the correlation with a visual quality index, has enabled to evaluate the actual fragility contexts within the study area. The use of a GIS has highlighted a characteristic that strongly impacts on the perception of a landscape, *i.e.* the increase in arable and permanent crops in recent decades. These activities, other than creating a different visual quality of the landscape, exploit the soil, modifying its natural state and relevant vital functions, causing as a direct consequence a lack of soil organic matter (low fertility) and, generally, the loss of biodiversity and climate change.

The obtained results could help to formulate new advanced tools aimed to landscape protection, which could be suitably employed by technicians and policy makers in their decisions aimed to proper landscape planning, mostly if the relationship between soil fertility and landscape quality are considered, together with the application of more indices for a detailed in-depth spatial analysis of the various considered factors.

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Souhrn
Půda je jedním z nejdynamičtějších prvků v krajině. Jedinečnost kterékoli krajiny je dána dynamikou půdních procesů. Ochrana půdní diverzity zmanemná ochranu charakteru krajiny. V regionu Basilicata byla zkoumána změna využití území (land use) za posledních téměř 30 let (1990 – 2018). Za pomoci GIS metod byla zkoumána dostupnost organické hmoty a půdní úrodnost. Na zemědělsky využívaném území byl využit *Sharpe index*, výsledky ukázaly snížení velikosti území určeného pro trvalé zatravnění a heterogenitu zemědělskýy využívaných ploch, stejně jako nárůst orné půdy a trvalých kultur. Tyto aktivity příliš vyčerpaly půdu, způsobily ztrátu organické hmoty a následně i úrodnosti, ztrátu biodiverzity a ovlivnění venkovské krajiny v negativním slova smyslu.

Contact:
Canio Manniello
E- mail: canio.manniello@unibas.it