Case study

ANALYSIS OF THE EVOLUTION OF LANDSCAPE AND LAND USE IN A GIS APPROACH

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Abstract *The use of Geographical Information Systems facilitates spatial analysis and allows the understanding of the evolutionary processes that occurred over the years and have led to the current conditions. Thanks to a comparison between an historical cartographic map with recent ortophotos, it was possible to evaluate the meaningful elements present in an area and their changes over time. A compared analysis, started early 1800, found that the study area, mainly its rural and forestry land, have been affected by deep transformations, due to natural events, human intervention, and changes in natural cycles, that resulted difficult to understand. The historical map represents the entire municipality of Ruoti (Basilicata Region, Southern Italy), traditionally devoted to arboreal cultivation or wood-sheep farming,. The map reports the town and the surrounding area in the Year 1812, showing the main rivers, the land use of the area, the different type of vegetations, expressed with different colors and symbols.*
The spatial analysis of this study area showed a succession of land use changes, influenced by the modern cultivation techniques, while vegetation changes give variations of the agro-forestry landscape over the years, and cultivation conversion caused a loss of CO_2 fixation value.

Key words: *GIS, historical map, land use, carbon balance*

1. INTRODUCTION

Multi-temporal analysis of land, with the support of GIS and historical document, is a very important tool for monitoring landscape diversity and for investigating changes in vegetation and landscape structure. In recent years, technical and spatial analysis of landscape have been developed. The issues of historical landscape analysis and the influential driving factor of landscape development provide an essential basis for tackling current environmental questions in spatial planning [3]. The *landscape* should be understood as a dynamic and open system, where biophysical, social and economic factors interact to define the current structure. The Knowledge of the historical landscape development should therefore be the starting point for long-term landscape monitoring [8]. The objective of this work is an analysis of the land use over two centuries in an area that represents the Municipality of Ruoti. Through a comparison of chronologically different land cover maps it was therefore possible to assess and quantify the CO_2 variation in this area.

2. Material and methods

2.1 Study Area

The study area is represented by Ruoti Municipality (55 km^2) located in the central-western part of Province of Potenza, in Basilicata Region, Southern Italy. The territory has a considerable morphological variability, with the presence of soils of different age. This area is characterized by an hilly territory, the elevation being in the range 400 - 1000 m.a.s.l..

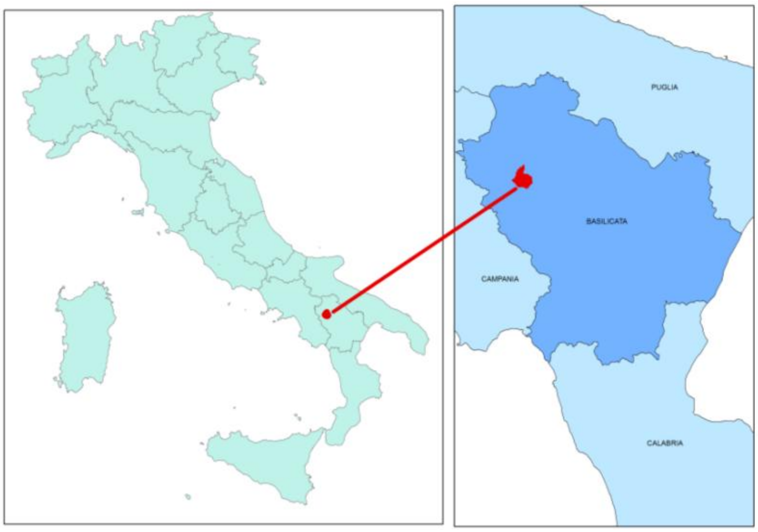

Fig. 1: Study Area.

The study area is crossed by the most important rivers present in this territory: the "Fiumara di Avigliano" and is bounded in the south by the "Fiumara di Ruoti". Both rivers are part on the hydrographic basin of the river "Sele". The geomorphological survey, however, has shown the presence along the slopes of several landslides. The study area is predominantly occupied by agricultural land (40%), forest and semi-natural areas (57%) and artificial surfaces (3%). The high-hilly landscape of the study area is characterized by an arable land, present especially in the hills, wide pastures in the north-area and vineyards. The mountains are covered with rich woods consisting mainly of underwood , such as fir-wood, with pieces of "Abies Alba" (a biotope surveyed by Italian Botanical Society).

2.2 Cartography and data

Land use changes in the study area were examined in two time periods: years 1812 and 2012. The historical information, dated 1812, derived from an historical map preserved in the "Archivio di Stato" (State Archives) in Potenza and from information wrote in the "Catasto Napoletano" (Neapolitan Cadastral Office) dating the Year 1812.

Fig. 2: Historical cartographic map year 1812.

The historical maps were produced in border disputes by legal experts and technical part, they represented a comparison between a documentary tradition, such as diplomatic writings, and feudal judicial and investigation of the soil. The map reports the town and the surrounding area, and shows the main rivers in the area. In the north part there is the presence of lands that can be classified as arable land, in the central part of the territory there is the alternation of olive groves and vineyards. The other part of land consists of forest and underwood. The maps was firstly scanned and digitized within a Geographic Information System, than the land use categories were extracted. The "Catasto Napoletano" expressed a breakdown of the agricultural and forest land in 4 time periods:

1753, 1812, 1929, 1959. In relation to year 1812, the data derived by a land description are based on the reports of the holder and on valuation of different types of vegetation. At the end of the original table it was written that data of agricultural and forestry lands are expressed without a specific use finalization, the so-called "Partite speciali" (Special lots). So, the total area expressed by the data of the Catasto Napoletano is not the same as the total area expressed by the determination of land use with the historical map.

2.3 Data analysis

The historical map was geo-referenced through a sequence of rectification and referencing procedures with control points on the map at know locations. Thanks to the different simbology present on the map it was possible the identification of the various types of land use. To determine land use of year 2012 recent digital ortophotos were utilized. Aerial photos were scanned and converted into a digital image and subsequently it was possible the identification of a great number of elements in the area: land use, farms hydrographic network, infrastructures, etc.

3. RESULTS AND DISCUSSION

3.1 Land use analysis

From the superposition of different base maps it was possible to identify the different categories of land use. The number of classes identified has increased, mainly due to the improved detail provided by the base. The results of the territorial analysis are expressed in the following table.

Table 1 represents, for each data and for each different cartographic support, the landscape use; the comparison has enabled the analysis of land changes from 1812 to present days, covering a time period of 200 years, giving information about the historic persistence of soil use typologies along with their time-driven modifications. Dominant land use typologies of the site have been grouped in order to better compare the output data through a more evident highlighting of variations in time.

Visualizing spatial data expressed in Fig. 3, we can observe a decrease in the arable land, a reduction of forested surfaces and an increase of continuous and discontinuous urban fabric. The urbanized area has undergone a substantial increase especially after the Second World War. As reflected by a widespread tendency in different areas of the region, the areas for agriculture and crops have been significantly reduced, almost halving the benefit of natural areas in terms of their role in the equilibrium of the natural ecosystems.

Table 1: Land use analysis from 1812 to 2012.

	"Catasto napoletano" 1812		Historical map 1812		Ortophotos 2012	
Land Use	Area ha	Share %	Area ha	Share %	Area ha	Share %
Arable lands	2527	51	1683	31	1541	28
Fluvial zone	0	0	205	4	126	2
Vineyard and Olive groves	341	7	723	13	145	3
Forest	1973	40	1903	35	1697	31
Underwood and Oaks	8	0	405	7	1320	24
Chestnut groves, pastures and natural land	124	2	125	2	444	8
Reed beds and vegetable gardens	11	0	0	0	0	0
Urban fabric and discontinuous urban fabric	0	0	85	2	231	4
Surface "M.s."	38	1	0	0	0	0
Agricultural land with vegetation	0	0	375	7	0	0
	4986		5504		5504	

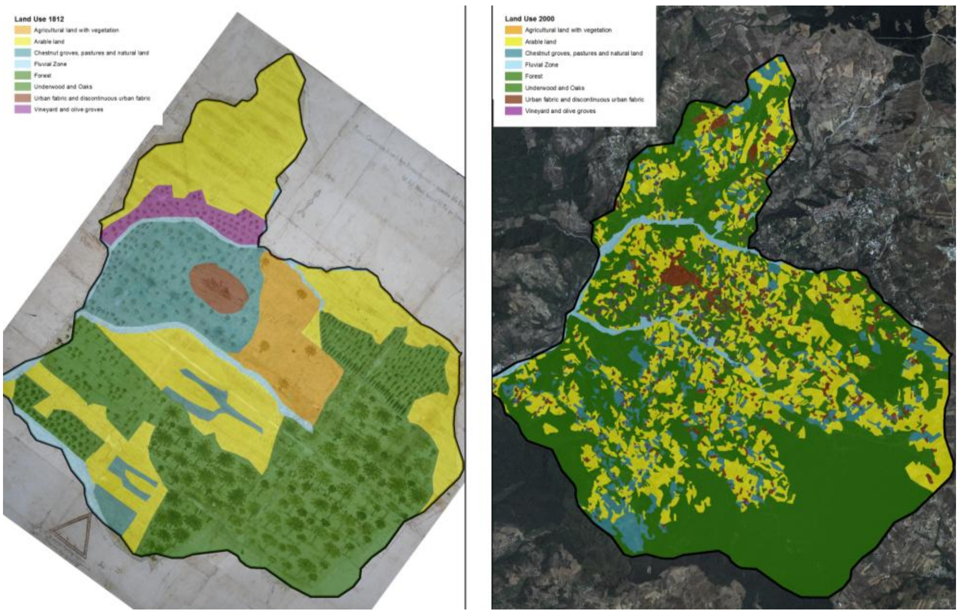

Fig. 3: Land use maps for different time periods – Left: the Historical Map. Right: the recent ortophotos.

3.1 Carbon dioxide balance

With the aim to quantify the effect of land use changes on the environment, with a special emphasis on air quality, the CO_2 time variation connected with land use was estimated. CO_2 fixation rates were calculated through adopting the user-friendly CO2FIX V.3.2 model [5] tool for the dynamic estimation of the carbon fixation potential of forest management, agroforesty and afforestation projects. CO2FIX V.3.2 is a multi-cohort ecosystem-level model based on carbon accounting of forest stands, including forest biomass, soils and products. Carbon stored in living biomass is estimated there with a forest cohort model that allows for competition, natural mortality, logging, and mortality due to logging damage. Soil carbon is modeled using five stock pools, three for litter and two for humus. The dynamics of carbon stored in wood products is simulated with a set of pools for short-, medium- and long-lived products, and includes processing efficiency, re-use of byproducts, recycling, and disposal forms. The model CO2FIX V.3.2 estimation of the total carbon balance of alternative management regimes in forests is disconnected in age, and therefore has a wide applicability for both temperate and tropical conditions [5] and the conditions for European Countries [7].

The CO2FIX model was developed as part of the "Carbon sequestration in afforestation and sustainable forest management" (CASFOR) project, which was funded by the European Union INCO-DC program. [6]. CO2FIX is a carbon book-keeping model that simulates stocks and fluxes of carbon in (the trees of) a forest ecosystem, the soil, and (in case of a managed forest), the wood products. It simulates these stocks and fluxes at the hectare scale with time steps of one year [4]. Some of the results of CO2FIX have been used in the IPCC 1995 climate change assessment. The estimated biomass concerns to crop at maximum production levels, not taking into account the entire length of the cycle (for example poly annual crops).

In order to initialize the model, different analysis parameters were used. The assumptions that were made were consistent with the software input characteristics [6] and the local area characteristics [2]. For forestry area the following characteristics were used: tree species, area, age, dominant height, standing volume, growth class and the coordinate of the stand.

Woodland in the study area is represented by tall oak trees, with prevailing *Quercus cerris*. Rotation length is 80 years with maximum biomass in the stand equal to 2000 Mg/ha. The allocation factor for foliage, branches and root production were taken from existing CO2FIX runs for comparable species. The turnover (annual rate of mortality of the biomass component) was evaluated in 0.3 for foliage, 0.06 for branches and 0.05 for roots.

The soil organic matter compartment consists of dead wood, litter layers and stable humus in the soil. On the basis of this analysis, a total carbon stock ranging from 32 to 134 Mg/ha and an average atmospheric carbon fixation approximately equal to 25 MgC/ha/yr were estimated.

In the study area, the orchard areas are generally vineyards with rare presence of olive grove. For the purpose of CO_2 calculation, the orchard area was compared to tall trees forest with a rotation of 20 years and periodical removal of organic matter through agronomic practices like pruning, comparable to a turnover (annual rate of mortality of the biomass component) of 0.3 for foliage, 0.07 for branches and 0.04 for roots.

In an orchard, carbon balance depends on the intrinsic structural and morphological characteristics of each species and it is also influenced by population density, rearing system, and especially on the canopy and aboveground and underground woody organisms. Moreover, in the case of young plantation, canopy has to provide for a relatively small amount of branches and roots and, consequently, primary production is net and the surplus of organic matter increases every year up to maturity when dry matter increases over time and subsequently tends to zero [11]. Based on such a principle, it is possible to estimate the average yearly fixation of atmospheric carbon as being equal to 7.25 MgC/ha/yr for the orchards, to 2.75 MgC/ha/yr for shrubland and to 3.6 MgC/ha/yr for arable land.

On the other hand, urban areas represent a source of CO_2 emission from both municipal and industrial combustion; a yearly amount of 15.0 MgC/ha/yr of CO_2 release into the atmosphere was therefore estimated on the basis of a report on the environmental state of Basilicata Region [1].

All the above-mentioned values of average atmospheric carbon fixation were adopted for each one of the two time periods (Years 1812 and 2012).

The data resulting from the implementation of the GIS gave the values reported in Table 2 expressed in terms of areas occupied by the different vegetation typologies and, applying their respective CO_2 fixation rates, in terms of absolute values of annual fixation of CO_2. The fixation of CO_2 does not include the effects of the agricultural machinery, supplies and transportation on CO_2: in woodland these factors are almost absent, while in case of orchard and arable land they depend strongly by crop techniques, and in some cases are negligible.

Table 2: Annual fixation of CO_2 in the study area.

Year	Woodland		Orchard		Shrubland		Arable land	
	Area ha	Annual fixation MgC/ha/yr	Area ha	Annual Fixation MgC/ha/yr	Area ha	Annual Fixation MgC/ha/yr	Area ha	Annual Fixation MgC/h a/yr
1812	2513	62834.15	723	5241.11	125	343.89	2058	7407.84
2012	1823	45579.68	145	1049.51	1320	3628.83	1986	7147.98

Table 3: Urban and total annual fixation of CO_2 for the studied areas.

Year	Urban		Total	
	Area ha	Annual fixation MgC/ha/yr	Area ha	Annual fixation MgC/ha/yr
1812	85	-1270.01	5503.73	74556.98
2012	231	- 3459.71	5503.72	53946.29

Examining Table 2 and Table 3, in the investigated scheme it is clear that the greatest changes in land use occurred after the abandonment of large areas that over time have become shrubby, going from 125 hectares in 1812 to 1320 hectares in 2012, accompanied by a strong expansion of inhabited areas, going from 1.5% to 4.2% of the total surface.

The percentage decrease in orchard was equally considerable with decreases reductions increased from 13% to 2.5%.

The arable land has remained almost unchanged, while the forested area also suffered a sharp contraction (about 28% lower, form 2513 hectares in 1812 to 1823 hectares in 2012).

As a result of the different performance in terms of CO_2 fixation concerning the investigated study area, all these land changes caused progressive decrease in carbon dioxide sequestered by the biotic agents embedded in the soil.

We can finally argue that the fixation of land carbon in Year 1812 was higher than in more recent periods, and that during time the land carbon balance worsened: the cultivation conversion occurred during time caused a constant loss of CO_2 fixation value [6] while heavy emission of greenhouse effect gas in the atmosphere by urban settlements were at the same time increasingly growing.

This pattern could be considered a typical situation also for many other areas located in Southern Italy or even elsewhere this approach seems to be considered as an useful tool for the planning and management of the rural landscape and environment: the study case showed that a sound planning in agricultural activities could significantly contrast the release in the atmosphere of CO_2 deriving from the diffusion of anthropic activities.

4. CONCLUSIONS

Under the general framework of the territorial analysis, aimed to constitute a suitable support for a proper planning activity, it is extremely important to know which were the evolutions that changed the landscape over the years. This analysis has shown the differences, in term of land use and in terms of CO_2 fixation, that have occured in the Municipality of Ruoti, starting from 1812 to the present. Human development causes an environmental pollution determined by the urban settlements and their activities. The use of this approach for other environmental factors, such as water, soil etc., would lead to a more comprehensive understanding of landscape development dynamics through its principal environmental components, contributing to the proposal of production oriented politics that achieve compensation of natural balance alterations, and a real application of the concept of sustainable development.

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