

# IMPLEMENTING MULTI-TEMPORAL CARTOGRAPHY INTO A GIS FOR ANALYZING RURAL LANDSCAPE AND PROTECTING FOREST HERITAGE

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## Abstract

Understanding the profound changes generated by the interaction between human activities and natural components, requires an investigation of rural landscape, that would strongly benefit by the implementation of GIS technology. In this framework, a multi-temporal study may offer significant hints for analyzing landscape evolution on time. This paper presents a spatial analysis methodology, developed to comprehend past dynamics of rural landscape, including its morphology and vegetation, to compare current changes, so envisioning potential future trends for well-planned interventions, aimed to landscape protection. This method was applied on a case study implemented in Southern Italy, where an historical map depicting the Municipality of Ruoti - traditionally devoted to arboreal cultivation or wood-sheep farming - has been retrieved. This map, reports the Town and the surrounding area in the Year 1812, including the Site of Community Importance (SCI) “*Abetina di Ruoti*” woodland, showing main rivers, alternation of olive groves and arable crops, and vineyards layout. The multi-temporal analysis performed implementing into a GIS this historical cartography, joined to more recent maps, enabled a compared examination of this study area, its rural land and forestry heritage, and their deep transformations, showing a great potential for assessing and monitoring landscape diversity and vegetation dynamics.

**Keywords:** Rural Environment; Land use changes; Historical maps; Spatial analysis; Site of Community Importance.

## Introduction

The analysis and the knowledge of the historical landscape development, ought to be a starting point for long-term landscape monitoring. The *landscape* should be understood as a dynamic and open system, where biophysical, social and economic factors interact among themselves, to define the current structure. The environmental changes occurred during the last decades, mainly caused by anthropic activities and changes in land use, have been dynamic, since they “evolved” considering human needs and the socio-economic conditions, also influenced by the natural forces and continuous interactions with the surrounding context. An accurate analysis of the performed variations and the global monitoring of all ecosystems, is necessary to propose suitable environmental protection politics (Statuto et al., 2013). A multitemporal land analysis, with the support of GIS and historical documents, may reveal as an important tool for monitoring landscape diversity, while analyzing changes in vegetation and landscape structure (Statuto et al., 2019a). The results of investigating historical developments primarily consist of quantitative/statistical information about land-use change which can, for instance, be used for the continuous monitoring of landscape transformation, or to assess forest biomass production along time.

This paper presents a local study on the land use evolution using historical and recent maps. It is aimed to analyze, in a specific way, the land use dynamics from 1812 to 2018, by a comparative examination of different historical cartographic supports and more recent maps (Liu et al., 2018). This approach, would enable to obtain conclusions about the rural landscape changes, their connection to human activities - agricultural production, in particular - as well as to natural events, and the consequences on the rural land. This analysis, by proposing a methodology supported in GIS tools to evaluate changes that make comparable maps from different dates and data sources, may enable policy decisions that support sustainable development, acknowledging present and future development trends and their potential economic, social, and ecological impacts. The technical and spatial analysis methodologies applied could so ensure proper land planning and management choices.

## Material and methods

### Study area

The study area (fig. 1) is represented by the entire Municipality of “Ruoti” (55 km<sup>2</sup>) located in the central-western part of the Province of Potenza (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.

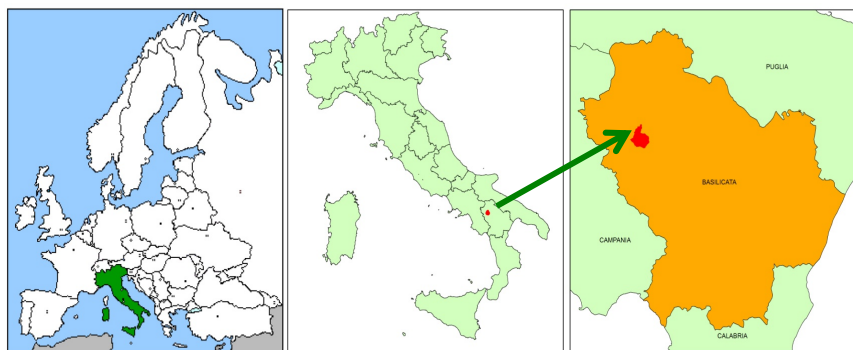


Fig. 1: Study area

The study area is crossed by the most important rivers present in this territory, *i.e.*: the "*Fiumara di Avigliano*" stream - which bounds it in the south – and the "*Fiumara di Ruoti*" stream. Both of these two waterways are part of the hydrographic basin of the main 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 (37%), forest and semi-natural areas (61%) and artificial surfaces (2%). The high-hilly landscape of the study area is characterized by an arable land, present especially on the hills, while wide pastures and vineyards cover the northern area. The mountains are covered with rich woods, consisting mainly in underwood and fir-wood, with some pieces of "*Abies Alba*" (a biotope surveyed by Italian Botanical Society).

### Site of Community Importance (SCI) “Abetina di Ruoti”

The importance of this site is due to the presence of relict populations of white spruce, of considerable importance in terms of germplasm conservation. As early as 1971, the Italian Botanical Society censused the "*Abies Alba*" as a biotope of relevant vegetation and conservation interest, due to the presence in the area of nuclei of native white spruce. The Abetina di Ruoti (fig. 2) is a forest that was described as "an almost pure forest of *Abies alba*, rich in magnificent and colossal specimens" (Basilicata Region, "Rete Natura 2000"). The undergrowth is rich in shrub and herbaceous species, including some rare and endemic species.

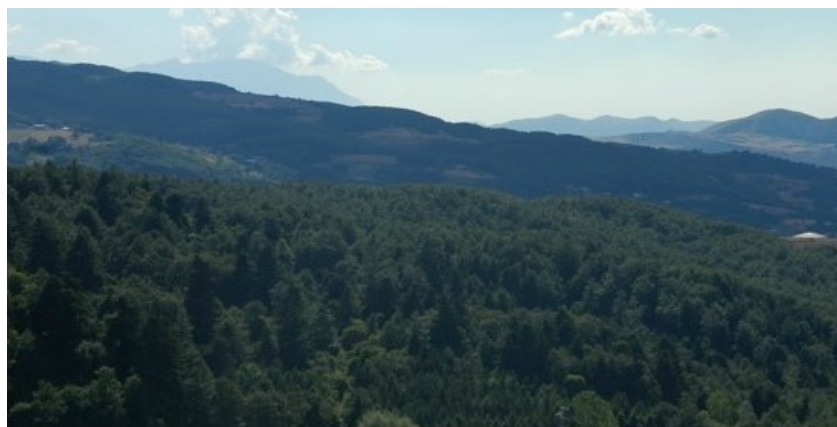


Fig. 2: Abetina di Ruoti

### Cartography and data analysis

Land use changes in the study area were examined in two time periods: years 1812 and 2018. The historical information, dated 1812, derived from an historical map (fig. 3) preserved in the "Archivio di Stato" (State Archives) in Potenza.



Fig. 3: Historical cartographic map (year 1812)

The historical map was geo-referenced through a sequence of rectification and referencing procedures, with control points on the map at known locations. Thanks to the different symbology present on the map, it has been possible to identify the various types of land use. The different categories of land use in the study area were calculated for the two analyzed periods.

### Results and Discussion

For each considered time period, and taking into account the different base maps above, various categories of land use were identified, considering the symbols present on the historical map and from recent orthophotos, that are able to display the current ground features. For the different categories of land use, using the GIS function, the total area expressed in hectares (ha) and the percentage (%) of the study area have been calculated. Their variation over more than two centuries was also determined.

The results of the territorial analysis are reported in Table 1, that 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 more than 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 (fig. 4).

From the analysis of land-use evolution it can be noticed how, during the investigated time span of more than two centuries, the land use for agricultural production has progressively decreased (from 40.26% to 36.87%), to the benefit of the natural areas, that have in the meantime expanded (from 12.53% to 17.03%), occupying most of the area lost by the former. This phenomenon was probably due to the constant increase of agricultural mechanization and diffusion of chemical products into intensive agriculture. Also forest area surface has increased, with an important impact on the local forest heritage.



Tab. 1: Analysis of land use in the two different years

Land Use Categories	Years		1812		2018	
			ha	%	ha	%
Urban fabric (continuous/discontinuous)			84,66	1,54	90,47	1,64
Agricultural area			2215,83	40,26	2029,22	36,87
Forest			2308,08	41,94	2428,64	44,13
Pastures and natural land			689,74	12,53	937,09	17,03
Fluvial zone			205,18	3,73	18,07	0,33
			<b>5503,49</b>	<b>100</b>	<b>5503,49</b>	<b>100</b>

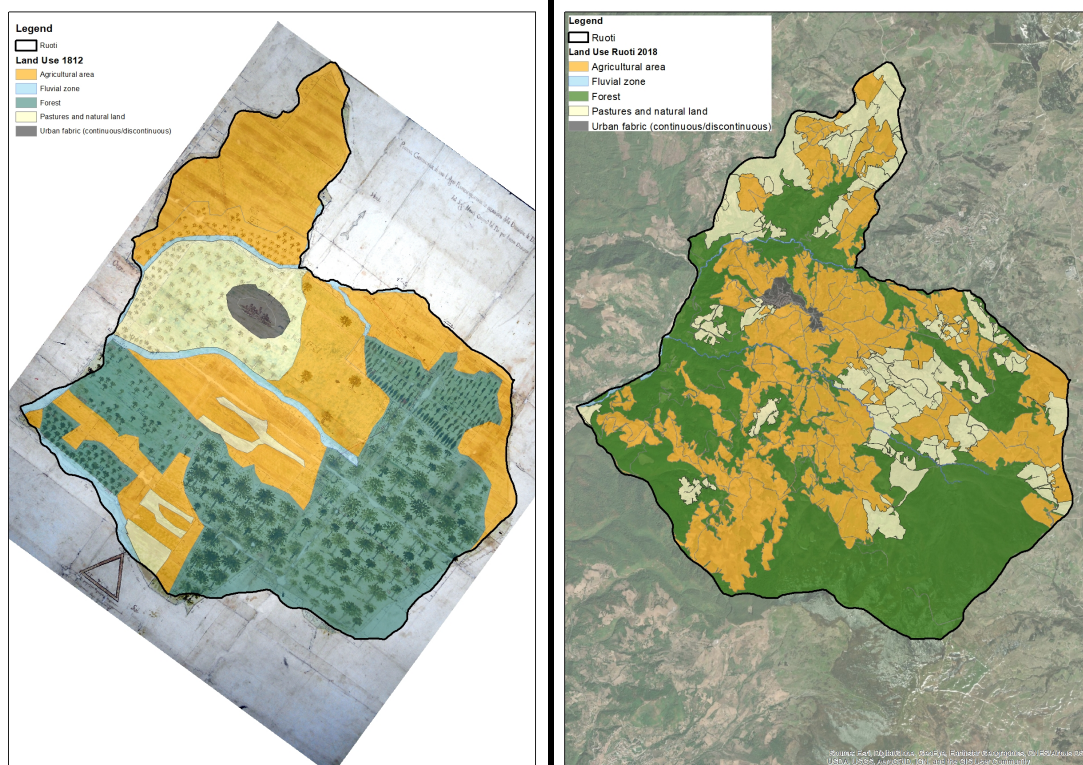


Fig. 4: Land Use categories in different time periods

## Conclusion

The role of territorial analysis is extremely important and delicate, to pave the way for proper planning activities. The understanding of the landscape's evolution over the years, both in morphological and vegetation terms, considering the special interest of the local forest heritage, represents a highly valuable database usable by public decision makers in the normal processes of making economic and political choices to govern rural landscape. The spatial analysis that was conducted, enables to assess relationships between forest biomass – with its relevant renewable energy potentials – and rural land, by using GIS technologies. This approach, allows to understand the landscape dynamics of the past, current developments and possible future trends, so as to optimize biomass resources and bridge the gap between energy systems modeling and landscape planning. It results to the concept of "*Energyscape*", as a virtual point for an interdisciplinary analysis, focusing on optimal exploitation of the energy potential and landscape protection (Statuto et al., 2019b). Similar information should be adequately considered to help addressing the need for suitable development policies and appropriate land management planning, aimed to protect forest heritage and rural landscape.

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## Souhrn

Lidská činnost vedla ke změnám souvisejícím se změnami ve využívání půdy v zemědělských a lesnických oblastech a na venkově. Změny sociálních a ekonomických podmínek, ke kterým došlo v průběhu minulého století, způsobily významné změny ve venkovské krajině s různými dopady na životní prostředí. Porozumět těmto změnám je nyní snadnější díky novým nástrojům a technologiím. Územní analýza ukazuje s podporou geografického informačního systému (GIS) a historických map dynamiku využití půdy, k níž došlo v průběhu let, aby bylo možné vyhodnotit důsledky proměn půdy na venkovské prostředí a krajinu. Studovaná oblast, která se nachází v regionu Basilicata (jižní Itálie), odráží společnou dynamiku přítomnou v mnoha venkovských oblastech jižní Itálie. Pro správné vyhodnocení je důležité dát dopady do souvislostí s půdou, dynamikou využívání půdy a socioekonomickými podmínkami oblasti. To je možné díky metodikám GIS, které jsou schopny vytvářet specifické modely pro studované oblasti a umožňují implementaci historických modelů pro kvantitativní a kvalitativní studie, což umožňuje pochopit vývoj krajiny a venkovské půdy. Mimořádné vlastnosti zobrazení, které tyto moderní informační technologie nabízejí, zvyšují vnímání studovaných oblastí a zlepšují informační aspekty a možnosti vizuální simulace vývoje využití půdy. Zvláštní pozornost je třeba věnovat managementu využití půdy a zemědělské činnosti, protože mohou ovlivnit některé přírodní cykly ekosystémů a kvalitu lesa.

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