A Remote Sensing Methodology to Assess the Abandoned Arable Land Using NDVI Index in Basilicata Region

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Abstract. European Commission in 2009 assessed that in the period 2015–2030 about 11% of agricultural land in the EU are under high potential risk of abandonment due to factors, which has strong and known environmental and socio-economic consequences. The diverse impacts of abandonment need to be addressed via a broader set of policy instruments to alleviate the negative effects or even - reverse the trends in the early stages of the process. The clear identification of abandoned agricultural land is fundamental for a correct mapping for the future management and monitoring of the territories. In this context, this study proposes an innovative method for the detection and mapping of abandoned arable land through the use of remote sensing techniques and geo-statistical analysis. The combined use of Sentinel 2 images and the Landsat constellation, the use of NDVI index and change detection analysis made it possible to identify the change in agricultural use and/or abandonment of land in the eastern part of the Basilicata region in the period 1990–2020. (Italy). All process has been developed integrating Remote Sensing and Geographic Information System (GIS), using open-source software.

Keywords: Abandoned land · Time series · Geographic information system

1 Introduction

Most of the European territory is used for agricultural purposes, agriculture plays an important role in the conservation of the EU environmental resource [6, 7, 21]. It interacts with and contributes to the maintenance of a wide range of valuable habitats. Appropriate land management practices and agricultural practices guarantee the protection of ecosystems [1].

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In the majority of EU Member States, agricultural land is expected to decrease not only due to land-use changes in favor of urban expansion and afforestation but also to land abandonment processes [11]. Agricultural land abandonment represents the largest land-use change process in Europe [20].

The abandonment of agricultural activities and, more generally, of the territory is under the attention of the international scientific community, as it can generate environmental and landscape impacts, as well as negative socio-economic impacts [9, 13].

Environmental and social problems related to abandonment include: (1) the reduction of landscape heterogeneity (often associated with increased fire risk); (2) soil erosion and desertification; (3) the reduction of water stocks; (4) biodiversity loss [1]. The effects on the territory are very different in relation to the territorial contexts and therefore it differs according to the climatic, ecological, biological, pedological, geological and topographical differences of the territories. The causes and extent of agricultural land abandonment also differ from region to region. In fact, in the internal marginal areas of Southern Italy, starting from the 1970s/1980s, there has been a constant and exponential abandonment which is causing a change in the ecological and pedological balance of the territory. In these areas, following an increase in cereal cultivation favored by the Agrarian Reforms for the South and an increase in mechanization, there was an increase in the agricultural area also used in the most marginal areas and little devoted to cereal cultivation. In the following decades, with the changes in socio-economic conditions, due to the crisis in the agricultural sector, which madeceariculture economically unfavorable, and following agrarian reforms linked to the community agricultural policy (i. And the "set-aside"), we witnessed a a slow and progressive abandonment of agricultural cultivation [8, 23].

Among the consequences of environmental degradation linked to agricultural abandonment there is the phenomenon of land degradation, and in the specific case, of soil erosion. In fact, the abandonment of cultivated areas can cause alterations at the pedological level, which combined with anthropic factors, climatic morphology and orography of the territory, leads to surface erosion phenomena of the soils.

This paper discusses the historical analysis of abandoned agricultural land in Basilicata Region (south Italy), providing the dynamics of changes of abandoned agricultural land and the distribution of such land across the area.

The methods used to study and evaluate the abandonment and/or change of use of agricultural land in literature are common, the most common are the application of spatial analysis through GIS, remote sensing and direct measurements on soils through sampling and laboratory investigations. The remote sensing technique is more flexible because it allows in a short time observe large areas using a series of spectral indices. The remote sensed data represents a great help to support the planner in order to study the phenomenon and monitor it. Spatial data bases to refer to are, for example, those on vegetation cover and land use maps.

Several studies have shown that Basilicata is particularly affected by the phenomenon of abandonment of agricultural soils with the consequent risk of erosion and land degradation. An estimate of the abandoned land on a municipal and regional scale is of fundamental importance to identify the characterization of the surface of soils, its variations over time and the identification of the area's most susceptible to decay. A useful tool for studying the response of vegetation to changes climate is the analysis of historical series deriving from satellite images. In many studies [10, 19, 24] is done use of multi-time series to highlight positive and/or negative anomalies of the vegetation. In this work, the analyzes conducted concern the application of techniques of remote sensing and spatial analysis for estimating historical changes in agricultural land use.

This work was based on the integration of remote sensing techniques and Information Systems Geographical (GIS) with FoSS (Free and Open-Source Software) technologies and open datasets e freely available. The use of new technologies and the integration of the different datasets of territorial data, offer the opportunity to study and monitor the evolution of the territory a large temporal and spatial scale. The increasing efficiency of analysis techniques and the interoperability of the various data, represent a strength for the planner in terms of definition of plans and strategies consistent with real needs and environmental problems [15, 18, 22].

2 Material and Methods

2.1 Dataset and Instruments

The reference satellite data is Landsat, used for the calculation of the series historical data of NDVI (Normalized Difference Vegetation Index), which can be downloaded for free (after registration) from the site [5]. Landsat is a constellation of remote sensing satellites observing the Earth, represent a basic point for the historical analysis of phenomena terrestrial. The Landsat database has remotely sensed images from 1972 to present, one maximum spatial resolution of 30 m and up to 11 spectral bands.

The land cover classification has been based on two open datasets usable. The first concerns the Corinne Land Cover 2018 (CLC) provided by the Copernicus program through the Land Monitoring Service [12]. The second is the 2013 Nature Charter in scale 1:50.000 in format freely available from the ISPRA website [14].

2.2 Study Area

The study area concerns a territorial context of the Basilicata Region particularly vulnerable to the phenomenon due to the combination of anthropogenic and natural factors. The analyzes and processing were performed in an area of approximately 1550 km^2 within the Basilicata Region (Fig. 1), comprising the territory of 17 municipalities.

Analyzing the Corine Land Cover II level 2018 [corinne] land cover map with respect to the overall study area (Table 1 and Fig. 2), it can be seen that the area is mainly occupied by agricultural areas of different type. In fact, considering the arable land, the heterogeneous agricultural areas, the permanent crops (vineyards, olive groves, orchards and wood arboriculture) and stable meadows, agricultural activity is of little interest more than 80% of the entire study area. Instead, the natural areas (wooded, shrub and grassland areas) they occupy almost 18%. The study area can ideally be divided into two areas: the west part, in correspondence with the areas with a more complex and diversified morphology, it is the most heterogeneous from a land cover point of view.

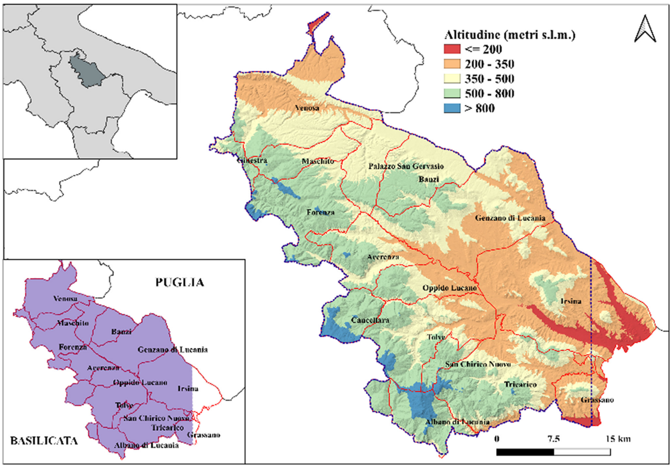

Fig. 1. Overall framing of the study area.

The remaining part, however, in the light of different morphological and geological characteristics, is represented almost exclusively by arable land and natural areas are linked to a few areas and to the impluvium areas.

3 Discussion and Results

The aim of this work is to evaluate and identify the areas subject to the phenomenon of crop abandonment and/or agricultural transition in the period 1990–2020. A first step in identifying areas subject to agricultural transition and/or crop abandonment involved the use of the normalized difference vegetation index (NDVI). NDVI is an indicator that provides crop health status based on leaves reflectance [2, 3].

This type of index is known as the most accurate indicator of ground-level biomass, as it reflects green density and photosynthetic activity [16, 17]. The NDVI vegetation index takes into account the ratio of the reflectance of the leaves to various wavelength and provides us with the health of the crop. The higher the index, the more the crop it is in optimal state. Values can be around in a range from -1 to $+1$ [4] (Eq. 1)

$$\text{NDVI} = \frac{NIR - RED}{NIR + RED} \tag{1}$$

The NDVI index has been extensively employed in multi-temporal approaches [2, 16, 23] because a single image of the date it is not always sufficient to differentiate crops on the basis of their spectral signatures.

The methodology herein applied, involved the use of LANDSAT 4/5 TM and LANDSAT 8 OLI available from 1990 to 2020 (1990, 1992, 1993, 1994, 1999, 2000, 2001, 2004, 2005, 2009, 2011, 2014, 2017, 2019, 2020). To create a realistic phenological curve, it has been assumed that arable crops have an annual cyclicality, where we find a maximum of NDVI values in the spring periods (March and April) and a minimum in

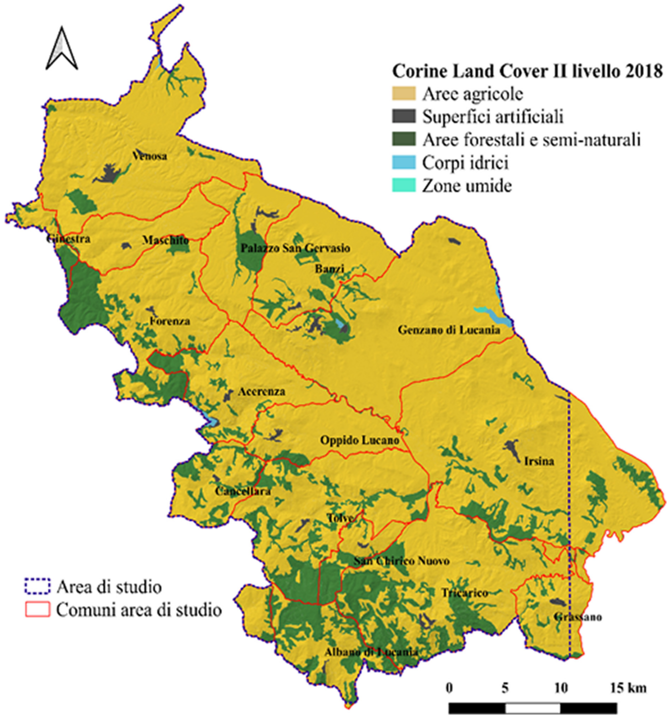

Fig. 2. Land cover map based on Corine Land Cover II level 2018 [12]

Table 1. Land cover based on Corine Land Cover I Level expressed in hectares (ha) and percentage (%) compared to the overall study area [12].

CLC 2018	Hectares	Km^2	%
Agricultural areas	126618.57	1266.18	81.45
Artificial areas	1244.04	12.44	0.80
Forest and semi-natural areas	27140.09	271.40	17.46
Water	377.29	377	0.24
Wetlands	78.99	0.79	0.05

the autumn months (October and November). In the absence of snow, the Earth's surface NDVI rarely drops to zero, as woody vegetation and soil maintain positive NDVI throughout the year. The negative and zero values are typically caused by cloud contamination, by bodies water or missing data. After calculating the NDVI difference for each year (spring - autumn), the next step was to discriminate the images related to each single year, through change detection analysis, the values of the value of the difference of NDVI of probable arable land areas (equal to NDVI values greater than 0.5) from all other values. A binary raster was thus obtained, by conventionally assigning the value 1 to the pixels of the areas probably cultivated with arable land and 0 to all the other areas.

Subsequently, through raster and vector analysis operations, we proceeded to analyze the historical series of the results obtained, quantifying in terms of km 2 the areas that do not have underwent no change in the use of agricultural land (areas always cultivated with arable land and areas not cultivated with arable land) and, above all, those that present an agricultural transition, switching from arable farming to another type of agricultural land use and/or abandonment.

The objective of this type of analysis was to be able to identify the areas that in the period analyzed have undergone a probable change in agricultural land use and/or abandonment.

The results obtained were subsequently crossed with the classes of the Nature Charter (2013) divided into agricultural areas (Fig. 17) and non-agricultural areas (Fig. 18). The data obtained from the overlay of the maps of the agricultural transition areas, divided in 3 decades, with the CNAT they made it possible to identify which classes are farms discriminated by CNAT that have been subject to change of use of agricultural land and/or abandonment.

From the preliminary investigation based on the values of the delta NDVI (dNDVI) calculated from 1990 to 2020, and from the subsequent change detection analysis on the time series it emerged that since 1990 to date the areas that have never been cultivated with arable land amount to approximately 595 km^2 while those that have undergone a possible change in land use and/or abandonment they amount to approximately 430 km^2 as can be seen from the figure (Fig. 3).

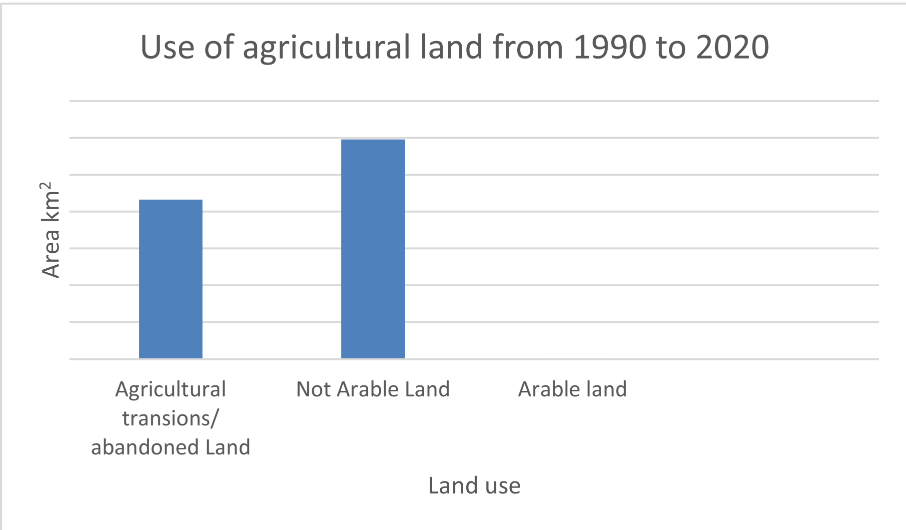

Fig. 3. Agricultural land use in km^2 resulting from the history analysis of the NDVI series.

The areas indicated as "Agricultural Transitions" indicate areas that during the thirty years 1990–2020 have undergone agricultural abandonment and/or change in land use passing from cultivation to arable land to another type of cultivation.

The Fig. 4 summarizes year by year the amount in km^2 of these areas in the years analyzed. It is clear that the years in which there has been a greater transition of agricultural land use and/or abandonment are those relating to the second and third decade.

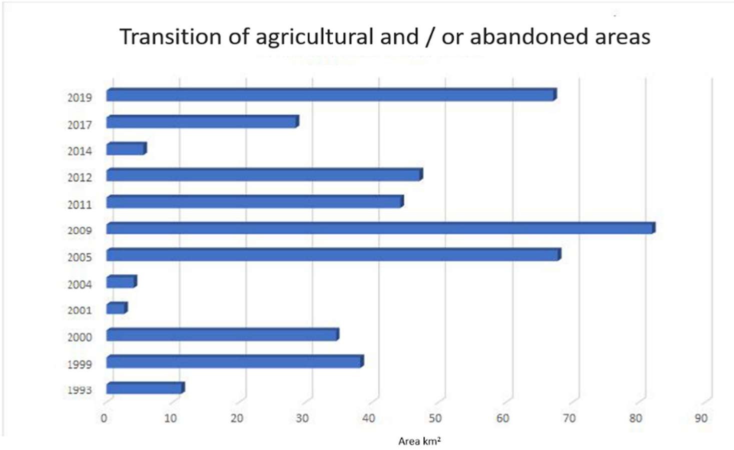

Fig. 4. Diagram in km^2 of the transition e/o abandoned area in the period 1990–2020.

It is more difficult to discriminate and evaluate abandonment from 2010 to today, as these areas may be subject to vegetative rest and/or crop rotation, and therefore need of further evaluation analyzes.

4 Conclusions

The entire procedure was carried out with QGIS e related plugins. In this work, the tools used are all open source and analytics spatial studies carried out concerned the simultaneous use of different types of free of data charge. This allows to adopt the same techniques in other territorial contexts. Landsat satellite images proved to be a particularly suitable tool for the purposes of this study provide similar information on land cover as they ensure coverage continuous and global even very distant in the past (when, very often, they represent the only source of information available).

The obtained NDVI time series data dataset provide high quality data for the mapping of the phenomenon of abandonment of arable land.

Considering the need to investigate these areas more in depth, it was carried out a study that can provide guidance for the development of an identification method of any abandoned agricultural land on a large spatial scale and managing to discriminate age of any abandonment and/or agricultural transition.

The abandonment of agricultural land, therefore, is one of the most important manifestations of change of use of cultivated land, and it is a complex phenomenon that requires a multidisciplinary approach to study its causes and consequences. Agricultural land they are typically abandoned due to a combination of economic aspects and factors natural that cause the area to rest for long periods of time.

The abandonment of agricultural land has both positive and negative effects on the environment depending on many factors such as location, frequency, subsequent management, geographical environment surrounding, and hydrological conditions of abandoned agricultural land.

Future improvements of this method will include the use of new algorithms for improve the accuracy of the identification of agricultural transition and/ or abandoned area, to distinguish these areas from others.

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