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Evolution of Soil Consumption in the Municipality of Melfi (Southern Italy) in Relation to Renewable Energy

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Abstract. Soil consumption represent an important indicator of soil management, in last few years the European States have been promoted the use and installation of renewable energy sources, with a consequent soil consumption increase. The aim of this work is to implement a procedure that analyzes the change detection of the soil consumption and discriminate those related to soil consumption due to installation of renewable energy sources from that due to built-up areas. The select test site is the Municipality of Melfi (Southern Italy) because is highly significant because is characterized by fragmented and various environments. The increase of urbanization is due to the growth of built-up areas and the exponential development of renewable sources installation. The work herein presented concerns an application study on these processes with the images of Sentinel-2 satellite. In order to produce a synthetic map of soil consumption, the Sentinel-2 images were classified using a supervised classification. A first map of soil consumption was obtained divided the area characterized by urbanization from the area with the presence of the renewable energy sources. Eolic class have been subdivided and reclassified, divided the relevant street from the turbine pad. Eolic class have been reclassified discriminate the relevant street from the turbine pad and subdivided into other subclasses referred to the power wind turbines, in order to quantify the soil consumption related to each one. All processes have been processes developed integrating Remote Sensing and Geographic Information System (GIS), using open source software.

Keywords: Soil consumption · Renewable energy · Open source software

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1 Introduction

Soil consumption is a phenomenon associated with the loss of soil defined as a change from a non-artificial cover (soil not consumed) to an artificial ground cover (soil consumed). Land cover is defined as the biophysical coverage of the earth's surface, including artificial surfaces, agricultural areas, woods and forests, semi-natural areas, wetlands, bodies water, as defined by Directive 2007/2/CE.

In Italy the SNPA (National System of Environmental Protection) monitors soil consumption phenomenon and ISPRA (Superior Institute for the Protection and Environmental Research) every year elaborates a study of the state of art of the phenomenon. In Italy soil consumption continues to growth, though making an important slowdown in the last one years, probably due to the economic condition. Between 2016 and 2017 the new artificial roofs covered approximately 5400 hectares of territory, i.e. on average just over 14 hectares per day, about 2 m^2 of soil irreversibly lost every second. In absolute terms in Italy there are more than 23000 km^2 ($\sim$7.65% of national territory) of soil lost. After having touched even the 8 m^2 at the second of the years 2000 and the slowdown started in 2008–2013 (between 6 and 7 m^2 per second), soil consumption is consolidated over the past three years, with reduced speed of soil consumption. There is always increased environmental sensitivity to problems of soil conservation and its functionality [9].

Soil consumption represents an important indicator of soil management and policies in reference with settlements processes and policies to protect and enhance the natural areas. Artificial land use trends could represent an effective indicator of the settlement process quality and could also provide information about the efficacy of protection and exploitation policies in natural and rural areas. Urban transformation has changed the concept of a city based on a center and suburbs surrounding it, with the space outside the urban area mostly characterized by rural landscapes [11]. The migration of the population from the countryside to the city involves an increasing demand of new buildings with consequent soil consumption. Moreover, in many territorial contexts, such as Basilicata, the phenomenon of urban sprawl is strongly present. The risk is that the application of urbanization policies without rules in the countryside, produce waterproofing of territory, wears out soils and distort landscapes [8]. Costs of urbanization grow, making increasingly difficult to sustain investment for public transport sector, construction and maintenance of road infrastructure and public services (public lighting, garbage collection, etc.). Other criticisms linked to urban sprawl are aesthetic pollution, noise and air pollution, environmental impact, and soil consumption. Urban sprawl and soil consumption generates a highly fragmented agricultural and natural landscape [7]. This phenomenon produces natural islands, defined by the boundaries of new urbanized areas, which are too small to accommodate the life of certain animal species; consequently soil consumption has also a negative impact on biodiversity [10].

In recent years the urban sprawl phenomenon is joined by an ever increasing consumption of land linked to renewable energy, which has so far been neglected.

In the last few years, in line with the European policies [1–3], which have targeted the increase of energy production from renewable sources in 2020, the European States have promoted and encouraged the use and installation of photovoltaic panels and wind turbines, with a consequent increase of soil consumption by these. The installation of renewable energy sources from environmental sustainability point of view cooperate to contributes to the decrease in the use of fossil energy sources, but introduce a new classes of soil consumption until now ignored, in disagreement with the goal of European Commission [4] that the expect to zeroing by 2050 the soil consumption.

The work herein presented concerns an application study on the process of soil consumption, carried out remote sensed information from Sentinel 2 satellite by Copernicus Mission. Copernicus is a European Mission with the aim to provide accurate information and plays an important role in data management for natural phenomenon monitoring and management. The mission is based on a series of 6 types of satellites, called Sentinels, specialized in precise applications. In particular Sentinel 2 is characterized by a multispectral sensor with mid high spatial and temporal resolution.

In order to produce a synthetic map of soil consumption, Sentinel 2 images were classified used an automatic classifier Support Vector Machine (SVM) based on machine learning theory [12]. All process steps have been developed integrating Geographical Information System and Remote Sensing, and adopting free and open source software QGIS (see: http://qgis.osgeo.org).

2 Material and Methods

2.1 Data

Multi-spectral and multi-temporal satellite data with medium and high spatial resolution are very appropriate in soil consumption phenomenon evaluation. Data used in present work is a satellite image Sentinel 2 (source: https://scihub.copernicus.eu/dhus/#/home) on 13 april 2018. Sentinel 2 satellite acquired images with 13 bands, from infrared to thermal infrared wavelengths (Table 1), characterized by a mid high spatial and temporal resolution. Sentinel 2 data have been processed with QGIS software.

Table 1. Sentinel 2 satellite feautures.

Satellite	Bands	Range wavelength	Resolution (m)
Sentinel 2	Band 1 – Coastal aereosol	0.443	60
	Band 2 – Blue	0.490	10
	Band 3 – Green	0.560	10
	Band 4 – Red	0.665	10
	Band 5 – Vegetation Red Edge	0.705	20
	Band 6 – Vegetation Red Edge	0.740	20
	Band 7 – Vegetation Red Edge	0.783	20
	Band 8 – NIR	0.842	10
	Band 8a –Vegetation Red Edge	0.865	20
	Band 9 – Water vapour	0.945	60
	Band 10 – SWIR – Cirrus	1.375	60
	Band 11 – SWIR	1.610	20
	Band 12 – SWIR	2.190	20

2.2 Study Area

The study area is located in Basilicata Region, in the Municipality of Melfi (see Fig. 1), the third populous Municipality of the Region, with its 17878 habitants and $205.12\ \text{km}^2$ of extention. The settlement of the FCA Sata industrial center in the 1990s contributed to increase the population with consequent urban expansion linked to the construction of new buildings. Starting in the 2000s, the promotion of the installation of renewable energy sources (wind and photovoltaic) contributed to a substantial increase in soil consumption.

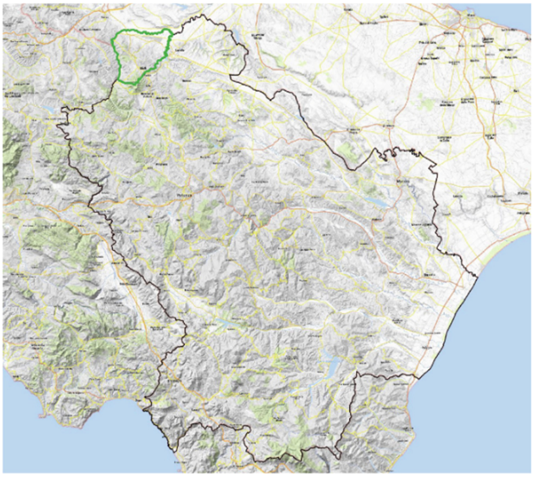

Fig. 1. Study area (Basilicata Region and Melfi)

2.3 Methodologies

The methodology herein developed has been implemented in order to carry out an analysis to quantify the soil consumption due to renewable energy using Sentinel 2. Nowdays, satellite time series and ancillary data currently available, even free of charge (from national and international spatial agencies) and offer a great potential for a quantitative assessment of soil consumption. SVM models and algorithms are based on supervised learning approaches, also called machine learning, that are considered to be very powerful and widely used within both industry and academia [5]. During the last ten years, SVMs have been showing a great potential for data classification also in satellite data processing [6] and for these reasons has been adopted in this work.

The methodology developed to obtain a detailed map of soil consumption due to renewable energy sources, regard the use of SVM classifier, which is effective in recognizing and discriminating the spectral signatures of vegetation, water, buildings, roads, through remote sensing images. The used image of Sentinel 2 (level 2A[1])

[1] Level 2 https://earth.esa.int/web/sentinel/user-guides/sentinel-2-msi/product-types/level-2a.

acquired the 13 April 2018 was processed at 10 m of spatial resolution with the following bands 2, 3, 4, 5, 6, 7, 8, 8A, 11, 12. Following the SNPA reference, the soil consumption classes used to define the training areas are divided into two macro classes, ground consumed (level 1) and soil and not consumed (level 2). The first one can in turn be divided into reversible consumed soil and permanent consumed soil.

Many classes are not present in the Melfi area. Particular emphasis was placed on the identification and classification of renewable energies to quantify consumption of soil through the period 2010, 2014, 2018. For this reason, a new class of consumed soil coded with the value 119 absent in the reference SNPA (see Table 2) was added to the above legend.

Table 2. Legend of classification

Code	Description	Code	Description
1	Soil consumed	118	Dump
2	Soil not consumed	119	Eolic pad
11	Soil permanent consumed	121	Dirt roads
12	Soil reversible consumed	122	Dirt areas and construction sites
111	Buildings	123	Mining areas
112	Streets (asphalt)	124	Quarry
113	Railway	125	Photovoltaic field
114	Airport	126	Other artificial covered areas
115	Port	201	Artificial water buildings
116	Other areas sealed unbuilt	202	Roundabouts and road junctions
117	Permanent greenhouses	203	Unpaved greenhouses

The supervised classification process is an iterative process that ends with the choice of the output map after performing a photointerpretation check with orthophotos and data of the same period and with the evaluation of the accuracy matrix. At this point, considering that the map of soil consumption called bu_2017_utm33 N (SNPA) has a spatial detail that is not very high in some Italian territorial contexts, such as that of Melfi, some information layers of the Geo-Topographic Database have been exploited) of Basilicata Region - DBGT (source: https://rsdi.regione.basilicata.it/) (see Table 3).

Using Map Algebra, the 10-m rasterized information layers, or subsets thereof, were inserted on the previous classification map, replacing the corresponding pixels. This process was applied only on irreversible consumed soils since the DBGT update year is 2014.

Table 3. Legend of equivalence between DBGT and SNPA code.

DBGT Classes	Type	SNPA code
Area attrezzata suolo	Not further qualified humanised area	116,122
el_stradale_grafo	Paved/Unpaved	112,121
Area a serv stradale	Roadside service area	116
Attrezzatura sportive	Sports fields, stairs, outdoor pool	12,122,111
Edifici_is	Built-up	111
Edifici_min_is	Built-up	111
El_copertura		11
Rete_ferroviaria_grafo		113
Manufatto_industriale	Silos container, tank, greenhouses	12,11,0203

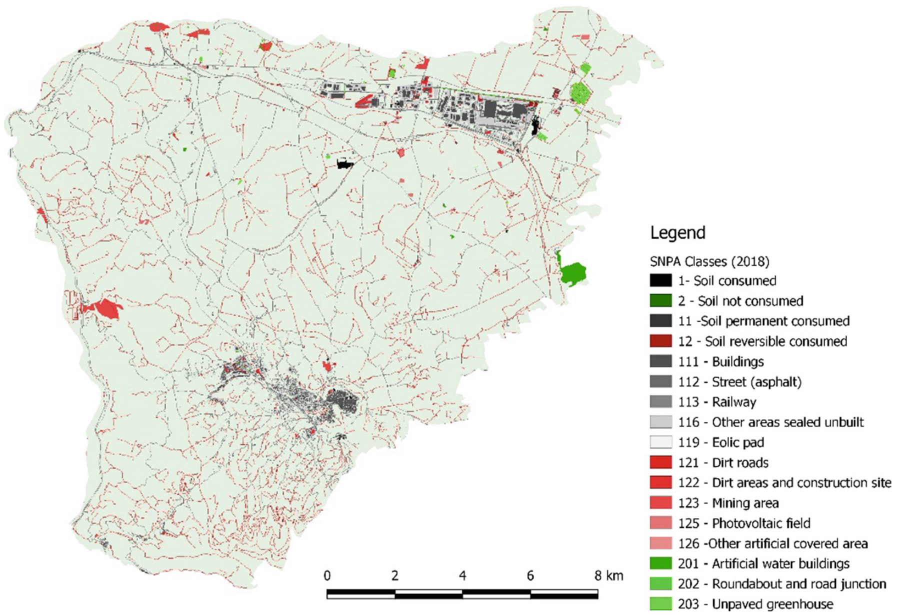

Fig. 2. Classification map

2.4 Results

The map thus obtained has indications on all the classes present in the Melfi area (see Fig. 2). Starting from this we proceeded to analyze in detail the pixels that can be associated with renewable energies regard the years 2010, 2014 and 2018.

Figure 3 represents a zoom of a small area (in yellow rectangle) characterized by the presence of installation of renewable energy (eolic installations and photovoltaic panels), in particular is evident the growth of soil consumption due to the expansion of wind turbines (blue circles) in the area. While is also evident the decrease of photovoltaic panel installation (red rectangular area).

Eolic class have been subdivided and reclassified, divided the relevant street from the wind turbine pad. In according with the goal of European Commission, that the expect to zeroing by 2050 the soil consumption, Eolic class have been subdivided into other subclasses referred to the power of wind turbines, in order to quantify the soil consumption related to each one. The pixels relative to the soil consumed by the wind turbines have been classified in the first category in the case of area pertaining to the single turbine (pitch) and as second category in the case of service street.

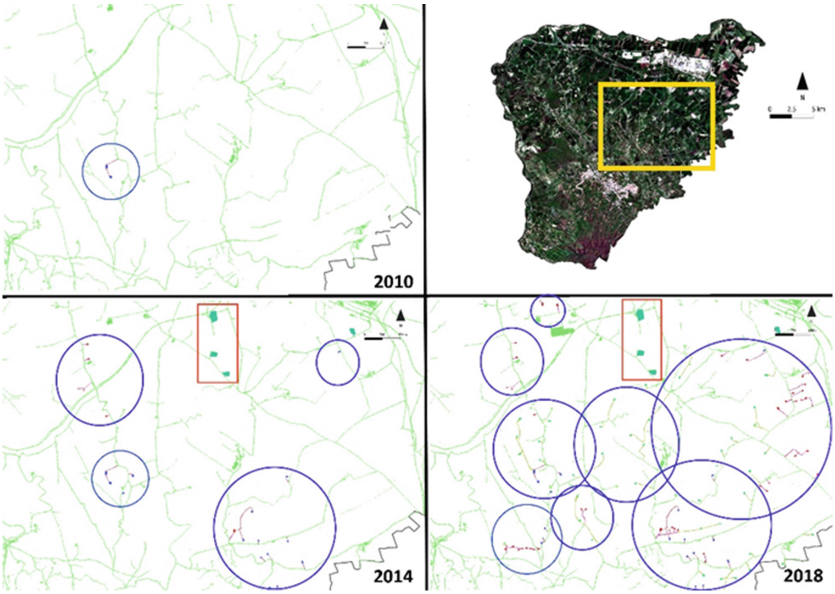

Fig. 3. Variation of eolic installation and photovoltaic panels from 2010 to 2018 (Color figure online)

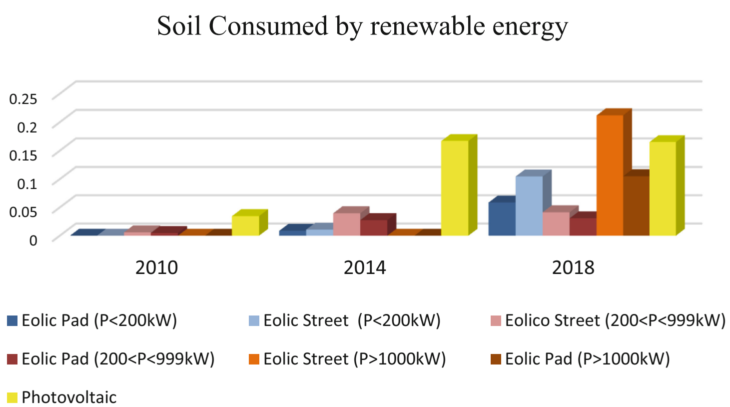

Fig. 4. Soil consumption due to renewable energy (2010–2018).

Figure 4 summarized and quantify the percentage and the area (km^2) of soil consumption in different classes: urbanization, eolic and photovoltaic sources.

Analyzed the soil consumption due to urban expantion and renewable energy is evident how in the first case the trend is constantly growing, while in the latter trend shows a strongly increment starting from 2014 caused by the development of small and large eolic stations because the economic policies have been promoted the installation of wind turbines.

3 Conclusion

This work shows that Melfi has an important and worrying soil consumption phenomenon in relation with the habitants. Infact soil consumption related to the installation of eolic turbines is more than the real energy requirement.

As a future development of this work is to monitor the phenomenon of soil consumption linked to renewable energy by expanding this type of analysis to other areas of the Region. The soil is a common good and is a finite good to be protected and monitored, it is desirable that local administrations implement intervention policies to limit the proliferation of the phenomenon.

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