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Solar plants, environmental degradation and local socioeconomic contexts: A case study in a Mediterranean country

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ABSTRACT

Photovoltaic plants developed on rural land are becoming a common infrastructure in the Mediterranean region and may contribute, at least indirectly, to various forms of environmental degradation including landscape deterioration, land take, soil degradation and loss in traditional cropland and biodiversity. Our study illustrates a procedure estimating (i) the extension of ground-mounted photovoltaic fields at the municipal scale in Italy and (ii) inferring the socioeconomic profile of the Italian municipalities experiencing different expansion rates of ground-mounted photovoltaic fields over the last years (2007-2014). The procedure was based on diachronic information derived from official data sources integrated into a geographical decision support system. Our results indicate that the surface area of ground-mounted photovoltaic fields into rural land grew continuously in Italy between 2007 and 2014 with positive and increasing growth rates observed during 2007-2011 and positive but slightly decreasing growth rates over 2012-2014, as a result of market saturation and policies containing the diffusion of solar plants on greenfields. We found important differences in the density of ground-mounted solar plants between northern and southern Italian municipalities. We identified accessible rural municipalities in southern Italy with intermediate population density and large availability of non-urban land as the most exposed to the diffusion of solar plants on greenfields in the last decade. Our approach is a promising tool to estimate changes in the use of land driven by the expansion of photovoltaic fields into rural land.

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1. Introduction

Since photovoltaic energy contributes to reduce pollutant emissions, the spread of solar energy plants has been widely supported as a response to global climate change (Bergesen et al., 2014) in regions with optimal conditions for photovoltaic fields due to a large and continuous solar irradiation along the year (Espinosa et al., 2014; Gunderson et al., 2015). Incorporating solar plants on existing grazing or agricultural land provides an additional income stream to land owners and promotes diversification of revenue for years when agricultural productivity is low or for crops that are relatively low value. Similar benefits have been demonstrated with wind developments on agricultural lands (Holmes and Papay, 2011). Based on these premises, ground-mounted photovoltaic fields are becoming a common infrastructure in the Mediterranean region and may contribute, at least indirectly, to various forms of environmental degradation including landscape deterioration, land take, soil degradation and loss in traditional cropland and biodiversity. While energy, economic and environmental impacts of photovoltaic plants have been generally seen as positive, the large scale use has a negative impact on rural landscapes (Carullo et al., 2013; Naspetti et al., 2016). Specific impacts on soils and rural communities (e.g. in terms of permanent or temporary soil sealing, total or partial soil shading, degradation of land, habitat fragmentation and loss of traditional agricultural practices) have been identified and require further investigation (Beylot et al., 2014; Hernandez et al., 2014a; Koldrack et al., 2014).

Solar power installations can be either temporary or permanent, and can be mounted at a variable distance from the ground, causing a variable impact on soils and on the overall land quality. Crops that are shade tolerant and low height may become suitable for production in an area with photovoltaic fields (Harinarayana and Sri Venkata Vasavi, 2014). At the same time, shade from solar infrastructure generally reduces crop productivity. Moreover, agricultural activities involving large machinery may have limited options for co-location with solar infrastructure (Beckman and Xiarchos, 2013). Soil shading by extensive photovoltaic fields can also reduce its infiltration capacity, altering the surface hydrological balance and determining, in some cases, an increased runoff possibly enhancing soil erosion processes. Previous studies have proposed strategies to reduce the environmental impact of photovoltaic fields (e.g. Graebig et al., 2010), indicating some possible solutions including a more complete integration into buildings and infrastructures - keeping ground-mounted installations to a minimum (Holmes and Papay, 2011). It has been also proposed to restrict the installation of ground-mounted systems on low-quality land, including brownfield sites or in the close vicinity of highways and railway lines (Beck et al., 2012). In both cases, spatially-detailed diachronic information on the expansion of solar plants into rural areas is required to support fine-tuned strategies aimed at reducing the environmental impacts of photovoltaic plants.

However, local-scale information on the spatial distribution of ground-mounted photovoltaic fields and their possible impact on rural landscapes are generally scarce, fragmented or poorly comparable among regions or countries. Occupied surfaces are one of the critical variables regarding the environmental performances of large-scale ground-mounted photovoltaic installations. The occupied surface mainly determines the impact of large-scale installations on land quality (Costantini and Lorenzetti, 2013).

A rapid expansion in solar generation capacity has been recorded in Europe since 2005: solar-based electricity generation increased more than 10 times over the period 2005-2010 (Eurostat, 2012). According the recent report "Energy, transport and environment indicators" elaborated by Eurostat, the gross inland consumption deriving from solar photovoltaic source in the 28 European Union countries increased from 126 to 7939 thousand TOE (tonnes of oil equivalent) between 2005 and 2014. In 2012, Italy was the second country in the world for installed capacity of photovoltaic plants (INEA, 2013). Photovoltaic plants have developed recently in Italian rural areas, becoming highly attractive due to high earnings compared to traditional agriculture (Marcheggiani et al., 2013). An increased surface area of high-quality cropland was converted to solar power plants in the last decade (GSE, 2012). This phenomenon has progressively led to a significant reduction of the utilized agricultural area in some rural districts with traditional agro-forest environments, possibly determining loss in food production and the consequent alteration of the landscape value (Costantini and Lorenzetti, 2013; Kim et al., 2013; Tani et al., 2014).

A debate on the environmental impact of photovoltaic fields in terms of land occupation has progressively involved the public opinion in the very last years. Chiabrando et al. (2009) have tried to clarify the territorial impacts of the ground-mounted photovoltaic systems in Italy. Agricultural areas, destined to ground-mounted photovoltaic plants, have been estimated at 134 km^2, corresponding to 0.1% of Italian agricultural surface area (Squatrito et al., 2014). National institutions have recently placed some limits to the uncontrolled development of ground-mounted photovoltaic plants on rural land. National incentives granted to photovoltaic systems installed on agricultural land have been removed. The Italian Ministry of the Environment has proposed initiatives to manage and plan the installation of photovoltaic fields on rural land and to contain landscape and soil degradation, land take and loss of traditional cropland (INEA, 2013). A substantial reduction in the price for energy has been also observed in the last years; as a consequence, market has experienced a setback of new installations from over 1 GW in 2013 to about 385 MW in 2014, below the estimates of the beginning of 2014 (GSE, 2012).

Effective and reliable indicators based on the spatial distribution of solar plants are required to assess the environmental vulnerability of different local contexts to the expansion of ground-mounted photovoltaic fields (Schiffer, 2015). The present study proposes an indicator-based approach that assesses the expansion of photovoltaic plants installed on rural land in Italy, identifying at the same time the socioeconomic context of local communities experiencing various levels of photovoltaic plant density. Rural contexts were described considering topography, land-use and demography indicators. Our approach can be extended to other European countries, being possibly integrated in a comprehensive strategy harmonizing sustainable development and landscape conservation of traditional agricultural areas.

2. Methodology

2.1. Study area

The area investigated in this study extends the whole of Italy (301.330 km^2) and is administered by 20 regions and 8092 municipalities. Although the Italian coastline (including islands) extends nearly 7400 km, most of the continental land is hilly or mountainous. Topography, latitudinal range and proximity to the sea coast have had a strong influence on local climate, soil, vegetation and landscape (Salvati et al., 2011).

2.2. Data and variables

Elementary data of photovoltaic plants installed in Italy between January 2005 and December 2014 were derived from the Atlasole database provided by the Italian Energy Services Manager (GSE) by municipality and plant power. For each administrative region of Italy, the surface area of rural land occupied by photovoltaic fields was provided by GSE (2012). Plants were classified by installation support (e.g. ground, building or greenhouse roof, infrastructures). The total surface area of photovoltaic fields (m^2) was provided separately for each region, together with the number of plants and their total power (MW). The percentage of ground-mounted plants in the total number of installed photovoltaic plants was finally reported. On average, ground-mounted plants in Italy covered a surface area of 1.7 hectares per MW (GSE,