



# Energy Landscape Fragmentation: Basilicata Region (Italy) Study Case

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**Abstract.** All programs and policies that stimulated and continue to promote the construction of renewable energy production plants, pose a growing challenge to regional planners and administrators: how to manage the transformation of the landscape to find an effective sustainable arrangement for renewable energy technologies? In fact, while RES plants contribute to solve the global problem of climate change and to reduce emissions, at the local level they imply significant impacts on several components such as: land use, land take, diminishing aesthetic values, deterioration of habitat quality. The intensity of these effects depends on the location of the plants, the distance between the plants, the extension of the ancillary infrastructures and the technical characteristics. It is questionable whether the intensity of the negative impacts at the local level is more related to the technical characteristics of each installations or their dislocation on the territory. The present work is part of this debate, discussing fragmentation index resulted from the assessment of the current regional settlement structure of RES plants.

In facts, the case study concerns the territory of Basilicata region (Italy), which over the last years has seen an abundant increase in installation of renewable energy plants. The evolution of the regional energy system has been strongly influenced both by incentive policies and by (weak) urban and territorial planning policies. This approach could be a valuable contribution both in identifying a fragmentation threshold beyond which the expected negative impacts outweigh the benefits, and in providing useful procedure for managing future installations.

**Keywords:** RES · Fragmentation · Urban sprinkling · Urban sprawl

## 1 Introduction

The installation and operation of Renewable Energy Systems (RES) represents a significant land transformation. It produce effects on several territorial matrixes: land use change, land take, fragmentation of natural habitats with elimination of existing vegetation, visual impact on landscape components, change of micro-climate, glare from direct sunlight reflection (for photovoltaic fields) [1–5].

A process by which ecosystems, habitats of vegetation and animal populations are divided into smaller and more isolated units (fragments) is defined as fragmentation. The main causes of habitat fragmentation are infrastructures, the growth of urban settlements and the development of rural settlements far from the existing ones [6–8] and, from the last decade also RES installations.

Renewable Energy Sources are in continuous evolution at world level [9]. If the incentive to exploit renewable sources is known to be one of the characteristics of the policy of conservation of the territory, including that of protected areas, at the same time the concerns of local communities and governments about the environmental, territorial and landscape impacts of this technology are rapidly increasing.

The case study regards the Basilicata region in south of Italy where the Regional Environmental Energy Plan (PIEAR) in force since 2010 encouraged the electricity production from renewable sources. Indeed according to energy services manager report, since 2000, there has been a very substantial development of wind farms in Italy. At the end of 2017, 5579 wind farms had been installed, most of which (93%) were small (with a capacity of less than 1 MW). Southern Italy has the highest number of wind farms installed at the end of 2017, Basilicata is the region with the highest percentage of farms in the country 25.1%, followed by Puglia 21.0%.

Since the expected impacts certainly depend on the location of RES plants, it is useful to investigate the energy landscape at regional level through sprinkling index (SPX) that has already returned good results in describing the settlement fragmentation [10]. The sprinkling phenomenon can be defined as, “a small quantity distributed in drops or scattered particles” [11–13].

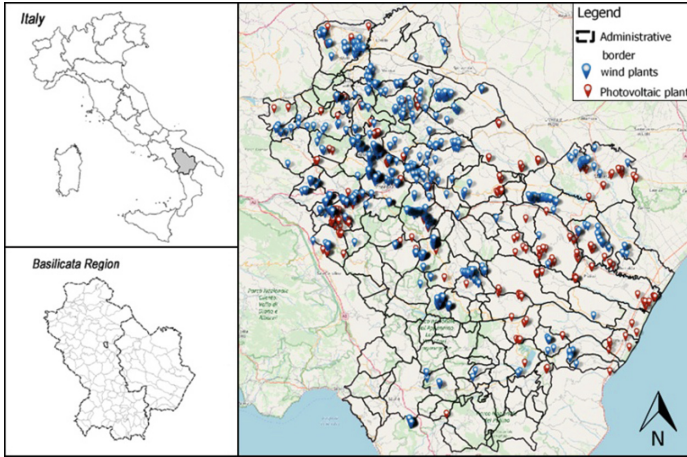
SPX index, based on the extent and distance between RES plant aggregates, has been calculated for three time intervals (2008–2014, 2014–2017 and 2017–2018) dividing the regional territory with a grid of 1 km<sup>2</sup>. The classification into six degrees of fragmentation has allowed us to see the evolution of the SPX index for each cell. In the majority of cases, the results show that the new installations took place following the sprinkling phenomenon.

## 2 Material and Methods

### 2.1 Study Area

Basilicata region in the south of Italy (Fig. 1), covers about 10.000 km<sup>2</sup> and has a population of 567.000 inhabitants (ISTAT [14], 2018). It is a mostly rural environment characterized by very low population and building density.

Despite this, according to ISPRA report 2018 [15], the percentage of land taken in Basilicata region was around 3.4%. Land take in Basilicata is due to the expansion of urban areas, the transformation of rural areas, and the use of agricultural land for renewable energy production through the construction of ground-mounted photovoltaic systems and numerous installation of wind turbine. Indeed, since 2010, a large part of the territory has been affected by the installation of RES plants. At the end of 2017, the number of RES plants was 2122, including wind turbines and photovoltaic fields with a total power output of about 1000 MW.



**Fig. 1.** Basilicata region study area.

## 2.2 Data Source and Processing

The basic geographical information structure is RES installations database derived from the combination of three official information sources: (1) TRC (Technical Regional Cartography produced by Basilicata Region and distributed through OGC standards in RSDI [16]), (2) GSE (National Energy Services Manager [17]) and (3) digitalization of plants from aerial photogrammetric survey at different dates: Ortho-photo and Google Earth images.

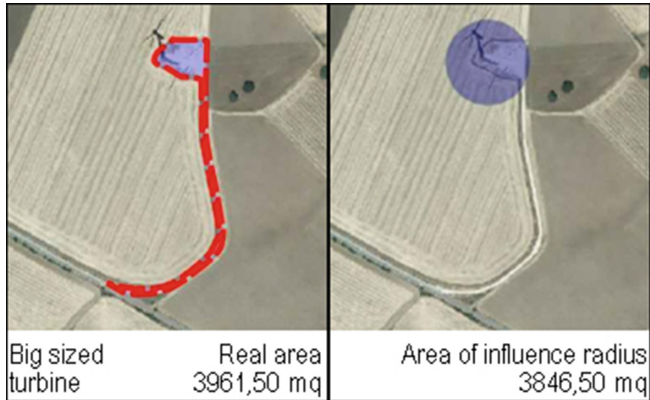
Selected data sources allowed to evaluate not only the spatial dimension, but also the temporal one. Three temporal phases have been identified: (i) 2010–2014, (ii) 2014–2017, (iii) 2017–2018. The RES database includes, among other information, attributes concerning the installed generation capacity [Kw] or [Mw] of individual wind turbines. Three categories of wind energy plants have been defined on the basis of installed capacity. Table 1 shows the three categories considered (micro-mini, medium sized and big sized turbines) with wind turbines number for each temporal phase. For photovoltaic fields the power output data was not available.

For the assessment of land take related to wind turbines and photovoltaic field, the area around the RES installation was considered within an influence radius proportional to the power output (Table 1).

**Table 1.** Wind turbines classification and number for every temporal phase.

Wind turbines	Power output (P) [Kw]	N <sub>2010–2014</sub> <sup>o</sup>	N <sub>2014–2017</sub> <sup>o</sup>	N <sub>2017–2018</sub> <sup>o</sup>	Influence radius [m]
Micro-mini	P < 200	165	476	1132	15
Medium	200 ≤ P < 1000	32	95	75	25
Big	P ≥ 1000	21	65	61	35
Photovoltaic fields	–	241	241	241	25

Regards wind turbines, influence radius was calculated after detailed analysis of several case studies for each category. An example is shown in Fig. 2. As regards the photovoltaic fields, a pertinence belt of 25 m from the perimeter was considered, which generally corresponds to the border area that includes structures and modules, technical rooms, access areas and circulation areas within the plant. In the absence of up-to-date land use data, this approach allows to consider compromised areas (reversible or irreversible) occupied by auxiliary structures such as roads and technical annexes.



**Fig. 2.** Big size wind turbine, comparison between real area and calculated area with the radius of influence.

Since the expected effects' (e.g. loss of habitat quality) extend over an area larger than the sum of individual stands, wind turbines were aggregated with a maximum distance of 250 m [10, 18]. It is assumed, therefore, that this surface is definitively borrowed from previous land uses.

### 2.3 Methodology

The energy landscape fragmentation was spatially calculated using the sprinkling index (SPX) [7, 19]. The study area is divided by a 1 km<sup>2</sup> grid. SPX index assumes that the most compact form of agglomeration growth is the circular one and is based on the Euclidean distance between two or more geometries within each cell. In this case, geometries are represented by photovoltaic fields and wind turbines aggregates. It is expressed by the following formula:

$$SPX = \frac{\sum \sqrt{(x_i - x^*)^2 + (y_i - y^*)^2}}{R}$$

Where  $x_i$  and  $y_i$  are the centroid coordinates of each - photovoltaic fields and wind turbines aggregates - polygon present in each grid cell of 1 km<sup>2</sup>;  $x^*$  and  $y^*$  are the

centroid coordinates of the major nucleus present in each cell.  $R$  is the radius of circular area of similar dimensions to those of the sum of the areas of the RES plants present for each cell.

SPX has a range of acceptable values from 0 to  $+\infty$ . As the index increases, the degree of fragmentation of a territory increases. The zero value can represent two situations: (i) “not fragmented” with the presence of a single aggregate with area much less than  $1 \text{ km}^2$ ; (ii) “not fragmented”, comparable to compaction phenomenon, with the presence of single aggregate with area of just  $1 \text{ km}^2$ . It is always advisable, therefore, to correlate the results of SPX index with the area occupied by the aggregate in each cell.

The SPX index produced a value for each grid cell that, through the subdivision into the six categories shown in Table 2, allowed us to identify the degree of energy landscape fragmentation. Null values of the index correspond to not urbanized cells, i.e. cells in which there is no aggregate.

**Table 2.** Fragmentation degree according to SPX index.

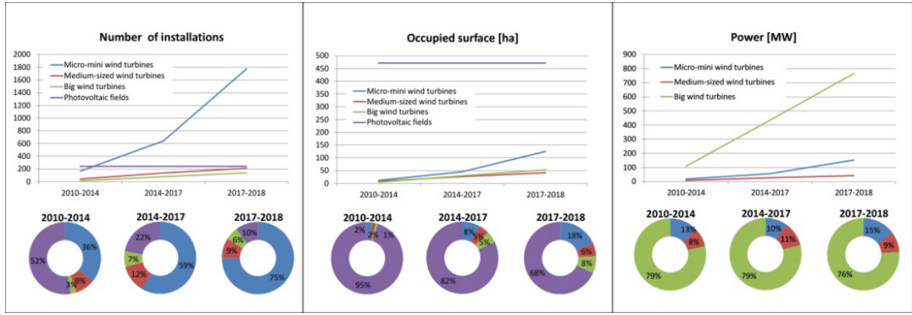
Fragmentation degree	SPX
Not urbanized	Null
Not fragmented	SPX = 0
Low fragmentation	$0 < \text{SPX} < 25$
Medium-low fragmentation	$25 \leq \text{SPX} < 50$
Medium fragmentation	$50 \leq \text{SPX} < 100$
Medium-high fragmentation	$100 \leq \text{SPX} < 200$
High fragmentation	$200 \leq \text{SPX} < 500$

### 3 Results and Discussions

The classification of wind turbines based on power production gives a clear picture of the current state of study area over the three time intervals considered. First graph in Fig. 3 shows the number of RES installations plants that took place in the time intervals analysed. Number of photovoltaic fields remains stable from the first time interval, while wind turbines are growing rapidly, especially in the micro-mini class. Indeed, between the first and the last time interval, the percentage of micro-mini turbines, on the total of RES plants, increases from 36% to 75%.

In the same way, the area occupied by the RES plants was analysed. In the second graph (Fig. 3), the radius of influence was considered as an area of encumbrance for each plant. Excluding photovoltaic fields, the micro-mini class of wind turbines has occupied, an area of 125 hectares during the last year. Regards the power [MW] (third graph in Fig. 3), the largest percentage is represented by the big wind turbine class.

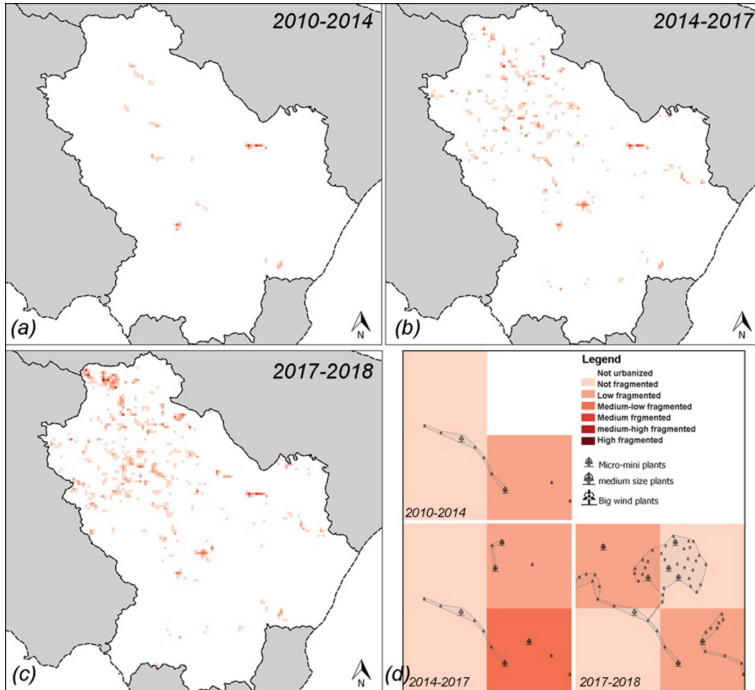
The Fig. 4 shows, in boxes *a*, *b* and *c*, SPX index distribution useful to assess energy landscape fragmentation over the time. The increase in number of cells affected by fragmentation from the first to the last interval is evident. In the box *d* is shown a



**Fig. 3.** Graphs representing the number, the area occupied [ha] and the power [MW] of RES plants in study area at three time intervals.

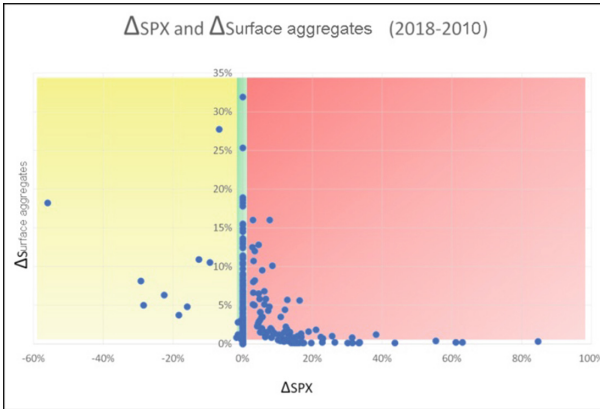
particular case of the phenomenon in which some cells vary their fragmentation degree between the first and the second interval and then return to the initial state.

Wind turbines installed far from the existing ones generate high degrees of fragmentation and therefore correspond to the sprinkling phenomenon. On the contrary, wind turbines installed near existing ones correspond to low degrees of fragmentation, i.e. to compaction phenomenon.



**Fig. 4.** Degree of energetic landscape fragmentation in boxes *a*, *b* and *c*; a detail a of phenomenon in box *d*.

To understand what was the main type of energy transformation that affected the region between the two extreme intervals (2010–2018), the percentage variation in SPX index and aggregates area were compared (Fig. 5).



**Fig. 5.** Comparison of SPX and aggregates surface variation between 2010 and 2018. (Color figure online)

The graph is divided in three colored zones: (i) yellow corresponds to cells that have been transformed following a compaction phenomenon; (ii) green corresponds to cells that have suffered variation in aggregate surface area but not in SPX value; (iii) red corresponds to cells that have been transformed following the sprinkling phenomenon. Most wind turbines have been installed away from existing ones to generate sprinkling.

## 4 Conclusions

The considerable increase in RES installations over the last decade contributes to the already high level of fragmentation caused by urban settlements [10]. Such process, occurred in a context of low settlement density, has to be considered with additional care in order to compare the affects produced on natural and ecosystemic [20–24] territorial components with those effects attributed to the traditional antropization factors (such as residential growth or road infrastructures development). In such view the Basilicata case study allowed to isolate the impact of RES settlement and, potentially, to set up standards for environmental assessment procedure of future installations.

The issue of the rapid evolution of energy scenarios is of considerable importance at the level of the whole of Basilicata, having experienced a rapid increase in a de-regulated territorial planning system. In facts, the increase in the number of wind turbines in the decade 2008–2017 occurred in the absence of the Regional Landscape

Plan and industry standards such as those for noise reduction or protection from exposure to electric, magnetic and electromagnetic fields.

Those considerations highlight the conflicts between global objectives and local values. Even if an effective balance is far to be achievable, our effort is to enhance the role of integrate planning approach [25–27] in order to distribute benefits of Low Carbon Transition policies (see also [28, 29]) without losing competitive values on which the strategies of regional sustainable development are rooted.

Future developments of this study include integrating the data obtained with the data on fragmentation caused by urban aggregates and assessing the environmental fragmentation caused by infrastructure in the region.

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