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WIND POWER AND LANDSCAPE. IDENTIFICATION AND CUANTIFICATION OF LANDSCAPES AFFECTED BY WIND POWER PLANTS IN ANDALUSÍA

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I. INTRODUCTION

According to data from the Andalusian Energy Agency (Agencia Andaluza de la Energía, 2013), the implementation of renewable energies in the Andalusian Autonomous Community raised the level of energy self supply to 13.6% in 2012, compared to 5.8% in 2006. Of this, 98.1% was renewable in origin, and renewable energies contributed 14.4% of the primary energy structure, with wind energy having the highest installed power (around 3252 MW from 144 different wind farms).

The positive connotations associated with renewable energies (they allow a reduction in high energy dependency and lower the amount of Greenhouse Gas emissions, which is one of the main vectors of action in the fight against climate change) mean that, broadly-speaking, a positive social, political and environmental view is held of these in Spain (ASIF, 2007). In addition, these energies are increasingly being understood to provide real opportunities for the promotion of endogenous and more balanced regional development (Díaz, Rodríguez and Zoido, 2010).

Despite all the positive connotations associated with these types of energy, their rapid rate of implementation, their excessive concentration and their competition with other land uses have led to numerous disputes associated with their development. These have mainly been connected with the siting of the infrastructures and their implications for the landscape, and have resulted in strong criticism of specific implementations in Spain (Frolova and Pérez, 2008).

II. OBJECTIVES

The objectives of this article consist of analyzing the landscape distribution of wind farms in Andalusia and identifying the surfaces in the region that have been subjected to

landscape changes as a result of the implementation of these infrastructures. They therefore correspond to the stipulations related to the subject set out in Art. VI of the European Landscape Convention (the need to identify landscapes and the main impacts occurring in these).

As complementary objectives, the implementation of these infrastructures in Andalusia, the degree to which they are concentrated in specific areas, and their presence in protected natural spaces will be detailed and evaluated. Finally, the utility of creating a geodatabase on the subject is broached as an instrumental objective to exploit as fully as possible the high geometric accuracy of aerial photographs and the work opportunities that a GIS environment offers (repository of geographical data, inter-operable services, spatial analysis, etc.).

III. METHODS AND SOURCES

A geodatabase of renewable energies in Andalusia was created for the analysis of the implementation and spatial distribution of renewable energy facilities. For this, spatial information about the siting of wind turbines and solar plants was photo interpreted and digitized using a series of aerial orthophotographs of the region over a time period from 1984 to 2011 that are published as Web Mapping Services (WMS) on the Andalusian Spatial Data Infrastructure geoportal.

This spatial information has been completed with information on the subject taken from the Andalusian Energy Agency, the Spanish Wind Energy Association (Asociación Empresarial Eólica) and the Spanish Photovoltaic Association (Asociación de la Industria Fotovoltaica), which characterize the plants according to their installed power rating and other information of interest (wind turbine number and model by wind farm, developer, etc.).

All this information (the basic information and the information provided by digitization) was entered into a geographical database, or geodatabase. The use of this database means that simple SQL (Structure Query Language) sentences can be constructed that are easily reusable when updating, making it possible to create virtual, dynamic and automatically updated relationships between data that enable a wide range of indicators to be generated for renewable energies.

Apart from the spatial database of renewable energies in Andalusia, the two previously existing characterizations of landscapes have been used for the area of study; the Atlas of Spanish Landscapes (Mata and Sanz (Ed.) 2004) and the Andalusian Landscape Map (Dept. of the Environment and Dept. of Public Works and Transport, 2005). These fully illustrate the wide range of landscapes in the region and have been used as the basis for delimiting the areas of analysis in the implementation of energy installations.

IV. LANDSCAPE DISTRIBUTION OF WIND FARM INSTALLATIONS IN ANDALUSIA

It can be observed that the greatest installed power in the landscape distribution of wind farm installations in Andalusia is sited in the "farmland" category (to be specific, in the "Gently undulating farmland on hills and ridges" landscape area). However, the "Coastal" category clearly stands out with respect to the number of wind turbines (with the greatest concentration of installations being in the "Coastal with shoreline mountains" area). The results show that in recent years there has been a change in the initial siting patterns for these

installations, with a move from landscapes with high levels of wind resources (the Straits of Gibraltar or medium size mountains) to other areas with specific favorable local conditions for their installation (specific places with a good combination of wind and opportunities to deliver the energy on highland plateaus, farmland and subdeserts).

This trend in distribution is most likely to continue, as technological development, with taller and more powerful wind turbines, and also the saturation of areas of greater wind potential (the Straits of Gibraltar) along with the difficulty to deliver energy from these areas, will continue to drive the siting of new facilities in inland areas in the region that, in principle, have less potential for generating wind power. This will inevitably, increase the size of the area affected.

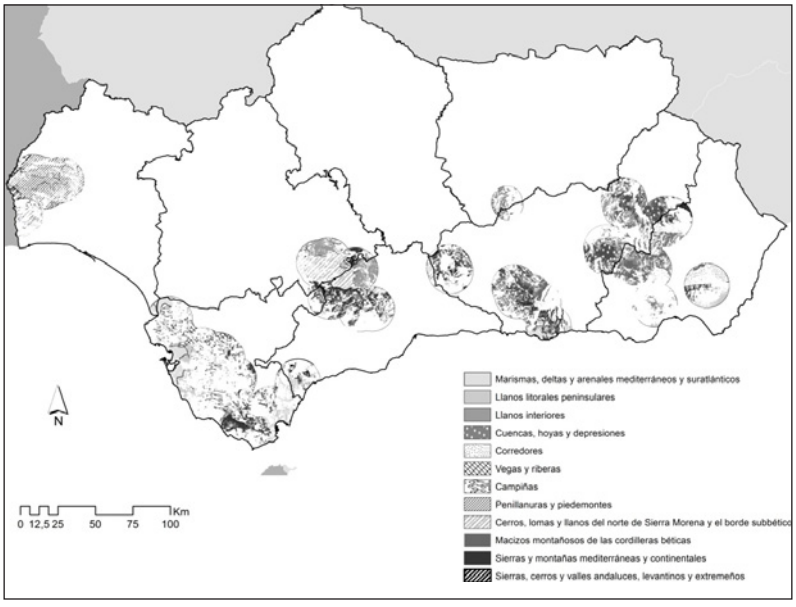
V. IDENTIFICATION OF LANDSCAPES AFFECTED BY WIND FARM INSTALLATIONS

The landscapes affected by wind energy installations were identified by using GIS to conduct a series of visibility analyses from the wind turbines, in keeping with the considerations of De Andrés and Iranzo (2011).

After working with the Geographical Information System and processing the information for the areas of influence (visible up to 15 km) of the wind farms in Andalusia on the basis of the Atlas of Spanish Landscapes, the analysis was seen to show that the implications of wind farms for the landscape go further than the mere uniqueness of each installation (Map 1).

One conclusion that stands out is the size of the surface area affected, 6,829 km^2, or 7.8% of the land surface of Andalusia. These figures show that this is a much more wide-

Map 1
LANDSCAPES AFFECTED BY WIND FARMS IN ANDALUSIA, 2010-2011



Source: Prepared by authors.

ranging and cannot be described as an occasional or local phenomenon, and again reinforces the need to establish valid methods to evaluate the impact of wind farms.

By way of an example, these implications for the landscape affect the inside of some protected natural areas in the region, where the installation of wind farms is forbidden by the laws that govern them. In addition, although there are no wind turbines inside these protected areas, part of the land that they cover is affected by changes in the landscape caused by nearby wind farms.

VI. MAIN LANDSCAPE DISPUTES LINKED TO WIND ENERGY

Compared to conventional power stations in Andalusia, which are highly concentrated at specific sites (only 26 municipalities out of 771 have a thermal or hydro-electric installation), renewable energies are very widespread in the region, which means that 257 municipalities have some kind of installation, even if we only count wind or solar energy installations. As they are decentralized and scattered, the effects of renewable energies on the region and landscapes are more widespread than those of conventional energies (Baraja and Herrero, 2009), and this also means that they have to be addressed in their own particular way.

The analyses show that until recent times the rate of wind farm implementation in Andalusia has progressively increased over the years in the Autonomous Community's attempt to comply with the proposed broad objectives, and attempts by developers and businesspeople to gain access to profitable compensation schemes. Be that as it may, in the social environment this intense implementation rate subordinated to the above-mentioned broad objectives that set with no prior evaluation of the potential of the Andalusian countryside for achieving them, has left people somewhat bewildered, as they see the number of installations of this type rapidly escalating in very specific areas.

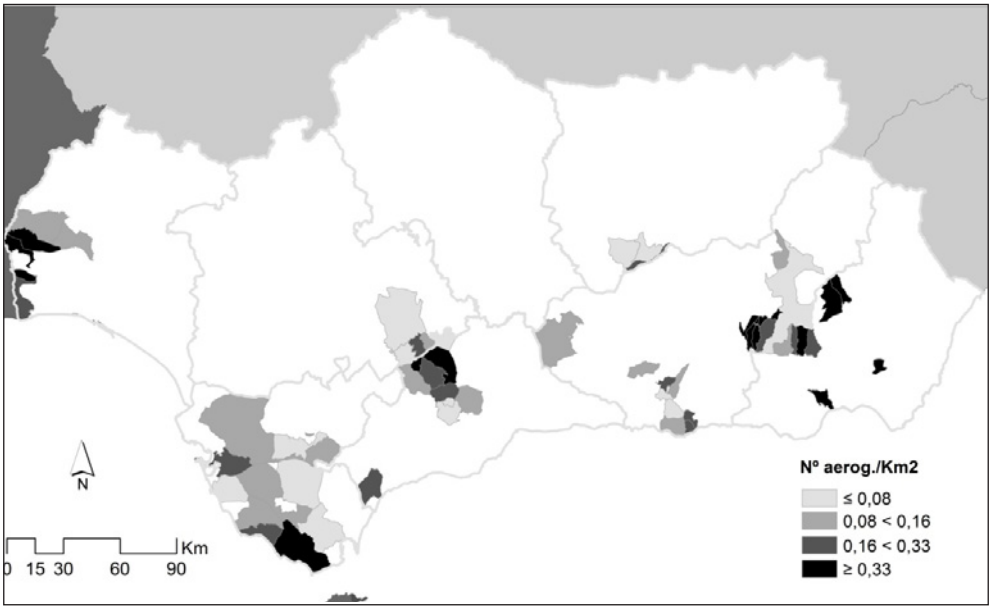
Similarly, the digitization of all wind turbines in Andalusia has enabled the density of wind turbines per square kilometer to be calculated, as is shown in Map 2. Tarifa has the highest figure (with 0.33 wind turbines/Km^2), and it is therefore the municipality where wind energy activity that has exerted the greatest pressure. Tarifa easily surpasses all other municipalities (it is followed by the municipality of Almargen (Malaga province) with 0.78, with Serón and Jerez de la Frontera currently in third and fourth places (0.55 and 0.34, respectively)).

In addition, the presence of wind farms in protected natural areas or in their vicinity can lead to a certain amount of rejection from the population, either because they contradict or delegitimize other lines of public action (nature conservation) or because they are obstacles in the way of other land uses related to the natural values that characterize these places (tourist appeal, basically) and have also required major investment efforts and public actions. In the case of Andalusia, 55 renewable energy plants (414 MW installed) are located inside one protected natural area or another in the region. Of these, 23 are large-scale wind farms with over 360 wind turbines installed.

Finally, one of the most important problems in the relationship between wind farms and the local population is the physical proximity of the installations to the municipalities where the people live. A range of recommendations have been found in the literature review in this respect that set the minimum safe distance at between 300 (Petit, 1994) and 500 meters (Simao, 2009), in order to avoid any impact from the noise generated by the wind turbines, on

the one hand, and on the other, to protect the population from any accidents that might occur. Table 1 shows the distance from wind turbines to the centers of population in Andalusia.

Map 2
DENSITY OF INSTALLED WIND TURBINES ON THE MUNICIPAL LEVEL



Source: Prepared by authors.

Table 1
POPULATION AFFECTED BY WIND TURBINES SITED UNDER TWO KILOMETERS FROM A CENTER OF POPULATION.

Distance (m)	No. wind turbines	No. of centers of population	Population (2012)
≤300	30	1	1151
301 ≤ 500	26	5	5945
501≤1000	217	13	6362
1001 ≤ 2000	652	39	49,348
Total	925	58	62,806

Source: Prepared by authors.

Although the total number of people affected (62,806 inhabitants) cannot be ignored, it is also true that these types of issues are unlikely to be repeated at the current time, given the tighter control over urban and spatial development that now exists; nonetheless, there might be the odd case of illegally constructed dwellings on land which cannot be developed, although these would not be classed as centers of population, as such.

VII. CONCLUSIONS

- The most general conclusion is that the far reaching importance of the subject -the interrelationship between wind farm installations and the landscape - has been substantiated, given the size of the areas already affected, their almost inevitable spread in the medium to long term, and the severe changes brought about in the landscape.

- From the methodological point of view, the usefulness and need to use Geographical Information Technologies has been proven for this subject area due to the analytical capabilities that they offer for integrating landscape bases into extensive regional areas, on the one hand, with accurate information about the installations sited in the area, on the other. The need to generate a geodatabase has been demonstrated in this regard, and for this all the wind turbines in Andalusia have been digitized, improving on previous methods that were based on taking the geometric center of wind farms as their only reference. The information obtained as to the impacts and real effects produced by the installations was therefore much more accurate and detailed.

- The analysis of the factors that predominated in the siting of the wind farms installed to date shows that they have been limited to quantifying the amount of wind resources and the opportunities for delivering the energy generated, without taking into account the landscape values of the lands on which they were sited and any impacts that they might have on these. This focus will have to change given the growing size of the area affected and the upsurge in landscape awareness among the administrations and the population.

- The need to consider the visual effect of wind farms not only because of the specific locations where they are sited, but also because of the wider area within which they are visible to the eye, as has been done in the present article. This has confirmed that the implications for the landscape are felt further afield than just at the installation itself and allowed them to be quantified; good examples of this are some of the Andalusian Natural Parks which, despite the installation of wind turbines inside the parks being banned, see their landscapes affected by the implementation of wind farms in their immediate surrounding area.

This article was based on a study on the regional scale, but more detailed studies need to be conducted on the local scale to be able to accurately determine the real effects. The methodologies of these detailed studies must inevitably include public participation instruments (unfeasible on the regional scale) in line with what is set out in the European Landscape Convention; according to this the landscape is defined as "an area as perceived by people", and the landscape quality objective will be "the formulation by the competent public authorities of the aspirations of the public with regard to the landscape features of their surroundings". As such, the perceptions, valuations and aspirations of the local population should unavoidably constitute reference points for any specific decisions taken on the matter.

- Finally, as a conclusion regarding the present state-of-affairs, emphasis must be put the need and opportunity to exploit the current slow-down in the expansion of installations (due to the economic crisis and changes in the rules and regulations as to the continuation of public aid) as a pause that allows the impacts that have already taken place to be reflected upon, and more accurate methods to be developed to evaluate the effects on the landscape together with policy instruments that would stop them becoming more severe in the future.