Do wind turbines impact plant community properties in mountain region?

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Abstract

The emergence of renewable energy infrastructures calls for a better understanding of their impact on biodiversity. The aim of the present study was to investigate in a mountain region the impact of a wind turbine on plant communities in their vicinity. A field survey was conducted in a wind farm situated in the Southern Romanian Carpathians, five years after the turbines were installed. We tested for the effects of the presence of the turbine and the distance to the turbine on plant species richness, on five plant ecological indicators and on the quality of the pastures. Overall, 33 plant species belonging to 16 families were recorded, and among them 21 were recorded in both the presence and the absence of wind turbine. The presence of a turbine did not affect the structure of the plant community, as the majority of the plots exhibited similar plant species richness and composition. Finally, the values of the ecological indicators and the pasture quality were not altered by the presence of the turbine. Such analyses could be extended over longer time periods so as to capture potential long-term effects and by integrating other environmental factors such as microclimatic conditions or soil properties.

Key words: wind energy, mountain pasture, plant ecological indicators, pastoral value

1. Introduction

Over time, the landscape of Europe has undergone radical changes that have induced specific phenomena such as habitat fragmentation and loss (Lindenmayer and Fischer 2006), thus giving rise to a major problem for what concerns biodiversity (Fahrig 2003; Didham 2010; Pătru-Stupariu at al. 2015). A new challenge is the potential environmental impact of the renewable energy sources and their supporting infrastructures. Assessing their impact is a target within the framework of international policy instruments and treaties, such as the Pan-European Biological and Landscape Diversity Strategy (EEA 2005) or the European Landscape

Convention (Council of Europe 2000). For instance, wind farms situated in mountain regions are of particular interest (Hastik et al. 2015) because they potentially affect ecosystems such as pastures or wood-pastures, representing hotspots of biodiversity (Hartel et al. 2013). Thus, if such farms are going to be constructed in a near future in regions with a complex topography, such as in mountains, they have to be developed within the existing landscape and integrated with a minimum impact on biodiversity (Fang et al. 2018), and avoid potential land-use conflicts (Huber et al. 2017). The ecosystem service approach could represent an appropriate framework for finding suitable trade-offs between the production of renewable energy and the conservation of natural values (Egli et al. 2017). Therefore, one needs to better understand how to integrate this type of infrastructure in sites with high natural value, while maintaining the benefits gained from the natural environment and mitigating the disturbances on biodiversity (Davis et al. 2018). Particularly, it is a subject of interest to know how the presence of wind farms affects specific functions and values of the natural environment.

Several perspectives were already discussed, and specific issues were addressed in previous studies. The extensive development of the wind farms brought into attention an important but rather subjective perspective, referring to landscape aesthetics and people's perception (Thayer and Freeman 1987; Layne 2018). Over time, the focus was extended towards problems related to measurements and field observations related to changes in local-scale meteorology and ground-level microclimate (Petersen et al. 1998; Baidya Roy et al. 2004; Baidya Roy and Traiteur 2010; Armstrong et al. 2014), impact on soil (Wang et al. 2015) and fauna (Pruett et al. 2009; Bastos et al. 2016; Silva et. al. 2017). Recent studies brought into attention the impact of wind turbines on vegetation on the basis of satellite data analysis (Li et al. 2016; Tang et al. 2017; Xia and Zhou 2017) or simulations that were conducted for understanding the interplay between wind and vegetation under various scenarios of development (Peringer et al. 2016; Fang et al. 2018). Even more recently, the influence of wind farms on vegetation structure at local scale was analysed by performing systematic field surveys. For example, Urziceanu et al. (2018) inventoried the presence of rare and vascular plants, while Pustkowiak et al. (2018) linked the pollinator diversity to the plant species composition.

The aim of the present study was to assess the impact of a wind turbine on its surrounding environment and vegetation, based on *in situ* measurements in the vicinity of the installation and at various distances from the turbine. We focused on a wind farm situated in a mountainous region in Romania, which is among the top ten European countries with technical potential for wind energy in mountainous areas (EEA Report 2009). We tested whether the presence of a turbine after five years of operation alters the vegetation, which we assessed by means of the plant species composition and the quality of the pasture, as well as using several plant ecological indicators (for light, temperature, soil moisture, soil reaction, and soil nitrogen) for characterizing the environmental conditions.

2. Material and methods

2.1. Study site

We selected an area situated in the south-western part of Romania, which was acknowledged as having high wind energy potential (Dragomir et al. 2016). The study site (Topleţ) was located in the SW Romanian Carpathians, in the Mts. Mehedinţi (Supplementary Fig. S1), in the neighbourhood of the Peak Meteriz-Dranic (800 m a.s.l., coordinates: 44°46’24” N, 22°25’19” E). In the site, the mean annual temperature is 8.5 °C and the average precipitation ranges from 650 to 750 mm per year. The mean wind speed is 6.5 $m.s^{-1}$ and occasionally values of 20 $m.s^{-1}$ were measured (EIA 2012). The vegetation is a mixture of pastures and forest patches, which represent a traditional form of semi-open natural landscape (Buttler et al. 2009) that has a high biodiversity (Gillet 2008). The wind farm has two Vestas 112-3.0 MW turbines functional since 2011.

2.2. Experimental design

We considered two transects (TI and TII) passing through the turbine location, called "turbine transects", and two transects (CI and CII) situated at a 300 m distance from the turbine transects, called "control transects" (Supplementary Fig. S2). This specific sampling design, including a spatial repartition of the plots along two transects, took into account the expected wind direction and therefore transects TI and TII delineated an angle centred at the turbine. The directions of TI and CI and of TII and CII coincided, the aim being to generate a 'copy' of the two turbine transects. Each transect was composed of five 1 × 1 m plots with a 50 m distance between plots (Supplementary Fig. S2). The four transects included one plot situated on the upwind side (i.e. −50 m) and three plots situated on the downwind side (i.e. +50, +100 and +150 m) of the turbine tower (Supplementary Fig. S2). The downwind closest plot to the intersection of the transects was expected to be most influenced by the air flow induced by the rotation of the turbine blades. All together there were eight plots on the turbine transects and eight on their control counterparts.

2.3. Plant inventory

Firstly, an inventory of the plant species present in each of the sixteen plots was performed in May 2015. Secondly, we assessed the ecological preferences of all the plant species. We used the method of Sârbu et al. (2013), adapted from the method of Ellenberg et al. (1992) for the specific soil and climatic characteristics of Romania. The ecological indicators considered were those for light, temperature, soil moisture, soil reaction and soil nitrogen. For each indicator, a value (ranging from 0 to 10) was assigned to each plant species

(Supplementary Tables S1 and S2), reflecting habitat requirements of that species to the corresponding ecological factor. For each indicator, a mean value per plot was calculated as the arithmetic mean of the values associated to each species present in the considered plot. Thirdly, the pastoral values of the plant species were assessed by a 5-class ranking system according to the herbivore consumption preferences (Supplementary Table S2): graminee fodder, feed fodder, other fodder plants, non-consumable plants, and plants damaging the grassy rug of the meadows (Maruşca et al. 2014). For each category, a mean pastoral value for each plot was calculated as the ratio between the number of species in a considered category and the total number of species in the plot.

2.4. Statistical analysis

Statistical analyses were performed with the R software (version 3.3.1), using package *"vegan"*. Significance was evaluated in all cases at $P < 0.05$. A linear model approach was used to test for the effects of the turbine presence, the distance to the turbine (ranging from −50 m upwind to +150 m downwind), and their interactions on plant species richness, on the five ecological indicators (light, temperature, soil moisture, soil reaction, and soil nitrogen) and on the five pastoral value indicators (graminee fodder, feed fodder, other fodder plants, non-consumable plants, and plants damaging the grassy rug of the meadows). Then, a correspondence analysis (CA) was conducted using the presence/absence data of the thirty-three plant species to see whether the presence of the turbine induces a shift in the plant community. Finally, in order to test for the difference of species composition between both plant communities (wind turbine *vs.* no wind turbine presence), an analysis of similarities (ANOSIM) was performed.

3. Results

Overall, 33 plant species belonging to 16 families were recorded across the 16 plots (Supplementary Table S2). Among them, 21 species were found in both the presence and the absence of the turbine. Six plant species (*Dactylis glomerata*, *Genista sagittalis*, *Leucanthemum vulgare*, *Lotus corniculatus*, *Ranunculus bulbosus*, *Rorippa kerneri*) were found only in absence of a turbine, while six plant species (*Capsella bursa pastoris*, *Convolvulus arvensis*, *Echium vulgare*, *Erodium cicutarium*, *Pimpinella saxifraga*, *Poa bulbosa*) were found only in presence of a turbine. The presence of a turbine did not affect the plot plant species richness, with a mean of 11 plant species recorded both in the presence and the absence of a turbine (Tables 1 and 2). Additionally, the presence of a turbine did not affect the structure of the plant community (ANOSIM, R = –0.13, P = 0.99; Supplementary Fig. S3), as the majority of the sixteen plots exhibited a similar plant species composition (Fig. 1).

Based on the average scores of the five ecological indicators (Table 1), the study site was characterized by a strong light exposition, a cold and dry climate, and a slightly acid soil with no nitrogen limitation (Table 1, Supplementary Table S1). The values of the five ecological indicators were similar in presence and in absence of a turbine (Tables 1 and 2), and we observed only a significant influence (P = 0.045) of the Turbine × Distance interaction factor for the soil reaction parameter. This suggests an increase of soil reaction from upwind to downwind in presence of a turbine and, in the opposite, a decrease of soil reaction from upwind to downwind in absence of a turbine (Table 2, Supplementary Fig. S4).

With respect to the pastoral value, the species identified in the sixteen plots belonged to six categories, namely graminee fodder, feed fodder, other fodder plants, non-consumable plants, plants damaging the grassy rug of the meadows and toxic and harmful species. The corresponding mean values of the six categories were similar between the turbine and control transects (Tables 1 and 2). The majority of the plants were fodder species (belonging to the graminee, feed or other fodder plant categories) and the quality of the pasture was not altered by the presence of the turbine (in Table 1, the mean values for fodder species sum to 0.62 and to 0.65, indicating a percentage of 62% *vs.* 65% of fodder plants in absence and presence of a turbine, respectively).

4. Discussion

Since renewable energy (e.g. wind power) can be a part of the solution to the carbon and climate issues (Pacala and Socolow 2004), it is crucial to understand the reciprocal interferences between presence of wind turbines and vegetation development, especially for optimizing future developments of wind parks. The results obtained in the present study are related to the influence of wind turbine on plant communities after five years of operation. We analysed the plant species characteristics, with a focus on the ecological preferences of plant species and their pastoral value.

The outcomes of the analyses indicate that there is no significant difference between the characteristics of the vegetation and its environment in the presence of the turbine as compared to its absence. Thus, we reported for the first time an absence of wind turbine impact on the neighbouring vegetation after five years of wind farm operation in the studied mountain region, and no effect neither on the pastoral value of the grassland. These results go along with the findings of Urziceanu et al. (2018), which indicated that even rare and threatened vascular plants can be found in the neighbourhood of a wind farm in the studied hilly region. Similarly, in a case study conducted in a homogeneous agricultural landscape, Pustkowiak et al. (2018) indicated that plant species richness around wind turbines was comparable or even higher to that found in grassland patches or in neighbouring cropland.

Conversely, several other studies showed that changes in plant community structure after the installation and operation of a wind turbine can occur. Such changes were due mainly to shading (Saidur et al. 2011) or drying (Baidya Roy et al. 2004) effects and can have cascading effects on the physiology of plants and the soil properties (Armstrong et al. 2014; Dodd et al. 2005). Since microclimate changes may affect the vegetation characteristics such as the pastoral value of the grassland (Durau et al. 2010), it is worth to systematically investigate how spatial variability of local climate and other environmental factors such as topography (Šrůtek and Doležal 2003) and soils (Gobat et al. 1989) can induce, in interaction with the presence of wind turbines, effects on vegetation development (Riesch et al. 2018). In the present study, we reported an absence of impact of the turbine as assessed by plant ecological indicators, suggesting that the wind farm did not significantly alter the environmental characteristics in the studied mountain region. We saw an effect on the soil reaction, a pattern which could be related to the downwind turbulences influencing the rain distribution and the snowpack, which in turn can affect soil processes (Gavazov et al. 2017, Robroek et al. 2013). Nevertheless, we acknowledge that the investigation of more wind farm sites would be needed to make the statistical comparison more robust.

Time could be a key factor for investigating how the changes induced by wind turbines on microclimate (Baidya Roy and Traiteur, 2010) may cascade to changes in vegetation structure (Brand et al. 2011). Here, we reported the absence of wind turbine impact after five years of wind farm operation. However, as simulations showed, vegetation occurring in the neighbourhood of wind turbines could also have a long-term feedback effect on wind resource distribution in mountainous regions (Porté-Agel et al. 2011; Fang et al. 2018). This calls for long time monitoring of the interdependencies between wind turbine efficiency, local meteorological conditions, soil properties and vegetation characteristics. In a broader context, such integrated approaches could contribute to mitigate the negative effects of wind turbines on the environment and to maintain the fragile ecological equilibrium in valuable landscapes (Burton et al. 2011; Zhou et al. 2012).

5. Conclusion

We conducted a field survey to investigate the impact of a wind turbine five years after its installation on plant communities in their vicinity in a mountainous region. The statistical analyses indicated no significant differences between the two conditions (turbine presence *vs.* turbine absence) on both plant species richness and composition, their relationships to environmental factors and their pastoral value. The values of five ecological indicators were, in general, not altered by the presence of the turbine and a slight effect on the soil reaction was noticed.

Such analyses could be extended by investigating whether, over longer time periods, the wind turbines could influence the microclimatic conditions or the soil properties and, in turn, vegetation development (growth, patterning, structural properties), the distribution of the different species and their pastoral value, as well as potential feedback effects on the wind turbine efficiency. Such inter-disciplinary analyses could help to predict potential environmental changes and avoid the harmful impact on biodiversity.

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Conflict of Interest The authors declare that they have no conflict of interest.

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Fig. 1. Correspondence analysis (CA) based on the presence/absence of thirty-three plant species recorded in eight plots close to the wind turbine and eight plots without turbine (control). Variance explained by each principal component are shown in brackets.

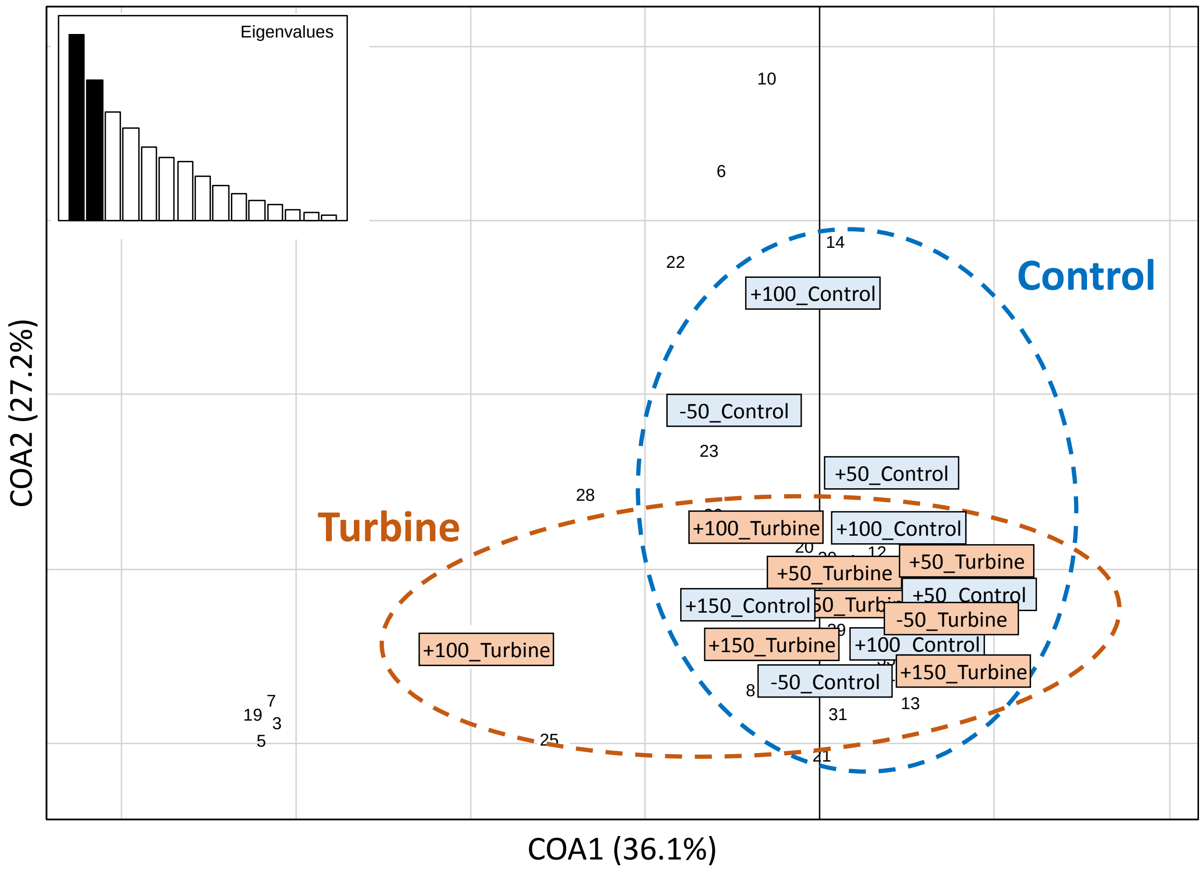

Table 1. Mean values ± SD (n= 8) of plant species richness, 5 ecological indicators and 5 pastoral value indicators in presence/absence of turbine. GF= graminee fodder; FF= feed fodder; OFP= other fodder plants; NCP= non-consumable plants; PD= plants damaging the grassy rug of the meadows.

	With turbine	Without turbine
	Mean ± SD	Mean ± SD
Plant species richness	11.13 ± 2.30	11.50 ± 3.16
Ecological indicators		
Light	7.71 ± 0.24	7.69 ± 0.19
Temperature	2.61 ± 0.65	2.51 ± 0.92
Soil moisture	2.66 ± 0.43	2.76 ± 0.59
Soil reaction	3.19 ± 0.69	3.15 ± 0.81
Soil nitrogen	5.14 ± 0.49	5.26 ± 0.66
Plant pastoral value		
GF	0.14 ± 0.05	0.14 ± 0.04
FF	0.16 ± 0.06	0.19 ± 0.09
OFP	0.32 ± 0.07	0.32 ± 0.09
NCP	0.17 ± 0.10	0.17 ± 0.09
PD	0.22 ± 0.08	0.18 ± 0.12

Table 2. Effects of the turbine presence, the distance to the turbine, and their interactions on plant species richness, 5 ecological indicators and 5 pastoral value indicators. *T*-values and associated *P*-values are indicated. GF= graminee fodder; FF= feed fodder; FP= other fodder plants; NCP= non-consumable plants; PD= plants damaging the grassy rug of the meadows.

	Turbine		Distance		Turbine × Distance	
	t-value	*P*-value	*t*-value	*P*-value	*t*-value	*P*-value
Plant species richness	-0.15	0.881	-0.67	0.517	0.07	0.942
Ecological indicators						
Light	0.06	0.952	0.41	0.693	0.08	0.934
Temperature	-0.78	0.452	-1.14	0.276	1.53	0.153
Soil moisture	-0.25	0.804	0.83	0.424	-0.03	0.977
Soil reaction	-1.36	0.200	-1.92	0.079	**2.24**	**0.045**
Soil nitrogen	-0.33	0.747	-0.35	0.731	0.04	0.973
Plant pastoral value						
GF	0.29	0.777	1.18	0.260	-0.81	0.437
FF	-0.71	0.494	-0.37	0.715	0.29	0.777
OFP	-0.04	0.968	0.79	0.445	0.08	0.935
NCP	0.19	0.850	-0.32	0.757	-0.27	0.790
PD	0.50	0.624	-0.23	0.826	0.09	0.928