Socio-environmental impacts of wind farms on the traditional communities of the western coast of Ceará, in the Brazilian Northeast

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ABSTRACT

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The global expansion of wind power has resulted from the development of scientific research that aims to establish an energy network which minimizes the emission of pollutants derived from the combustion of fossil fuels. Ceará, in the Brazilian Northeast, has a considerable potential for the generation of environment-friendly power, due to the occurrence of strong winds on many parts of the coast and at higher elevations. Given this, the present study aimed to evaluate the socio-environmental damage caused by the installation of a wind farm on the coastal plain of the municipality of Camocim, on the western coast of the state, and to identify the consequences for the coastal environment and the traditional community of Xavier, which survives primarily on fishing, agriculture, and the extraction of natural resources. The study was based on the recognition and definition of the environmental components of the local landscapes, and the mapping of the community's territory, based on the social cartography approach. The study area is characterized by mangrove ecosystems, dune fields, interdunal lakes, fluvial-lacustrine coastal plains, and a sandy beach. The integration of these different environments underpins the traditional lifestyle of the local community, which is based primarily on the exploitation of natural resources. Given this, the community of Xavier, which is made up of 20 families, was affected directly by the installation and subsequent operation of the local wind farm (one of the largest in the Brazilian Northeast, with 50 wind turbines generating a maximum output of 104.4 MW, and approximately 135 km of transmission lines) through (1) the gratuitous occupation of a significant portion of the community's territory, (2) deforestation of fixed dunes, (3) the suppression of dunes by bulldozing, (4) burying of interdunal lakes, (5) disturbance of the margins of fluvial-lacustrine systems, (6) compaction and impermeabilization of the soil, and (7) artificial retention of mobile dunes. These findings indicate that the licensing of wind farms in the state ignores a set of socio-environmental principles. The results of this analysis indicate the need for a regional blueprint for the development of effective socio-environmental policies for the sustainable exploitation of the coastline of the Brazilian Northeast, and in particular for the definition of the sectors most appropriate for the installation of wind farms, such as the coastal plains, which have been classified as the alternative sites with the best potential, as long as effective licensing measures are implemented.

ADDITIONAL INDEX WORDS: *Socio-environmental impacts, generation of wind power, Brazilian coast.*

INTRODUCTION

The production of wind energy in Brazil has expanded exponentially over the past few decades, and currently generates gigawatts of electricity (Regueiro, 2010, Fernandes and Oliveira, 2012). Studies of the country's eolic potential began in the 1970s, and indicated the predominance of winds with an excellent potential for the generation of electricity, in particular along the coast, and in areas of higher elevation in the interior of the country (Amarante *et al.*, 2001, Januzzi, 1994).

Worldwide, the expansion of eolic energy has been mediated by the growing need to develop alternative sources of energy to substitute fossil fuels. The quest for alternatives was stimulated in particular by the oil crisis of the 1980s, and predictions of the eventual collapse of fossil fuel reserves (Castro, 2005; Jara, 2011).

While studies have shown that no alternative energy source will be able to satisfy any country's demand completely (Naturlink, 2006; Sateikis; Lynikiene; Kavoleles, 2005), the generation of eolic energy appears to be one of the most viable options for Brazil. In addition to avoiding the emission of pollutants, the generation of wind energy is based on the exploitation of a sustainable resource, that is, the wind (Hays, 2005).

The current estimate of the eolic energy potential of Brazil for the generation of electricity is of the order of 143 GW (Brasil, 2009). In addition to providing a clean and renewable source of energy, the Brazilian government has given priority to the

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development of this alternative technology (Lima, 2008; Aneel, 2005, 2009; Adece, 2010; Pellegrini, 2012; Cede, 2011).

In the most recent report of the Global Wind Energy Council (GWEC, 2011), Brazil was considered to be the leading Latin American country in eolic energy potential, which has attracted the interest of major corporations in the eolic energy industry. The Energy Research Company (EPE) has estimated that, at its current rate of growth, the total production of Brazilan eolic installations will exceed 11 thousand MW in 2016 (Neuls, 2012).

The northeastern Brazilian state of Ceará is characterized by constant winds with a mean velocity of between 5 and 9 m/s and favourable topography, which combine to make this state one of the country's most promising regions for the production of eolic energy (Seinfra, 2008). However, the results of the present study indicate that the majority of the capacity installed on this coastal plain has caused grave socio-environmental impacts. The licensing, installation, and operational phases of the wind farms on the coast of Ceará have all had a range of impacts on the region's natural and social environments. These impacts have been related primarily to the degradation of the areas occupied by traditional, indigenous, and riverside populations, which have altered features of the coastal plain that have considerable scenic and ecological value, such as dune fields, sources of freshwater, and mangrove forests (Meireles, 2008, 2011a).

Given these questions, the present study investigated the socio-environmental impacts caused by the installation of wind farms on the coastal plain of the municipality of Camocim in the northeastern Brazilian state of Ceará. A number of different impacts were recorded in the environments traditionally exploited by the local communities of fishermen and subsistence farmers.

METHODS

A data base was established for the compilation of the available information on the geo-environmental characteristics of the Camocim coastal plain, derived from both a literature search and new fieldwork. The fieldwork, which diagnosed the alterations to the environment provoked by the installation and operation of the wind turbines, was conducted with the participation of representatives of the Xavier traditional community. This community is located in the municipality of Camocim, 379 km west of the Ceará state capital, Fortaleza, and approximately 100 metres from the northern limit of the wind farm.

Fieldwork was conducted using a checklist and direct observation, with a GPS navigator (Garmin Etrex) to record the geographic coordinates (on land and at sea) of the territorial elements relevant to the local community and the areas impacted. The morphological features of the beaches, coastal lagoons, and dune fields were defined using cartographic instruments (surveyor's tape, clinometers, GPS, and total station), with the help of multitemporal satellite images and total station for the mapping of specific impacts.

The maps were produced using high spatial resolution Quickbird satellite images from 2003/2004, provided by the state government, which were used to collect the points of interest and produce the image-map of the natural environments and areas of community use of the coastal plain between the Coreaú and Remédios estuaries. Semi-structured interviews were conducted in the community located near the wind farm for the evaluation of social impacts.

RESULTS

The coastal plain of Camocim presents a complex environment, characterized by mangroves, fixed and mobile dune fields, interdunal lakes, and fluvial-lacustrine ecosystems (Figure 1). These geomorphological features support a traditional local lifestyle based on the exploitation of the natural resources of coastal and marine ecosystems, which not only provides subsistence, but also a unique lifestyle intimately related to the seasonal dynamics of the different components of the local landscape.

The coastal plain at Camocim is topographically favourable to the installation and operation of wind farms, as well as meteorological monitoring stations. The wind farm that operates at this site is one of the largest in the Brazilian Northeast. The installation was projected to have a transmission line of 135 km in length, for a total of 50 turbines with a maximum capacity of 104.4 MW, sufficient to supply approximately 350 thousand residences (Tavares, 2011). Following the installation and operation of this wind farm, the traditional local communities, especially Xavier, have suffered considerable negative impacts to their daily activities and territorial use.

Based on the diagnosis of the study area, the principal consequences of this the installation of the wind farm for the dynamics and functioning of the natural systems of the Camocim coastal plain were identified as:

- **Removal of the vegetation from fixed dunes** for the construction of access roads and the operation of earth-moving equipment and auxiliary vehicles. This resulted in the elimination of sectors of the fixed dune fields, given that it was usually associated with the bulldozing and cross-sectioning of the dunes and the shoring of their bases;
- **Burial of fixed and mobile dunes** to level the ground for the installation of the turbines on the dune fields. This was necessary for the preparation of the land for the construction of a network of access roads and well as the installation of the subterranean ducts for the electric cables, construction sites and administration buildings, and the storage and maintenance of industrial equipment. These works resulted in the removal of large quantities of sand from the mobile and fixed dunes, which was replaced with coarser sand and clay (extracted from local quarries) for the compaction of the soil for the construction of the roads. Part of the sand removed from the dunes was bulldozed onto the fixed dunes and interdunal and coastal lakes, burying the vegetation and eliminating the surface water, provoking extensive topographic, podological, and morphological modifications;
- **Impacts to the fluvial-lacustrine systems** – the artificial retention of the mobile dunes resulted in a deficit of sand for these systems, interfering in the input of sediments which are leached into the coastal system during high water events. The unavailability of these areas to fishermen creates social impacts that interfere with the subsistence activities of the local populations;
- **Burial of interdunal lakes** for the construction of the access roads for the turbines;
- **Input of sedimentary substrates** for the impermeabilization and compaction of soils for the construction of access roads, construction sites and areas for the storage of materials. The compaction of the soil is essential to permit the transit of vehicles over the sandy substrate of the study area;
- **Artificial retention of mobile dunes** in order to impede their migration and potential burial of the roads. It was also necessary to retain the dunes during the construction of the wind farm in order to prevent the dunes from burying the installations or provoking erosion at the construction sites (turbine foundations and mountings, maintenance buildings and substations, and ditches for the installation of the electric cables).

The wind farms of the Camocim coastal plain are expanding over the dune fields. The modifications of the environment may result in cumulative effects on the integrity of the study area. The interference of the input of wind-borne sediments to the coastline will almost certainly have erosive effects on the transmission lines, for example (Meireles and Serra, 2002; Ruz and Meur-Ferec, 2003). Given this, coastal plateaus, located further inland, have been identified as more appropriate locations for the installation of
wind farms, due to their more adequate morphological, topographic, environmental, and social characteristics, as long as they are subject to effective licensing procedures. Any such alternative would require the application of principles of the evaluation o environmental equity (Laschefski, 2011).

Considerable social impacts were observed in the present study. A number of residents of the Xavier community confirmed in the interviews that they had suffered insomnia and constant discomfort ever since the installation of the wind farm, due to the noise of the turbines.

In November, 2009, one of the turbines exploded, and the local families were forced to take to the sea in their boats. They received one minimum salary (equivalent to 230 euros) as compensation from the company that manages the wind farm. One other striking contradiction of the Xavier community is that, while some turbines are located little more than 100 metres from some of the houses, the community itself had no electricity until the beginning of 2010.

Figure 1. Map of Natural environments of coastal estuaries Camocim between the river Coreau and Remédios, Ceará, Brazil.

The installation of the wind farm resulted in the burial of interdunal lakes which were a source of fishery resources and leisure for the local community. Access to the main town and the local environments used for traditional subsistence activities has also been impeded, and the local residents are now unable to reach some locations within the area of the wind farm which they had traditionally exploited for subsistence activities.

Overall, then, a set of environmental impacts was observed in the present study, which have induced serious impediments for maintenance of the traditional lifestyle of the local coastal communities. Given these findings, the assessment of alternative locations and technologies, together with the more systematic evaluation of long-term impacts and the better demarcation of areas destined for traditional subsistence activities, should be

contemplated in the policies adopted by the public authorities in Brazil for the development of alternative energy sources.

DISCUSSION

Wind farms have now been installed along much of the coastal plain of Ceará. This has had a sequence of environmental and social impacts on the region, and in particular to the territories occupied by traditional communities (Meireles, 2011b; Souza, 2001; Costa, 1997, 2004; Shiraishi Neto, 2010; Brasil, 2007, Guerra and Coelho, 2009; Diegues, 2000; Acserald, 2004).

Ellenbogen *et al.* (2012) from the Massachusetts Department of Environmental Protection and the Massachusetts Department of Public Health, in recently paper refers to records of the Wind Turbine Syndrome in a number of studies of the human populations that reside in the vicinity of wind farms. A number of problems were reported in relation to the continuous noise caused by the rotors, which affects the physical health and sleep of residents, causing headaches, tinnitus, vertigo, and nausea. In North Carolina (USA), the noise and vibrations generated by the turbines was shown to have caused illness in numerous local residents (Ottinger, 1991; Inatomi and Udeata, 2011).

Osborn (1996), Barclay; Baerwald; Gruver (2007), and Mendes; Costa; Pedreira (2002) recorded an increasing number of collisions involving bats and birds of prey following the installation of wind turbines at sites in Brazil and Europe (Soverningo, 2009). Similarly, Subramanain (2012) in studies conducted by Nature Climate Change between 2003 and 2011 and by the Eurec Agency (2002) at wind farms in Texas (USA) have shown that the downblast of warm air produced by the turbines provokes an increase in the temperature of adjacent areas of the order of 0.72°C, principally during the night, indicating the formation of micro-climates in these areas.

As in Xavier, a range of socio-environmental problems have been reported from a number of other sites in Ceará (Trairi and São Gonçalo do Amarante) and the Brazilian Northeast (Caitité in Bahia), and even European countries such as Spain and Portugal. These problems include the misappropriation of public lands, abusive or illegal occupation of properties, the destruction of the sources of public water supplies, the loss of quality of water and soils, and impacts to archeological sites on quilombola lands (Smith, 2011; Regueiro, 2011; CPT, 2012; Montenzano, 2007). Similar impacts were recorded in the traditional fishing community at Sítio Cumbe (Ceará), where the installation of wind farms and high voltage transmission lines has caused considerable socio-environmental damage, including the destruction of archeological sites (Meireles, 2008).

Despite the trends identified in the present study, both state and federal governments continue to invest increasing amounts of resources into the development of wind energy. At both levels of government, there has also been a relaxation of environmental licensing standards (Ecodebate, 2012; Regueiro, 2011; Baima, 2012).

CONCLUSIONS

The socio-environmental impacts recorded in relation to the installation of wind farms on the coastal plain of Camocim in the northeastern Brazilian state of Ceará are not unique to this region. The whole of the coastal zone of the state has suffered socio-environmental damage from the infrastructure necessary for the production of this "clean" energy. In particular, this process is provoking conflicts with traditional local communities related to the ownership of or access to areas traditionally used for subsistence activities. The potential for public health problems is also evident, given the proximity of local inhabitants to turbines and/or transmission lines.

The results of the present study confirm that the procedures followed for the environmental licensing of the installation and operation of wind farms in Brazil ignores socio-environmental principles, in particular those related to the prediction and prevention of impacts, as well as justice and equity. Major contradictions were observed, primarily in relation to the social and environmental injustices inherent to the lack of any systematic demarcation of traditional or indigenous territories prior to the installations of the wind farms and public policies that ignore the existence of these territories.

Ultimately, the installation of wind farms generates conflicts between society's need to generate alternative sources of energy, and the interests of local residents, which are reinforced by the contradictions inherent to the capitalist system of production. In this case, while the media tends to perceive the damage as being essentially environmental, it is, above all, social.

While the production of wind power is a necessity, then, it cannot or should not be achieved through the destruction of the complex socio-environmental systems of coastal areas. The development of a regional plan for the identification of more appropriate areas for the installation of wind farms should be one of the basic tenets for the formulation of adequate environmental and socioeconomic policies that will guarantee the sustainable use of the coast of Ceará. Participative and integrated actions that prioritize the conservation of the cultural values of the traditional coastal populations and their public lands, the region's biodiversity and its unique local scenery, will be essential to the sustainability of this activity, not only in Ceará, but throughout Brazil

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