

WINDS OF ENERGY TRANSITION AND THEIR IMPACTS ON THE LIVELIHOODS OF COASTAL COMMUNITIES IN CEARÁ, BRAZIL

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Summary

Due to its high wind potential, the State of Ceará has played a key role in Brazil's energy transition. In this region, wind farms are primarily located along the coast, also home to traditional communities. This study aimed to analyze the impacts of wind farms on the livelihoods of traditional coastal communities in Ceará. Secondary data were obtained from previous studies and official reports that identified the effects of wind energy developments on nearby communities. The results indicate that wind farms have altered the dynamics of fishing, agriculture, and community organization. These findings highlight the need for more equitable and sustainable energy policies that integrate the perspectives of traditional communities to safeguard their livelihoods amid the expansion of the wind energy industry.

Keywords: livelihoods, wind energy, traditional communities.

1. Introduction

Wind energy production in Brazil has grown exponentially over the last twenty-five years, especially in the northeast region. The coastal area of northeastern Brazil has high wind potential and accounts for 88% of the country's wind power projects (ANEEL, 2023). This region includes the State of Ceará, the country's fourth largest wind power producer, with 5.2 GW of installed capacity (ANEEL, 2025).

The parks in Ceará are mainly concentrated in the coastal area, characterized by its potential for tourism and wind energy production. There is also an intense and historic presence of traditional communities, defined as groups with their own forms of social organization, which occupy and use the territories and natural resources as a condition for their cultural, social, religious, ancestral, and economic reproduction, based on knowledge, innovations, and practices passed down through generations (Decree 6,040, 2007). These communities have their own livelihoods, built on strategies based mainly on using the territory's natural resources.

Since 2000, a new spatial configuration of the Ceará coastline has been designed, in which wind farms are predominantly located close to traditionally occupied territories. However, due to the ancestral relationship of these populations with the resources of their territories, this condition may accentuate the social, economic, and ecological impacts perceived by residents of the area (Silva et al., 2023; Silva et al., 2020).

In Ceará, environmental conflicts have been identified that arise from changes in the levels of access, control, or distribution of the territory's resources, as well as in the survival strategies implemented by local populations because of these territorial transformations.

This context has been studied in research that analyzes energy transition from the perspective of social inclusion, ecological conservation, and environmental justice, mainly in the global south. In common, a context of territorial expropriation, little community participation, and environmental compensation incompatible with the impacts caused is identified. (Lopez & Herrera, 2025; Milanez et al., 2025; Santana & Silva, 2021).

In Brazil, this field of study has been explored in depth; however, few studies are dedicated to understanding how these impacts affect livelihood strategies. For this reason, this study sought to analyze how the impacts of wind farms have affected the livelihoods (MV) of traditional communities on the coast of Ceará, in northeastern Brazil. The results provide insight into how the expansion of wind farms has impacted livelihoods. In addition, it contributes to the debate on energy transition, environmental justice, and the rights of traditional populations affected by wind megaprojects.

2. Materials and Methods

The study focused on the State of Ceará, which has 163 wind farms distributed across 18 municipalities (Figure 1), with 84% of these farms located on the coast (ANEEL, 2025). In addition to the high concentration of wind farms, approximately 324 traditional coastal communities are located on the coast of Ceará (Secretaria do Meio Ambiente e Mudança do Clima, 2024).

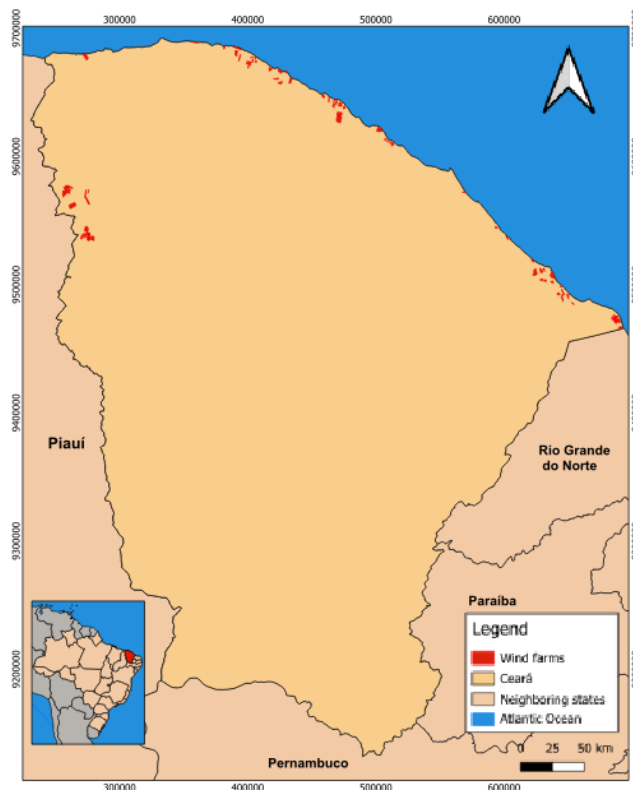


Fig. 1: Wind farms on the coast of Ceará

This research used a descriptive methodological approach with qualitative data analysis, based on “an interpretive perspective focused on understanding the meaning of actions, especially those of humans and their institutions” (Sampieri et al., 2014, p.9).

Methodological strategies seek to collect and analyze data that integrate the concept of livelihoods. Although widely discussed in international literature, this concept is still not fully defined. Braga, Fiuza, and Remoaldo et al. (2017) explain that this term has been used since the 20th century to explain the transformations in the configuration of livelihoods that societies, mainly rural ones, have experienced. For Gonçalves (2004), it consists of the articulation between the conditions and lifestyle of an individual or family group. Chambers & Conway (1991) define it as earning a living or daily sustenance. Livelihoods, therefore, are the activities carried out to achieve subsistence.

Livelihood studies are conducted through capital analysis, also known as asset analysis, which forms the basis for building subsistence. The quantity, quality (level of ownership, access, control, or distribution), diversity, and balance between these resources positively or negatively influence livelihoods (Speranza et al., 2014). These assets depend on external and internal factors in each community, structures, and processes that affect the configuration of livelihood strategies, restricting or increasing access to the five types of capital. Supply, demand, and the interrelationship between them, mediated by power structures and mechanisms, characterize livelihood changes. Rojas-Pinilla (2019) and Chaves (2019) categorize them as follows:

Natural – includes natural resources and environmental services necessary for life, such as soil, water, air, the hydrological cycle, fishing, forests, seeds, etc. These are particularly important for communities that have traditionally obtained their livelihood directly from nature through different forms of adaptation over time.

Physical – this category supports the best use of other available assets. It can change depending on the unit of

analysis. Housing, for example, refers to structures such as transportation, sanitation, energy, furniture, access, furnishings, etc.

Human – essential for the proper use of other available assets. It includes all practices, knowledge, skills, abilities, education, health, and the ability to learn and work. **Financial** – this can be in the form of money, savings, subsidies, or loans that allow for investments in subsistence. **Social** – this includes the construction of networks, organizations, and cooperatives that strengthen and provide sustainability to the means of maintenance.

The aim was to identify impacts generated by wind farm installation and/or operation that affect at least one of the five constituent capitals of MVs. The analysis is based on secondary data collected from official documents, scientific articles, and academic theses obtained through databases such as SciELO, Science Direct, and university websites. A content analysis was carried out, a technique used to treat and interpret qualitative data (Bardin, 2009). In this analysis, documents with the following terms were considered: "wind energy," "traditional communities," "environmental impacts," "socio-environmental impacts," "social impacts," and "livelihoods."

Most of the studies analyzed did not use the livelihoods approach and methodology. However, they were considered in this analysis because they presented impacts and changes in the affected communities.

The relevant information was extracted and tabulated in Excel software and then organized into matrices. This helped to understand how the impacts affect and which MV assets they are related to, making it possible to understand how the livelihood strategies of coastal communities in Ceará have changed since the arrival of the wind industry.

3. Results and Discussions

Studies that analyze socio-environmental impacts are interdisciplinary, given wind energy's environmental, social, political, and economic aspects. Despite the different approaches, the 23 documents analyzed showed that the impacts are similar in the different communities studied along the coast of Ceará (Table 1).

Table 1: Impacts produced, and capital affected

Phase	Impact	Affected Capital
Installation	Deforestation of mangrove and forest areas	Natural; human
Installation/Operation	Privatization of coastal areas, estuaries, etc.	Physical; human
Installation	Drying of lagoons	Natural; human
Operation	Noise emissions	Human
Installation/Operation	Compensation payments	Financial
Installation	Competition for local services	Social; financial
Installation/Operation	Job creation	Financial
Installation	Outsiders in the community	Social
Installation/Operation	Change in the landscape	Natural; physical
Installation/Operation	River sedimentation	Natural
Operation	Perceived reduction in marine animal species	Natural
Operation	Soil and groundwater contamination	Natural
Installation	Community polarization	Social
Installation/Operation	Access roads	Physical
Operation	Shadow effect	Physical

3.1 Natural and financial capital

All analyzed studies highlight the importance of natural and financial capital as the most affected and strongly related, which is why they will be discussed in this session. The strong relevance of natural capital as a basis for livelihoods was noted due to the presence of key resources such as the sea, a river, and mangroves, representing sources of food and income through fishing and fibers. In addition, crops, animal husbandry, and handicraft production are familiar supplementary income sources (Brannston et al., 2022).

Impacts such as river sedimentation, drying up of lagoons, and deforestation result in biodiversity loss (Chaves, 2019; Leite et al., 2022). Consequently, territorial transformations arise that force the local population to seek new strategies for accessing and controlling resources.

Regarding fishery resources, fishing in rivers and lagoons has been the activity most impacted by the parks' construction and operation, affecting families' food sovereignty. Silva's (2024) studies identified that the reduction in fish supply changed the strategies adopted in the activity, which has been attributed to the presence of the parks. The author explains that when a change weakens ecological sustainability, i.e., it decreases the quality or quantity of natural resources and biodiversity available for sustenance, this affects how the community interacts and mobilizes. This is because fishing has historically been a collective activity in the territory, but with the reduction in supply, fishermen began to fish alone.

The main strategies for increasing financial capital have been combining government support and formal jobs linked to human capital, such as health and education. The search for jobs outside the territory has been associated with the decline of major financial activities such as fishing and agriculture, with residents of these territories seeking formal jobs, including in wind farms. However, Torres Junior (2021) explains that the jobs offered do not serve the communities directly affected by the installation of wind farms. Generally, these are temporary jobs that last only during the installation period of the farm and are presented as precarious activities.

Similarly, impacts such as privatization of territories and reduction of ownership, access, and control of natural resources can reduce income, generate competition among indigenous peoples for resources such as water and arable land, creating a cascade effect that contributes to the potential for conflict and loss of traditional livelihoods. Harvey (2006) discusses competition for land use, which involves power struggles. According to the author, affected communities need very effective legal instruments to have autonomy and achieve some capacity for resistance against business groups. The same author notes that in these cases, negative ecological impacts are only considered after the impacts have occurred (Harvey, 2018).

3.2 Social capital

Another asset strongly influenced by wind farms is the social one. Studies report that the primary strategy of wind companies is to finance part of the community through associations, food, and/or financing services that municipal authorities should provide, such as school facilities (Gorayeb & Brannstom, 2016). This creates polarization between groups for and against these projects, resulting in internal conflict and weakening community organization capacity, hindering the search for dialogue with companies and institutions to receive compensation and/or measures that reduce the vulnerability generated by the perceived impacts.

With reduced opportunities to engage in subsistence activities, conflicts have frequently arisen in communities such as Cumbe, Xavier, and the Tremembé Indigenous people (Sousa, 2020; Chaves, 2019). Conflicts affect livelihoods because they can reduce trust, organizational capacity, and popular action, hindering collective organization to address community demands. On the other hand, conflict can drive the search to strengthen livelihoods.

In some communities, it was observed that, despite this trend toward polarization, the park's arrival led to community organization and the formation of networks with non-governmental institutions, churches, and efforts to seek a more effective presence of state action in that territory to protect residents. Silva (2024) reviews the context of conflicts that have accompanied the Tremembé da Barra do Mundaú indigenous people since the 1980s. This process began with the arrival of a tourist complex in the indigenous territory. During episodes of violence, threats of dispossession, and deep community polarization, they strengthened their social capital. They understood that the most effective, albeit not the fastest, way forward would be through a solid

relationship of reciprocity with institutions. The use of formal legal mechanisms tends to prolong the conflict, but on the other hand, it is the way in which it can be resolved definitively.

Thus, they built relationships with the National Indigenous Peoples Foundation (FUNAI), universities, and other communities that had already experienced similar conflicts. In 2014, two wind farms were built on the edge of their territory, and once again, they faced the threat of conflict. However, by this point, the internal organizations were already operating at full capacity, in addition to the knowledge gained from a decade of conflict, which resulted in more objective and immediate attitudes towards justice, through the Public Prosecutor's Office and the Public Defender's Office, to seek compensation and mitigating measures.

After identifying the farm's presence, the first strategy adopted was to seek the support of FUNAI and the State Public Defender's Office to seek adequate compensation through the courts for the impacts caused by the farms.

Although painful, the Tremembé case shows that the conflict strengthened the community. The tensions enabled them to consolidate support networks and expand their capacity for collective action. In this way, they transformed confrontation into an opportunity for organization, resistance, and affirmation of their rights. However, it is important to note that this strengthening of community organization could have happened without conflict. If companies had taken a more participatory stance and the State had acted more effectively, the community could have achieved the same level of coordination and defense of their rights without going through such a conflictive process (Silva, 2024).

3.3 Human Capital

Elements related to human capital often undergo transformations due to the closeness between traditional communities and large enterprises. With the growing need to seek survival outside their territories, local culture, medicinal knowledge, and food traditions are being replaced by non-traditional technologies and knowledge. The arrival of outsiders generates competition for rents (Table 1), which increases prices and makes access difficult for locals. In this same context, there are reports of an increase in prostitution and local violence (Torres Junior, 2021; Traldi, 2018).

It is important to emphasize that the nearby presence of a significant industry in traditional communities could be an opportunity to strengthen human capital by increasing access to education, with programs and funding for workforce training, which would enable the hiring of a significant percentage of local labor for strategic positions, thereby increasing local income. On the other hand, programs that strengthen food and medicinal knowledge would be a way to support communities and ensure community support for entrepreneurship. However, this was not identified in any of the studies analyzed. Specific compensation actions related to human capital were observed, but these do not guarantee a significant increase in access to education, health, or recreation.

The impacts listed in Table 1, such as "noise," "privatization of coastal areas, estuaries, etc.," and "changes in the landscape," can gradually lead to a loss of connection with the land, the center, and the roots of MV strategies (Lima, 2024). Tuan (1974) points to aesthetic appreciation as an ephemeral element that becomes meaningful only when it awakens memories or other sensations. Physical contact with nature, mainly present in rural communities, is also responsible for awakening sensations in human beings. "The attachment to the land of small farmers or peasants is deep. They know nature because they live off it (...)"

This physical intimacy, material dependence shape the farmer's topophilia, and the fact that the land is a repository of memories..." (Tuan, 1974, p.111). These feelings are strongly evident in traditional communities due to their dependence on the land for subsistence and the existence of emotional memories. "Illiterate peoples may be deeply attached to their place of origin (...) when they try to explain their loyalty to the place, they either point to ties with nature (the mother-earth theme) or resort to history" (Tuan, 1980, p.114).

The impacts of wind energy projects on traditional communities transform their human capital and weaken cultural and emotional ties to the land. However, if educational programs and initiatives to strengthen local knowledge were implemented, human development could be improved, and the connection to the land could be preserved.

3.4 Physical Capital

Regarding physical capital, the logistics of building and operating a park require access roads with structures for long and heavy vehicles. In this regard, it is common for access roads to be built or adapted to suit the transport of equipment and materials. This can have a positive impact when this infrastructure is shared with residents. However, the companies did not identify this practice voluntarily. In Camocim, the Xavier Community only accessed the road through a court order (Mendes, 2016). The local population of Cumbe, in the municipality of Aracati, on the east coast of Ceará, had part of their houses compromised by the intense traffic of large vehicles during the construction of a wind farm, in addition to the privatization of collective areas (Araújo & Meireles, 2019).

Community infrastructure often receives modest improvements through financial compensation or agreements between companies and municipal authorities. Silva (2024) explains that this practice adopted by companies consists of promising facilities that should be provided by the State, such as health centers, public schools, courses, and training. This removes responsibility from the State and meets community demand, a way of gaining support from both groups for the venture.

It was observed that the fewer resources and structure the community has, the fewer actions the company takes to engage with it. In Camocim, on the west coast of Ceará, the fishing community of Xavier, consisting of just 22 homes, is located 250 meters from a wind farm built in 2009. The community was impacted by the drying up of lagoons, privatization of its territory, changes in the level of wells, noise from the towers, and, as a conflict reduction strategy, the company carried out cleaning activities, as well as movie screenings and gift distribution on dates such as Children's Day, actions also related to human capital. This delighted the population, who did not have televisions in their homes, nor did they celebrate these dates with gifts (Mendes, 2016). The lack of infrastructure and financial resources was so significant in these families that these gestures were necessary. However, they did nothing to mitigate the impacts and won the sympathy of part of the community (Silva, 2019).

The most recurring impact among the studies analyzed is the privatization of areas. In Xavier, municipality of Camocim, the park is located within the community's territory, 250 meters away from the houses. In order to locate the towers, it was necessary to fill in the lagoons used as a food source. Thus, the implementation of the park caused a food shortage and made access to the nearest district, Amarelas, difficult, as the only access road was privatized by the park and the inhabitants were initially not allowed to use it (Silva, 2019).

The same community also experienced the shadow effect (Figure 2). This shadow effect is one of the visual impacts generated by wind farms. Bier (p. 105, 2016) points out that “the alternation between shadow and light projected by the blades causes dizziness in some people.”



Fig. 2: Shadow of the towers on the houses.

The impacts on the physical capital of communities near wind farms reveal risks and opportunities, depending on how the infrastructure is managed. This study showed that privatization of areas reduces the potential benefits for residents, and minimal, albeit symbolic, interventions are insufficient to mitigate conflicts and increase local acceptance.

3.5 Livelihoods at the regional and global levels

The impacts on livelihoods can be understood at different scales: local, regional, and national. At the local level, the impacts are mainly concentrated on natural resources and specific types of ecosystems. At the regional and national levels, impacts go beyond environmental degradation and include problems such as the invisibility of affected communities, the absence of legal instruments, and the slowness of the State in protecting traditional livelihoods.

To ensure the protection of these livelihoods, it is essential to develop policies that recognize the interdependence between communities and their natural resources, and to implement measures that effectively address the threats they face, promoting their well-being and survival.

It is worth emphasizing that the mere existence of capital does not guarantee the survival of a particular group. Besides the availability of capital, effective mechanisms for accessing and using it are also crucial. These mechanisms are generally made possible through structures (institutions) and the processes they carry out, whether in the form of public policies, regulations, laws, etc.

At the regional level, Ceará has a consistent legislative framework for attracting large-scale foreign investment, mainly in the wind energy sector. However, these instruments do not consider local communities as active actors in this context, which has been a key factor in the emergence of conflicts (Silva, 2024; Brannstom et al., 2021). Therefore, it can be concluded that the State has played a central role in the emergence of the conflicts analyzed and in their postponement.

Implementing large-scale projects is consolidated in a structure where deliberative power is concentrated in the State and companies. The instruments of State power, manifested mainly through regulations that are supposed to control the availability, diversity, and distribution of resources, have not effectively addressed the different interests equitably and sustainably. As a result, the studies analyzed show that communities have resorted to collective action to expose the negative impacts they have suffered and seek protection for their territory, which directly influences the configuration of their livelihoods.

Globally, the dynamics of development and intensive exploitation are damaging natural capital, while the benefits are concentrated in the economic centers of power in the Global North. Large conglomerates and transnational corporations manage to instrumentalize hegemonic discourses and government practices in countries of the Global South for their own benefit, to the detriment of local and regional communities. This concentration of power and resources exacerbates inequality in the distribution of costs and benefits in all dimensions: ecological, social, economic, financial, cultural, and institutional.

Finally, the studies reviewed show how these global policies contribute to a pattern of processes characterized by the degradation of natural capital and the loss of traditional livelihoods, altering local environments and exacerbating the gap between the beneficiaries of development and those who suffer its consequences. The impacts produced by installing wind farms are repeated in different territories and have been identified as a factor that negatively influences traditional livelihoods. This context has occasionally resulted in conflicts, generating an adverse cascade effect on these populations. Power asymmetries and top-down actions by these business groups have been identified as a factor in maintaining this context in the area studied. Therefore, adopting more participatory and respectful approaches to the territories affected by wind energy megaprojects is urgent.

4. Conclusions

The results analyzed show that the installation and operation of wind farms on the coast of Ceará generate important changes in the livelihoods of local communities. It was found that **natural and financial capital** are the most affected, due to the loss of fishing resources, the drying up of lagoons, and the privatization of territories traditionally used for subsistence. These changes lead to a reconfiguration of productive and food strategies, weakening food sovereignty and the economic autonomy of families.

Social capital is also compromised by community fragmentation and polarization between groups that are for and against the projects, a phenomenon encouraged by the selective actions of companies. However, in some cases, conflicts have driven processes of organization and collective strengthening. **Human capital** suffers indirect impacts related to the loss of traditional knowledge, increased social vulnerability, and precarious access to basic services. Despite the promise of employment and development, the job opportunities are limited and temporary. Regarding **physical capital**, infrastructure benefits are sporadic and often do not compensate for the damage caused by heavy machinery traffic, road privatization, and visual and acoustic impacts.

To summarize, although wind farms represent a source of clean energy, they reproduce inequalities and generate territorial tensions when they fail to consider the sociocultural reality of communities. It is concluded that the energy transition will only be fair and sustainable if it incorporates effective mechanisms for participation, compensation, and respect for traditional ways of life.

This work contributes to the debate on energy transition by showing that the impacts of wind farms transcend the environmental dimension and significantly impact traditional communities' livelihoods. Based on the livelihood capital approach, the research offers a comprehensive view of how wind projects can alter natural resources, social dynamics, economic strategies, and local cultural knowledge. The systematization of the impacts observed in different communities on the coast of Ceará allows for identifying patterns of vulnerability and resistance, contributing elements for formulating more equitable public policies and licensing processes that integrate the social dimension. In this way, the study contributes both to the academic field by strengthening the interdisciplinary analysis of socio-environmental conflicts and to the practical sphere by offering references that can guide a more just and participatory management of wind energy in inhabited territories.

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