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Wind power potential for irrigation of rice and maize using geoprocessing in the Baixo Jaguaribe river basin, Ceará State - Brazil

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Abstract

Realizing that there is currently a larger search for renewable energy sources and that the coastal region of Ceará has a strong wind potential, this work proposes to demonstrate, through geoprocessing techniques, the feasibility of using wind energy systems in the irrigation of corn and rice crops in the Baixo Jaguaribe sub-basin. The production map of these crops and the Atlas of Wind Potential in Ceará State were overlaid with the help of ArcGIS software. After the processing, it was verified that only 4.15% of the territory of the basin studied has winds capable to install wind energy systems, with predominance of winds between 6.0 and 7.0 $m.s^{-1}$. The use of other sources of renewable energy for irrigation purposes is suggested for this region.

Keywords: GIS, irrigation, renewable energy.

1. Introduction

Wind power production in Ceará stands out throughout the country, a fact that allocates the state as the second largest national producer of this type of energy, with more than 1073 megawatts (MW) of installed capacity; Because it has excellent viability in the territory of Ceará, especially the coast (CCEE, 2014; MME, 2015).

In 2001, the first Atlas of Brazilian Wind Potential was launched, which estimated the national potential at 143 GW, considering towers up to 50 m in height. With the expansion of the sector, most of the Brazilian states are reviewing their potential, now for wind towers of 120 m or more (MME, 2015).

Although government programs have made electricity available to most of the state's family properties (BRASIL, 2011; Salino, 2011), the cost is still relatively high considering the purchasing and productive power of this agricultural sector (Albiero et al., 2014). In order to reduce costs in family farming income, it is necessary to have access to wind turbine technology, which should be appropriate for each scenario (Wang et al., 2008; Barin et al., 2010).

Especially in the semi-arid region, characterized by irregular rains and large periods of drought, electricity expenses make the production process costly and ecologically detrimental to the environment (ANA, 2004). For instance, traditional crops in the northeastern semi-arid region, with beans and corn, consume between 4500 and 6000 m³ of water per hectare and about 700 kWh / ha (PLANVASF, 1989).

Turco et al. (2009) argue that irrigation is responsible for much of the energy consumption in an irrigated area, and can be even greater if the rural producer does not adopt good irrigation management practices. The lack of control of irrigation generates an increase in the cost of production due to the waste of energy and water. In most irrigation systems that use electric energy, 70% of the cost of production is due to the electric energy consumed (Melo, 1993).

In a study developed by Feitosa et al. (2014a), the authors aimed to simulate the generation of electric energy from the wind energy source as an alternative to the irrigated perimeter in the region of Russas, Ceará. For this, they used the software EOLUSOFT - Beta Version 1.0 NUTEMA-PUCRS. In the simulation, the wind system was an energetic alternative to meet the needs of rural electricity supply in the perimeter irrigated with the current wind speed conditions, being able to provide the essential supply, mainly with respect to the pumping of water for irrigation.

Once exposed, it is noted the need for the adoption of renewable energy sources in agriculture as well as wind energy. Thus, wind velocity mapping is essential, as it aims to identify areas with better use of wind power for conversion into electricity and to provide decision-making.

Feitosa et al. (2014b), in a work where they simulated the electric energy generated by means of aerogenerator in the irrigated perimeter Baixo Acaraú - CE, for the energy demand of the irrigation systems, demonstrated the feasibility of meeting the needs of rural electricity supply in that area with the conditions of wind speed analyzed for the site, being able to provide the water supply for irrigation.

Rodrigues (2006) and Sobral (2009) assert that systems of electric energy generation by means of wind energy are fundamental for the Northeast region of Brazil due to the high potential from the point of view of the use of this energy to promote sustainable development. Aimed at meeting the energy needs of the irrigated perimeters and for the sustainability of economic and social growth combined with the maintenance of natural systems, water, soil and biodiversity.

Based on the above considerations, it is intended to demonstrate the technical viability of the use of wind energy as a source of electricity in Ceará, specifically to meet the energy demand of the irrigation system of maize (Zea mays) and rice (Oryza sativa) In the Baixo Jaguaribe sub-basin, Ceará State - Brazil.

2. Material and methods

2.1 Study Area

The Baixo Jaguaribe sub-basin (Figure 1) covers 9 municipalities in Ceará and three irrigated perimeters. The Jaguaribe River drains an area of 5,452 km², covering about 137 km, which extends from the Peixe Gordo bridge on BR-116 to its mouth, located in the city of Fortim. The Jaguaribe river, in this region, has as main tributary the Palhano river, in which the Santo Antônio de Russas dam is located, with a capacity to accumulate 24,000,000 m³ (ADECE, 2011).

According to a more recent study by the Brazilian Institute of Geography and Statistics (IBGE, 2015a), Ceará presented in the 2015 harvest about 24600 tons of rice and a forecast of 18570 in the 2016 harvest. The basin studied here contributes 9490 tons, representing 51.10% of production for this year.

Regarding the maize crop, 130,800 tons were produced in the state, with approximately 2042 tons coming from the Baixo Jaguaribe basin. Numbers that show the socioeconomic importance of these crops in the region of Ceará.

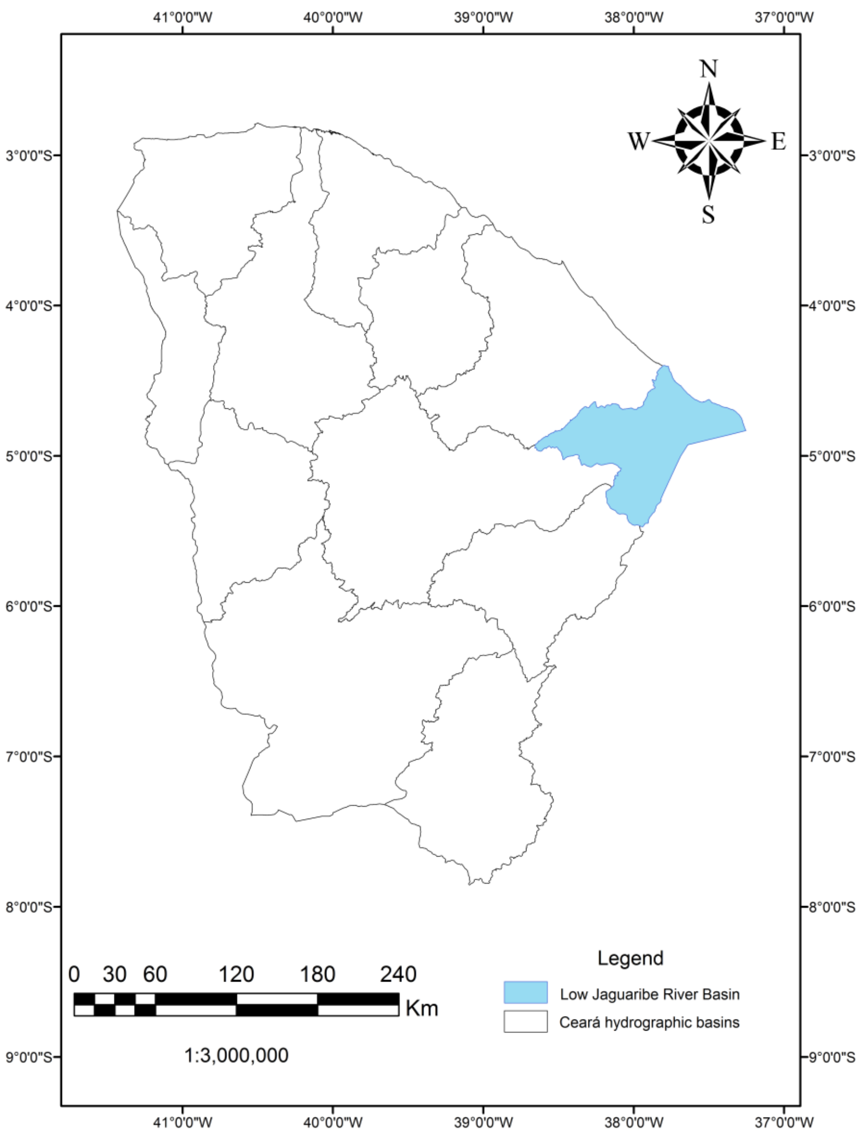

Figure 1- Location of the Baixo Jaguaribe sub-basin in the state of Ceará-Brazil. DATUM SAD69. Zone 24S.

2.2 Geoprocessing and overlapping thematic maps

The study was developed in the Laboratory of Geoprocessing of the Center of Agricultural Sciences of the courses of Animal Science and Agronomy of the Federal University of Ceará, Pici Campus. The software ArcGis version 9.7, produced by ESRI (Environmental Systems Research Institute).

With the help of the software Envi version 4.7, the Ceará Wind Potential Atlas was classified by the supervised method, using the maximum likelihood algorithm to obtain six classes of interest for wind speed: 2.8 to 4.7 m s^{-1}, 4.7 to 5.7 m s^{-1}, 5.7 to 6.6 m s^{-1}, 6.6 to 7.1 m s^{-1} and 7.1 to 8.0 m s^{-1} and 8.0 to 9.5 m s^{-1}. In this algorithm, each class is represented by a color and each pixel of the original image is classified according to the statistical distance between each pixel and the average of the color levels of each class.

The calculation is done for several pre-defined classes and the pixel is assigned to the class whose probability of belonging is greater (Assad and Sano, 1998).

The wind velocities were measured at 50 m height, from regional anemometric data and models of relief and roughness. The annual wind potential map of the Ceará Wind Potential Atlas (SEINFRA, 2001) was georeferenced using the ENVI software and converted into the TIFF (Tagged Image File Format) format.

The Atlas, launched in 2011, was the result of surveys carried out by Wobben and Thyssen companies with measurements added from previous studies of technical, financial and economic viability (Carvalho, 2003).

The Map of the Economic Research and Strategy Institute of Ceará (IPECE) for economic activities (Agropecuária - Culturas temporárias), dated 2012, was used as reference for this work (Figure 2). The points on the map correspond to 500 tons each and refer to rural establishments producing the crops evaluated here.

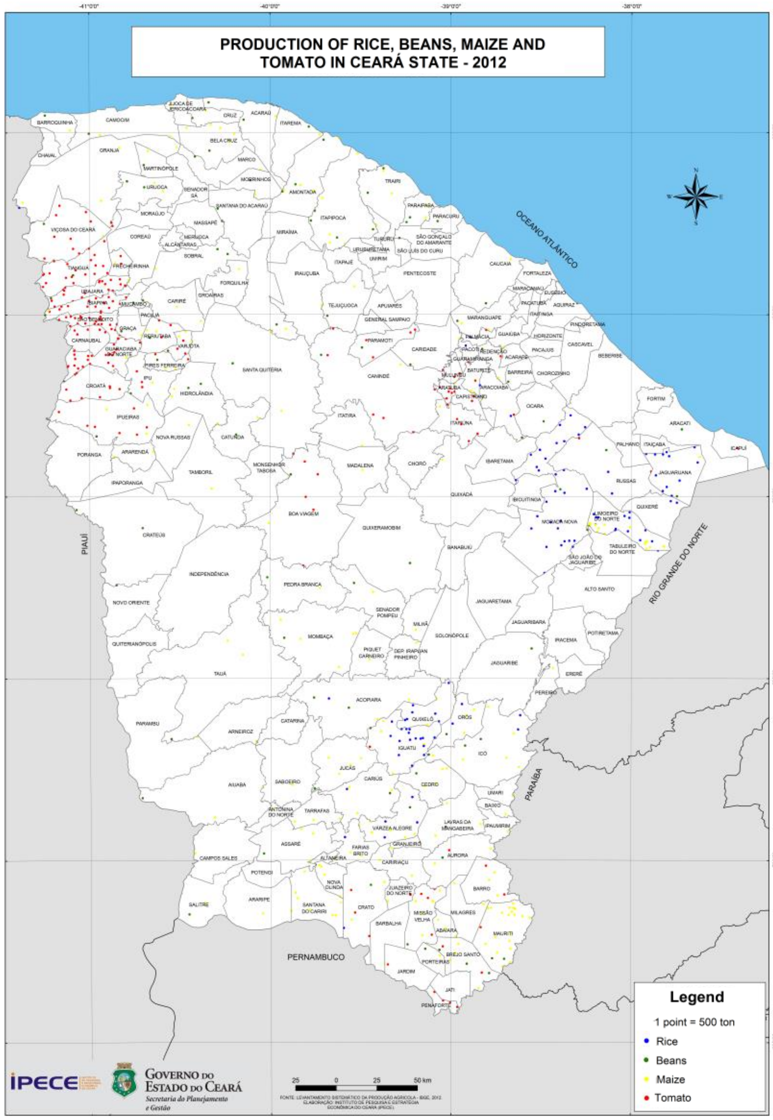

Figure 2 - IPECE Economic Activity Map (Agropecuaria, temporary crops). Source: IPECE (2012).

The overlap of the previous map with the Ceará state wind potential map shown in Figure 3 results in the map objectified in this work, showing which areas are feasible or non-viable for the implementation of wind turbines and the respective velocities found in the studied basin.

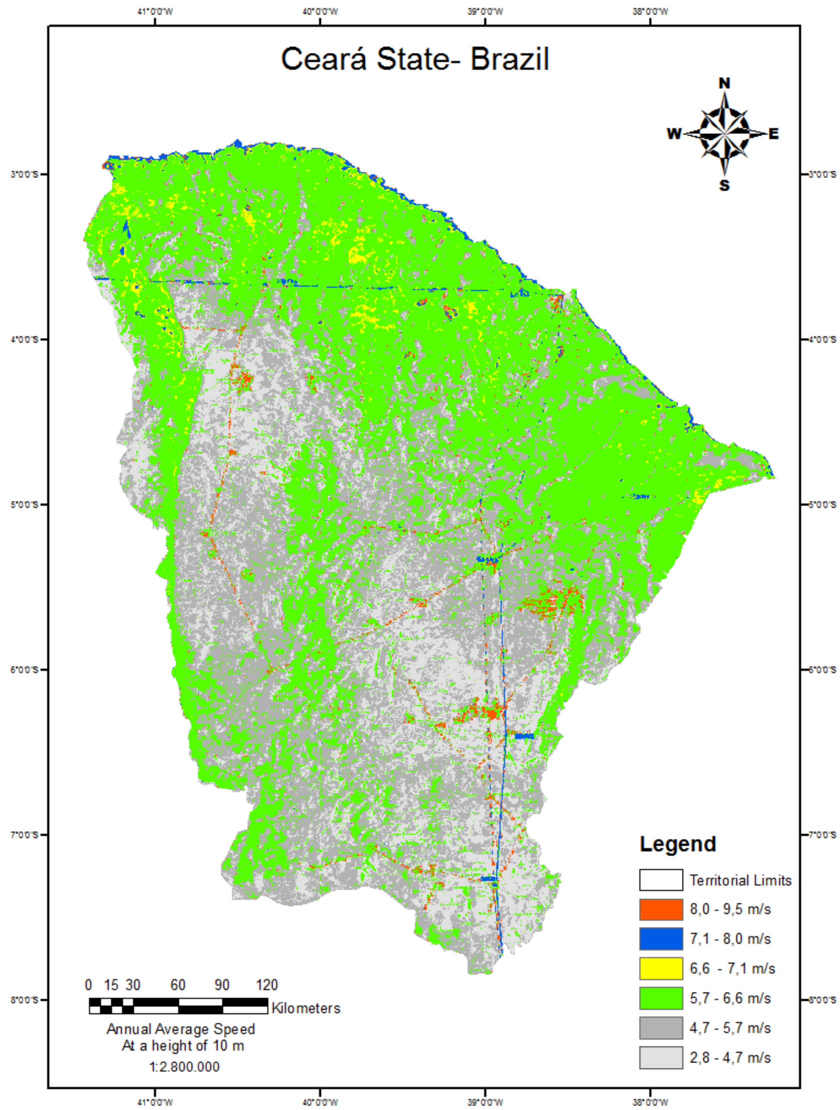

Figure 3 - Map of wind potential for the state of Ceará. DATUM SAD69. Zone 24S. Source: Praciano et al. (2012).

3. Results and discussion

According to Grubb and Meyer (1993), for wind energy to be technically usable, wind speeds greater than 7m s^{-1} to 50m in height are required. Thus, it can be seen in Figure 4 (obtained by overlapping with the Eolic Potential Map in Ceará - Figure 3) that few areas have this characteristic.

Praciano et al. (2012) evidenced in the map of the territory of Ceará with seven wind classes that there is an availability of higher speeds in the coastal region due to sea and terrestrial breezes coming from the coast (Moura, 2007), which favors energy production, Which corroborates the results found here.

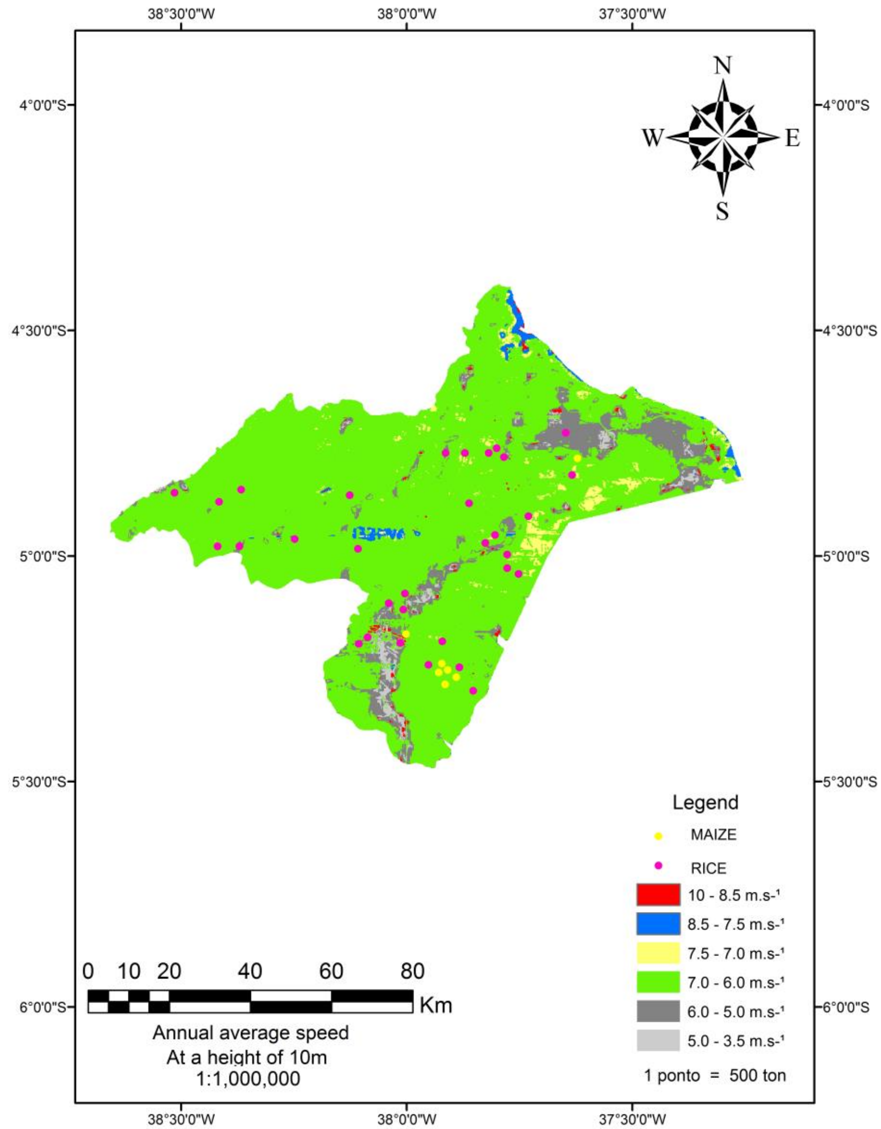

Figure 4 - Wind velocity map in the Baixo Jaguaribe sub-basin, CE. DATUM SAD 69. Zone 24S.

It was sought to elucidate the viability graphically with Figure 5, where the winds are classified only as viable or non-viable for use based on what Grubb and Meyer (1993) advocate.

It is observed in the following figure that only 4.15% of the area of the region has viable winds. This panorama shows the importance of knowledge about natural resources, given that the locality does not have conditions favorable to the generation of wind energy in the majority of the region. However, the study shows that it is interesting to identify locally with favorable conditions.

The transformation of wind energy into electricity is a technology that has become technically and economically viable over the past 30 years. Its production has been growing around 20% per year. Wind energy is a clean source of energy available worldwide and in places with wind speeds greater than $5 m.s^{-1}$ (Vogt, 2010).

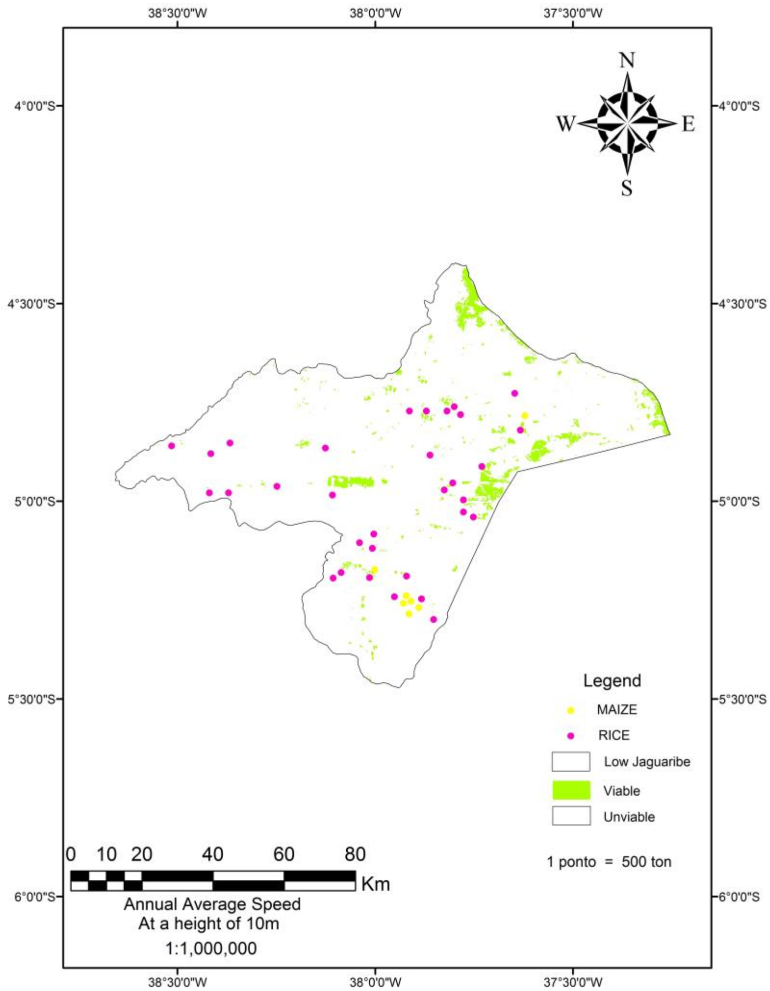

Figure 5 - Wind power feasibility map for irrigation of rice and maize crops in the Baixo Jaguaribe sub-basin, CE.

In order to better understand and evaluate the obtained data, a graph (Figure 6) was created with the division of each wind speed class available in the territory of the Baixo Jaguaribe basin and their respective percentages.

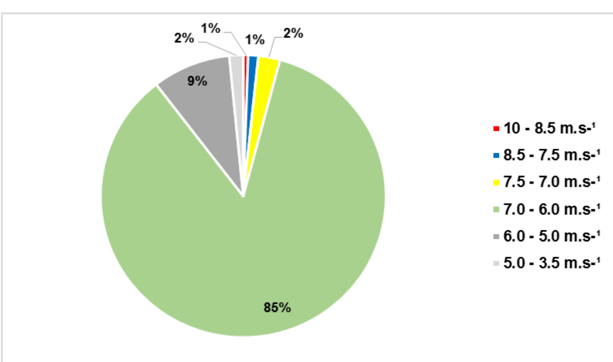

Figure 6 - Representation of wind velocity classes in percentages in the Baixo Jaguaribe sub-basin.

Despite the low expressiveness of wind areas suitable for the deployment of wind power, other alternative energy sources can be used, such as biogas, for example.

Given that the Jaguaribe region has, according to IBGE (2015b) data on municipal livestock production, numbers of approximately 7,600,000 cattle, 4,300,000 pigs, 4,000,000 goats, 8,000,000 sheep and 100,000,000 chickens. And, since it is known that waste from these animals is raw material for the generation of biogas, this renewable energy source is very interesting for this region, as well as for others of the state of Ceará, as already evidenced by Feitosa et al. (2014a) and Prado (2016).

4. Conclusions

It was verified that only 4.15% of the territory of the basin studied has wind suitable for the installation of wind energy systems and favorable conditions for the implantation of irrigation systems fed by wind turbines.

There is predominance of winds between 6.0 and 7.0 $m.s^{-1}$ (about 85% of the wind classes in the region.

It is suggested for this region the use of other sources of renewable energy for irrigation purposes.

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