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PRO-REITORIA DE PÓS-GRADUAÇÃO, PESQUISA E EXTENSÃO
MESTRADO EM MEIO AMBIENTE

LEONARDO HENRIQUE DE SÁ RODRIGUES

ZONEAMENTO DO POTENCIAL DE PRODUÇÃO DE ENERGIA EÓLICA NO MARANHÃO.

Orientador (a): Prof. Dr. Fabricio Brito Silva.

São Luís
2020

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Dissertação apresentada ao Programa de Pós-Graduação em Meio Ambiente da Universidade CEUMA, como requisito para obtenção do grau de Mestre (a) em Meio Ambiente.

Orientador: Fabricio Brito Silva

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Folha de aprovação da Dissertação de Leonardo Henrique de Sá Rodrigues defendida e aprovada pela Comissão Julgadora em 24/08/2020

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Resumo

O conhecimento sobre o potencial eólico de uma região gera informações para o planejamento de possíveis implantações de projetos de geração de energia, visto que, a falta de informação sobre as condições climáticas favoráveis para identificação de áreas com maior potencial eólico é a principal dificuldade para implantação de usinas eólicas de geração de eletricidade. O objetivo deste estudo foi desenvolver uma metodologia para utilização de dados provenientes de sensoriamento remoto para o planejamento de projetos de energia eólica no Maranhão. Foram utilizados dados mensais de velocidade do vento e precipitação, obtidos a partir do Instituto Nacional de Meteorologia – INMet e pela base de dados *Global Land Data Assimilation System* (GLDAS) fornecidos pela *National Aeronautics and Space Administration* (NASA). Inicialmente, os dados da velocidade do vento foram processados através da técnica de análise dos componentes principais (ACP). Em seguida, foi utilizado a técnica de análise de agrupamento denominada k-Medias. Para avaliação dos riscos das mudanças climáticas na produção de energia eólica foi realizado o método de Mann-Kendall. Por fim, foi realizado uma análise de regressão linear com o objetivo de identificar os parâmetros para validação entre os dados estimados pela base GLDAS e dados medidos pelas estações meteorológicas. Foram identificadas quatro Zonas homogêneas, a zona com os maiores valores de médias mensais encontra-se na região norte do estado no litoral. O período de maior intensidade dos ventos foi identificado nos meses de setembro (4,09 m/s) e outubro (4,23 m/s), nestes meses foram observados os menores valores de precipitação. As análises de tendência mostraram que a velocidade do vento vem aumentando ao longo dos 16 anos estudados. As análises desse estudo mostraram um cenário favorável para produção de energia eólica no Estado do Maranhão.

Palavras-chave: Planejamento energético, modelagem ambiental, sensoriamento remoto.

Abstract

Knowledge of the potential for energy production from wind speed generates information to help plan the possible establishment of energy generation projects. This is because the lack of information on favorable climatic conditions that is necessary to identify areas with greater wind potential is the main difficulty in the implementation of wind-based power generation plants. The aim of this study was to develop a methodology for using data from remote sensing to plan wind energy projects in Maranhão. Monthly data on wind speed and capture were used, after the *Instituto Nacional de Meteorologia* - INMet and based on data from the Global System for the Assimilation of Terrestrial Data (GLDAS), applied by the National Aeronautics and Space Administration (NASA). Initially, data on wind speed were processed using the principal component analysis (ACP) technique. Then, the cluster analysis technique called k-Medias was used. The Mann-Kendall method was used to assess the risks of climate change in the production of wind energy. Finally, a linear regression analysis was carried out to identify the parameters for validation between the data estimated by the GLDAS base and data measured by the weather stations. Four homogeneous zones were identified, the zone with the highest values of monthly averages is in the northern region of the state on the coast. The period of greatest wind intensity was identified in the months of September (4,09 m/s) and October (4,23 m/s), in these months the lowest precipitation values were observed. The trend analysis showed that the wind speed has been increasing over the 16 years studied. The analyzes of this study showed a favorable scenario to produce wind energy in the State of Maranhão.

Keywords: Energy planning, environmental modeling, remote sensing.

“Tudo posso naquele que me fortalece”

Filipenses 4:13

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Primeiramente a Deus, pela vida e graça em todos os momentos.

A minha família e amigos pelo amor, amizade, paciência, incentivo, sacrifício, e apoio incondicional durante toda minha vida.

Ao meu orientador, Dr. Fabricio Brito Silva (fonte de inspiração), pela amizade, ensinamentos, oportunidades, paciência e por ter me incentivado a continuar nos momentos mais difíceis.

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Lista de Tabelas

Lista de Figuras

Lista de Abreviaturas

ACP – Análise dos Componentes Principais.

INMET – Instituto Nacional de Meteorologia.

GLDAS – *Global Land Data Assimilation System.*

NASA – *National Aeronautics and Space Administration*

PCA – *Principal component analysis.*

SIG – Sistema de Informação Geográfica.

SDSS – Sistema de Apoio à Decisão Espacial.

WMO – *World Meteorological Organization.*

SUMÁRIO

1. INTRODUÇÃO

O conhecimento sobre o potencial eólico de uma determinada região gera informações para o planejamento de possíveis implantações de projetos de geração de energia, visto que, a falta de informação sobre as condições climáticas favoráveis para identificação de áreas com maior potencial eólico é a principal dificuldade para implantação de usinas eólicas de geração de eletricidade.

A energia eólica é considerada uma fonte de energia limpa e renovável, uma vez que, ao contrário de outros recursos energéticos que lideram a matriz mundial, não produz poluentes para o ar na geração e os seus recursos naturais (ventos) não se esgotam com a sua utilização, sendo sempre aproveitados. Além disso, a implantação de usinas de produção de energia eólica é um fator de desenvolvimento socioeconômico através do turismo, geração de emprego e aumento da renda das comunidades atingidas.

Vale ressaltar que contribuem para a redução da emissão de gases do efeito estufa, no entanto apresentam riscos econômicos ligados às variações climáticas. (FEITOSA et al., 2018).

O mundo em que vivemos hoje está intrinsecamente conectado em um ambiente social, político e econômico com o uso de energia. A exploração de recursos energéticos, especialmente os combustíveis fósseis criaram novos problemas em todo o mundo, como poluição, aquecimento global e efeito de estufa, etc. Estas razões estão forçando as políticas atuais a uma mudança no setor e uso preventivo de recursos energéticos que envolve a diminuição do uso de combustíveis fósseis e não renováveis, para uma utilização crescente de recursos renováveis. (FABRIS, 2018)

Os primeiros registros de utilização da energia eólica para produção de eletricidade foram no final do século XIX. Basicamente, é uma tecnologia que realiza a transformação da energia cinética dos ventos em energia elétrica, tornou-se viável e ganhou popularidade em todo mundo desde o surgimento até os dias de hoje. A concorrência internacional, aliado à anos de aprimoramento na fabricação, pesquisa e desenvolvimento, decorreu em avanços na eficiência dos aerogeradores, diminuição de custos e elevação na produção. Em particular, a energia eólica é vista como a fonte de energia renovável mais promissora devido aos benefícios que ela oferece e da produção de energia proveniente da movimentação das massas de ar que é algo inesgotável (CARDOSO, 2014).

Os ventos são partículas de ar em movimento, ocasionado pelos movimentos de rotação e translação da Terra e pela variação de pressão atmosférica resultante da alteração da temperatura na superfície. (MIYASHIRO et al., 2013).

O comportamento do vento varia de acordo com as características geográficas de cada região, como o relevo, clima, latitude e longitude. Em virtude disso, é necessário um estudo aprofundado para auxiliar no processo de tomada de decisão a respeito do potencial eólico de uma região (FABRIS, 2018).

Segundo a EPE (2016) a geração de energia elétrica no mundo é baseada, principalmente, em combustíveis fósseis como carvão, óleo e gás natural, em termelétricas.

No Brasil, as fontes hídricas contribuem com mais da metade da geração de eletricidade, enquanto as fontes eólicas representam 8,4% de participação na matriz elétrica do país, ou seja, aproximadamente 14 GW de capacidade instalada (ANEEL, 2018).

Nos últimos anos, os Sistemas de Informações Geográficas (SIG) surgiram como um sistema de apoio à decisão para auxiliar no planejamento e gestão espacial. Nestas circunstâncias, os métodos de avaliação multicritério (MCE) e o Sistema de Informação Geográfica (SIG) têm sido cada vez mais utilizados como um importante Sistema de Apoio à Decisão Espacial (SDSS) para avaliar locais adequados. O processo de análise de decisão multicritério baseado em SIG transforma e combina dados geográficos e juízos de valor para obter informação relevante na tomada de decisões espaciais. (JANGID, et al. 2016)

Através do sensoriamento remoto é possível elaborar mapas com zonas referentes ao potencial eólico para auxiliar na tomada de decisões da identificação de áreas com condições climáticas favoráveis para implantação de usinas eólicas.

Uma das principais contribuições das geotecnologias se deve ao fato de compensar a falta de instrumentos de medida em superfície em locais remotos como na Amazônia (FEITOSA et al., 2018).

O objetivo deste trabalho foi identificar zonas homogêneas relacionado ao potencial de produção de energia eólica no estado do Maranhão, utilizando técnicas de sensoriamento remoto.

2 Referencial teórico

2.1 Panorama da energia eólica.

A capacidade geral de todas as turbinas eólicas instaladas em todo o mundo até o final de 2017 atingiu 539.291 megawatts, de acordo com estatísticas preliminares publicadas pela WWEA. 52.552 Megawatt foram adicionados no ano de 2017, um pouco mais do que em 2016, quando 51.402 Megawatt foram adicionados. Este é o terceiro maior número já instalado dentro de um ano, após os anos recorde de 2015 e 2014. No entanto, a taxa de crescimento anual de apenas 10,8% é o menor crescimento desde o início da implantação industrial de turbinas eólicas no final do século XX. (ASSOCIATION, 2018)

A energia eólica tem grande importância, uma vez que vários países já possuem grande parte da energia elétrica produzida proveniente de produção eólica. Entre os países, podemos citar a Dinamarca (34%), Espanha (21%) e Portugal (Mais de 20%). Atualmente, 103 países e regiões, incluindo a Antártica, já utilizam energia eólica. Desses, a China é o que possui a maior capacidade instalada, seguida por Estados Unidos e Alemanha. (CARDOSO, 2014)

O Brasil apresenta um trabalho constante para subsistência de uma matriz energética limpa com o objetivo de cumprir os compromissos internacionais assumidos (SANTOS et al., 2017).

O Brasil é um país favorecido quanto ao aspecto energético, pois sua topografia, hidrografia e clima possibilitam o aproveitamento das várias fontes renováveis de energia, como a hidráulica, biomassa, eólica e solar (SCHMIDT et al., 2016). A Figura 1 apresenta a participação das fontes de energia na matriz elétrica brasileira, sendo que as fontes hídricas contribuem com mais da metade da geração de eletricidade.

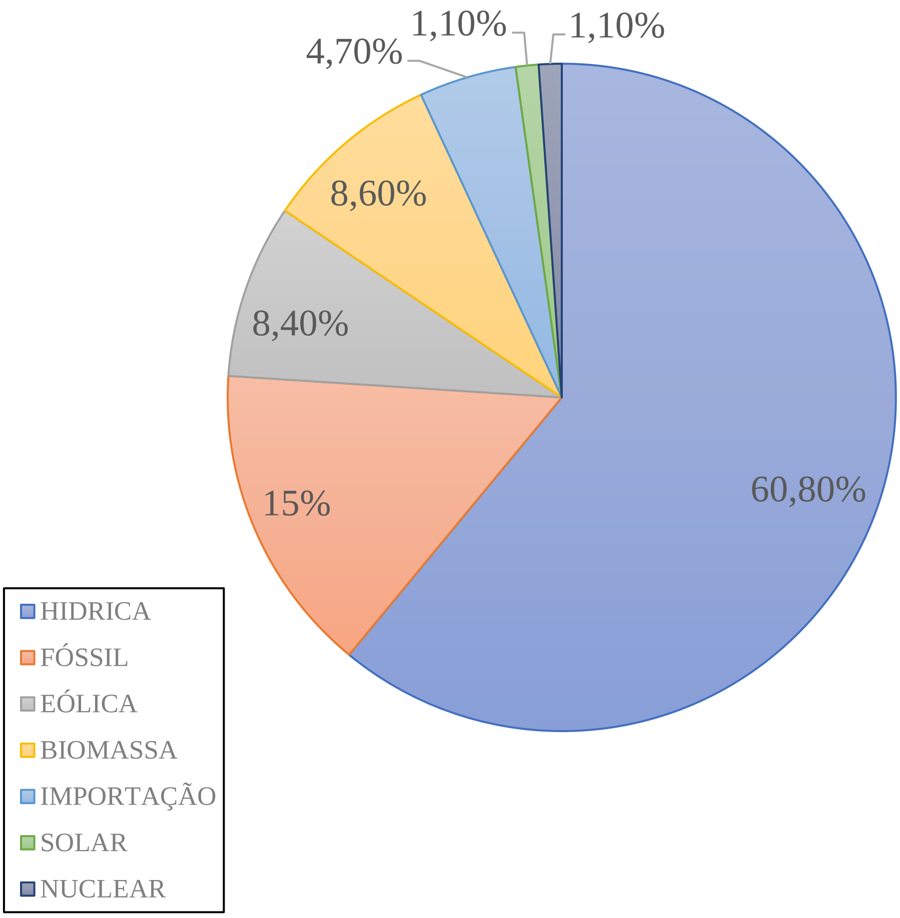

Figura 1. Matriz elétrica brasileira (ANEEL, 2018).

A figura 3 apresenta a evolução da capacidade instalada de energia eólica numa escala temporal de 13 anos. Atualmente, o Brasil possui 14 GW de capacidade instalada.

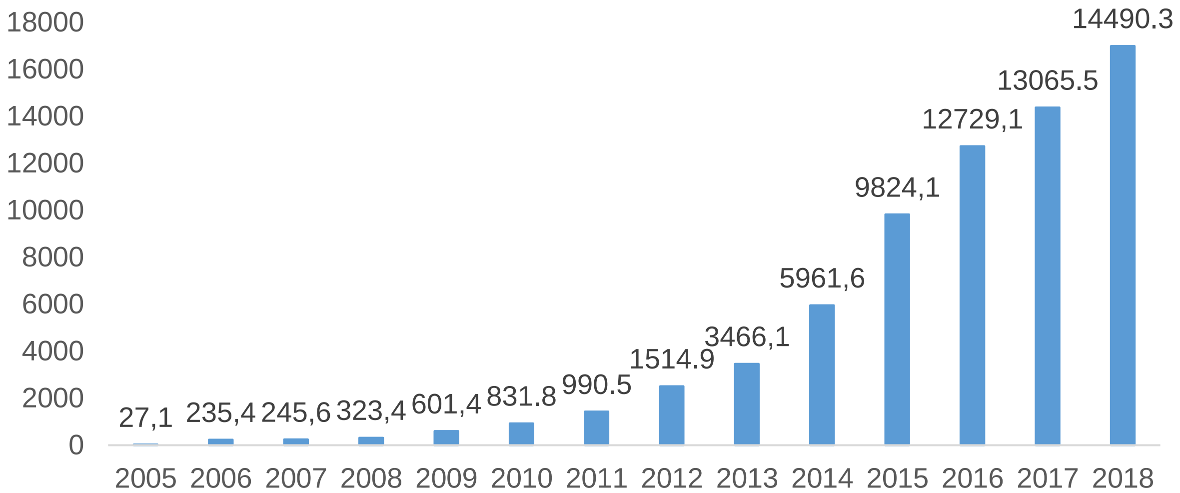

Figura 2. Capacidade instalada de energia eólica no Brasil.

A energia eólica é tipicamente aproveitada através da implantação de uma turbina em um local favorável. Uma turbina é composta de um rotor, anemômetro, controlador, sistema de passo, eixos de alta e baixa velocidade, caixa de engrenagens e gerador. O anemômetro mede a velocidade do vento e envia esses dados para o controlador, que liga a turbina eólica. Isso normalmente acontece quando o a velocidade do vento está entre 3,5 e 24,5 m s 1. (JOHNSON et al, 2016)

O sistema de pitch orienta as pás da turbina ao vento quando as condições são favoráveis, e o sistema de freios é acionado quando o vento é muito forte. Dada uma velocidade de vento suficiente, as pás da turbina irão rodar e consequentemente, fazer com que o eixo de baixa velocidade gire a uma taxa de 30 e 60 rpm. A caixa de engrenagens aumenta a taxa de rotação para que eixo de alta velocidade atinge uma rpm em torno de 1000 e 1800, o que é rápido suficiente para o gerador produzir eletricidade. (JOHNSON et al, 2016)

Depois de apenas 3 e 7 meses de operação, uma turbina eólica restaura a energia total que será gasto durante todo o seu ciclo de vida.

2.2 Características do vento

Atualmente, a energia eólica é tipicamente aproveitada através da implantação de uma turbina em um local favorável. Uma turbina é composta de um rotor, anemômetro, controlador, sistema de passo, eixos de alta e baixa velocidade, caixa de engrenagens e gerador. O anemômetro mede a velocidade do vento e envia esses dados para o controlador, que liga a turbina eólica. Isso normalmente acontece quando o a velocidade do vento está entre 3,5 e 24,5 m s 1. (JOHNSON et al, 2016)

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Os ventos são partículas de ar em movimento, ocasionado pelos movimentos de rotação e translação da Terra e pela variação de pressão atmosférica resultante da alteração da temperatura e altitude da superfície.

A combinação das áreas de alta e baixa pressão com a força de Corilis produzem os ventos predominantes. Os ventos de nordeste e sudeste estão entre os ventos mais constantes na superfície, pelo menos nos oceanos. Isso faz com que algumas ilhas, tais como Havaí e Porto Rico, possuem recursos eólicos em abundância. De fato, a superfície da terra varia muito de um ponto a outro. Superfícies diferentes afetam o fluxo de ar devido a variações de pressão, absorção de radiação solar, e a quantidade de umidade disponível. Os oceanos agem como um grande dissipador de calor, formando ondas, portanto, a movimentação do ar está diretamente associada à circulação oceânica. Todos esses efeitos levam a pressões diferenciais que variam os ventos globais e locais, como as monções. Além disso, aquecimento ou resfriamento local pode causar ventos locais persistentes em uma base sazonal ou diária, como a brisa do mar e brisas terrestres. (FABRIS, 2018).

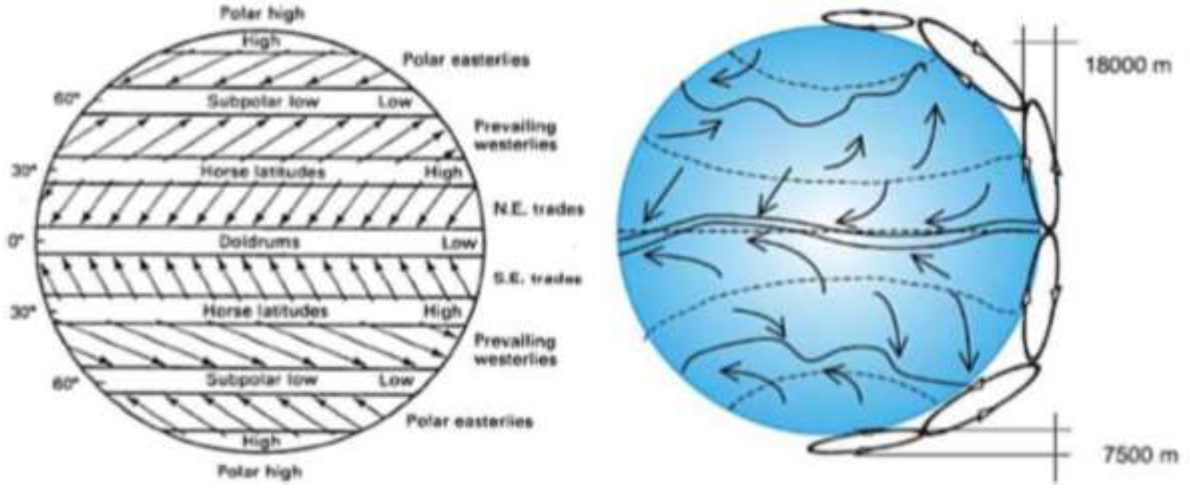

Figura 3. Sistema de distribuição global dos ventos (FABRIS,2018).

A densidade de energia eólica é um indicador importante para determinar o potencial dos recursos eólicos e descrever a quantidade de vento energia a vários valores de velocidade do vento num determinado local. O conhecimento da densidade da energia eólica também é útil para avaliar a desempenho de turbinas eólicas e nomear o vento ideal turbinas. A densidade de energia eólica se assemelha ao nível de energia no local que pode ser convertida em eletricidade usando turbinas eólicas (MOHAMMADI et al, 2016).

Uma utilização eficaz da energia eólica requer informações conhecimento das características do vento em uma área específica. As características da velocidade do vento podem ser explicadas usando uma velocidade do vento função de densidade. A função de densidade da velocidade do vento é importante determinar a seleção de locais adequados para um gerador eólico, projetando o parque eólico, projetando o gerador de energia, determinando a direção dominante do vento e avaliando as operações de gestão do sistema de conversão de energia eólica. Assim, pode-se concluir que as informações referentes à função de densidade de velocidade do vento são muito importantes para avaliar a capacidade e o potencial de desempenho da energia eólica em uma área.

Além da óbvia importância da densidade de energia eólica, existem outros fatores para o dimensionamento de turbinas em usinas de geração de eletricidade. Estes incluem fatores ambientais, como temperatura e extremos de vento, a presença de gelo, folhagem e edifícios, e assim por diante. Extremos de temperatura devem ser considerado porque os componentes da turbina, como vedações de borracha, podem enfraquecer a baixas temperaturas. Acúmulo de gelo na turbina as lâminas podem diminuir a produtividade da turbina.

Ventos extremos podem colocar uma carga crítica em uma turbina eólica, que pode impactar negativamente o desempenho de uma turbina e encurtar uma vida da turbina. A folhagem circundante e os edifícios próximos de um potencial local de turbina também são levados em conta porque aumentam a aspereza da superfície e obstruem a entrada vento. Fatores não-ambientais incluem todos os aspectos políticos, sociais e considerações econômicas. (JOHNSON et al, 2016).

O fluxo de ar acima do solo é retardado pela resistência de atrito oferecida pela terra superfície (efeito camada limite). Esta resistência pode ser causada pela rugosidade do solo em si ou devido a vegetações, edifícios e outras estruturas presentes sobre o solo. Teoricamente, o a velocidade do vento sobre a superfície do solo deve ser zero. A velocidade aumenta com altura até uma certa elevação, portanto, a velocidade aumenta sensivelmente a 20 m, acima do qual a influência da superfície é bastante fraca. (FABRIS, 2018).

2.3 Análise dos dados de vento utilizando técnicas de Sensoriamento Remoto.

Nos últimos anos, os Sistemas de Informações Geográficas (SIG) surgiram como um sistema de apoio à decisão para auxiliar no planejamento e gestão espacial. Nestas circunstâncias, os SIG têm sido cada vez mais utilizados como um importante Sistema de Apoio à Decisão Espacial (SDSS) para avaliar locais adequados. O processo de análise de decisão multicritério baseado em SIG transforma e combina dados geográficos para obter informação relevante na tomada de decisões espaciais. (JANGID, et al. 2016)

Com o advento da utilização de técnicas de sensoriamento remoto via satélite nas últimas décadas, a avaliação de recursos naturais se tornou mais eficiente, possibilitando a elaboração de mapas com zonas referentes ao potencial eólico para auxiliar na tomada de decisões da identificação de áreas com condições climáticas favoráveis para implantação de usinas eólicas. Se destacam pela abrangência das análises espacial e temporal dos recursos eólicos em terrenos planos, complexos e montanhosos.

3 Capítulo I: Artigo Submetido na Revista Climate Services

Zoning of wind energy production potential in Maranhão.

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Abstract

The aim of this study was to develop a methodology for using data from remote sensing to plan wind energy projects in Maranhão. Monthly data on wind speed and precipitation were used, from 2000 to 2016. Initially, data on wind speed were processed using the principal component analysis (ACP) technique. Then, the cluster analysis technique called k-Medias was used. The Mann-Kendall method was used to assess the risks of climate change in the production of wind energy. Finally, a linear regression analysis was carried out to identify the parameters for validation between the data estimated by the GLDAS base and data measured by the weather stations. Four homogeneous zones were identified, the zone with the highest values of monthly averages is in the northern region of the state on the coast. The period of greatest wind intensity was identified in the months of October and November, in these months the lowest precipitation values were observed. The analyzes of this study showed a favorable scenario to produce wind energy in the State of Maranhão.

Keywords: Energy planning, environmental modeling, remote sensing.

Introduction

Knowledge of the potential for energy production from wind speed generates information to help plan the possible establishment of energy generation projects. This is because the lack of information on favorable climatic conditions that is necessary to identify areas with greater wind potential is the main difficulty in the implementation of wind-based power generation plants.

Wind energy is considered a source of clean and renewable energy, because, unlike other leading energy resources in the world matrix, it does not release pollutants into the air during its generation. Furthermore, its natural resources (winds) are never exhausted by use; they can be continuously consumed without fear of depletion. It is worth mentioning that they contribute to a reduction in the emission of greenhouse gases, though they present economic risks related to the climatic variations. (FEITOSA et al., 2018).

Since ancient times, man has used energy to promote his own well-being and development. Without the exploitation of energy resources, it would not have been possible to achieve and build the world and society we live in today (Norman, 2018). The massive use of energy resources has become relevant since the industrial revolution. This is when, with the beginning of the use of the first steam engines, the first industries were born, and they began to use fossil fuels more intensively.

The world we live in today is intrinsically connected by a social, political, and economic environment related to the use of energy. The exploitation of energy resources, especially fossil fuels, has created new problems around the world, such as pollution, global warming, and the greenhouse effect, etc. These reasons are forcing current policies to change in the sector so that the use of fossil and non-renewable fuels is reduced, while the use of renewable resources is encouraged. (NORMAN, 2018)

The earliest records of the use of wind energy to produce electricity are from the late nineteenth century. The use of wind energy involves technology that transforms the kinetic energy of winds into electrical energy. The use of wind energy is a viable strategy that has gained worldwide popularity from the outset to the present day. International competition, coupled with years of improvement in manufacturing, research, and development, has resulted in advances in wind turbine efficiency, cost reduction, and increased production. In particular, wind energy is seen as the most promising source of renewable energy due to the benefits it offers and the production of energy from the movement of air masses that are inexhaustible (PREM 2018).

Winds comprise molecules of air that are in motion and are caused by the rotational and translational movements of the Earth as well as by the variation of atmospheric pressure resulting from changes in the Earth's surface temperature. (STEFAN 2018).

Wind behavior varies according to the geographic characteristics of each region, such as the terrain's relief, climate, latitude, and longitude. Because of this, an in-depth study is necessary to aid in the decision-making process regarding the wind power potential of a region. (PREM 2018)

This renewable energy, might be considered a clean fuel source, once does not produce gases that affects the air. In addition, the implementation of wind power plants gives rise to socioeconomic development through tourism, job creation, and the increased income of the affected communities.

The objective of this work was to identify homogeneous zones related to the potential of wind energy production in the state of Maranhão, using remote sensing techniques.

Material and methods

Study area

The state of Maranhão is in the extreme west of the Northeast of Brazil and in the extreme east of the Amazon Basin (Figure 1). The state is home to a transition area between the Cerrado and Amazon biomes. This area demonstrates high climatic variability, as well as a great deal of internationally recognized biodiversity, because it houses three RAMSAR sites (SILVA et al., 2016). A RAMSAR site is a wetland site designated to be of international importance under the Ramsar Convention.

Regarding climatic diversity, the state exhibits a warm and humid tropical climate to the northwest, typical of the Amazon region. In the Southeast, the region is marked by a warm and semi-humid tropical climate. The vegetation reflects the transitional aspects of the climate and soil conditions of the region between the Amazon (wet) and Northeast (semi-arid) regions. Varied ecosystems have developed because of these transitional features—from coastal environments with mangroves and flooded areas, to the dense ombrophilous forest that is characteristic of the Amazon (FEITOSA et al., 2018).

According to the National Energy Balance of 2016, 19.59% of the electricity generated in Maranhão comes from hydroelectric plants, 80.40% is from thermoelectric plants, and 0.01% is obtained from solar energy, sugarcane bagasse of sugar (biomass), and diesel oil. Regarding the energy generated by fossil sources, the state highlights its production of natural gas (EPE, 2016).

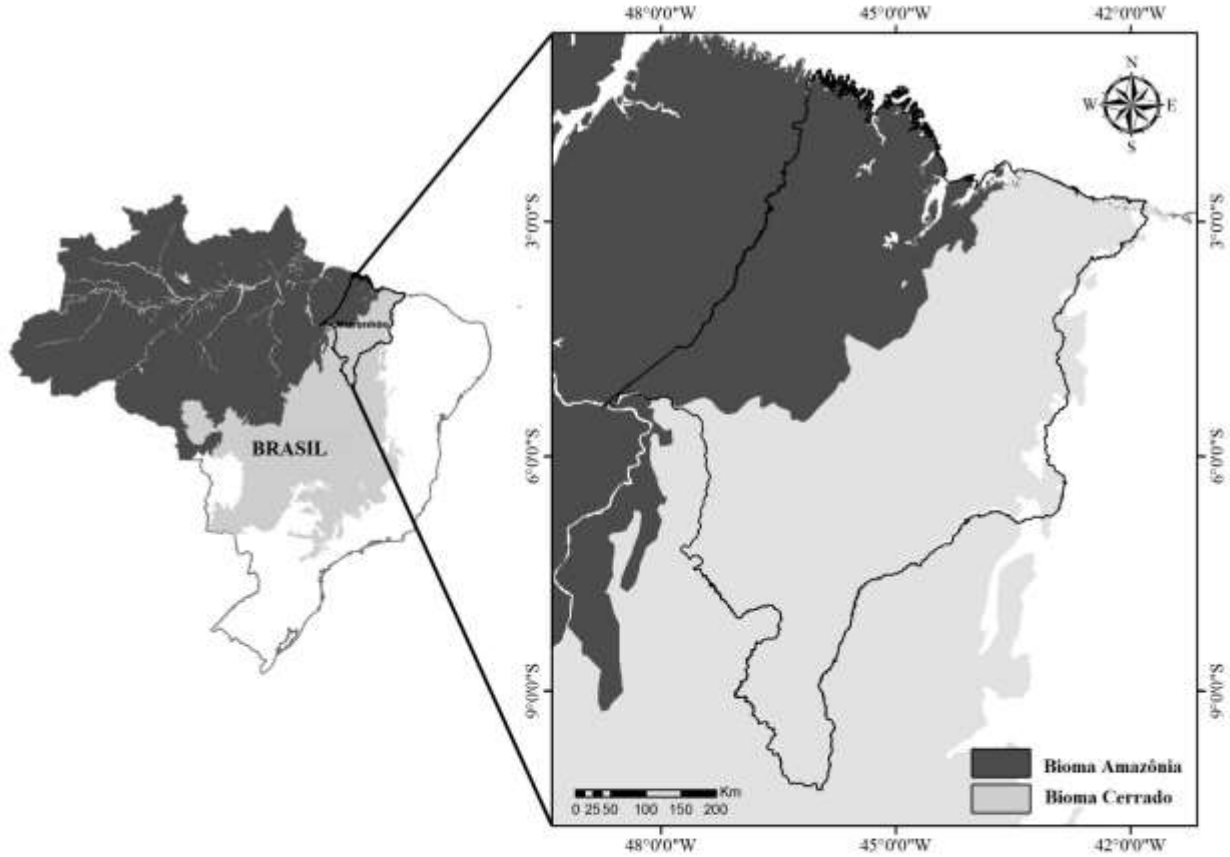

Figure 1 - Study area highlighting the location of the state of Maranhão in a transition area between the Amazon and Cerrado biomes (FEITOSA et al., 2018).

Data Acquisition, Analysis and Processing

The monthly wind speed data used in this study were obtained from the Global Land Data Assimilation System (GLDAS) database provided by the National Aeronautics and Space Administration (NASA). The data comprises 204 images as a time series over 16 years (from 2000 to 2016) with a monthly temporal resolution, and a spatial resolution of 0.25º. The validation of the data was carried out through conventional meteorological stations provided by the National Institute of Meteorology (INMET).

For data processing the software was used Quantum GIS 3.6.2. The monthly images of the wind speed from the GLDAS base composing a base of 204 images in the period from 2000 to 2016. A principal component analysis (PCA) was performed on wind speed data to reduce the dimensionality of the data and to represent the maximum spatial variability. The first image from the PCA was used to perform a cluster analysis technique known as k-means, to generate an image which is zoned according to the different classifications (homogeneous zones) of the the speed of winds (FEITOSA et al., 2018). This classification was necessary because the wind speed data exhibited maximum spatial variability.

Then, an analysis of clusters called K-Means was performed, being performed on the first component of the ACP, because it represents the maximum spatial variability. The K-Means analysis aims to generate a classified image in which it presents the classes (homogeneous zones) referring to the wind speed (MATHER e KOCH, 2010).

Linear regression analysis was used to characterize the relationship between wind speed and precipitation.

A cut time series will cover *El Niño* and *La Niña* intervals, as well as a 17-year period. To verify trends of increase or decrease in time series, a non-parametric statistical test called Mann-Kendall, recommended by the World Meteorological Organization (WMO), was used to assess trends in time series of environmental data (Yue et al., 2002) with a 10% confidence level (Kendall, 1955).

From the zones identified in the cluster analysis the monthly mean wind velocity and precipitation were calculated, thus generating the time series of each zone.

A linear regression analysis was performed to identify the parameters required to reconcile and validate the data estimated by the GLDAS database with the data measured by the meteorological stations.

To assess the amount of energy produced according to the tendency of increasing or decreasing wind speed, a model was used to simulate the production of wind energy. Carvalho (2017) described the model considering the following equation:

$$P = \frac{1}{2}\,\rho\,.\,A\,.\,V^3\,.\,A$$

Finally, a correlation analysis was carried out between the climatic data of speed and wind and the temperature indexes, the results of the meteorological stations, with the objective of verifying the relationship of the wind speed with the climatic variations that occurred over the years.

Results and discussion

Wind Speed Zoning

Figure 2 shows the result of the wind speed data processing methodology where four homogeneous zones related to wind speed were identified. Each zone is defined by a weather station that belongs to the *Instituto Nacional de Meteorologia* (INMET) from the municipality located in its respective zone. In the case of Zone 4, the municipality established is São Luís and the entire coastal region of the state. Chapadinha and the entire region of Baixo Parnaiba are in Zone 3. Zone 2 is in Balsas, as well as the southern region. And Zone 1 with the city of Imperatriz and most of the Amazon Biome within Maranhão.

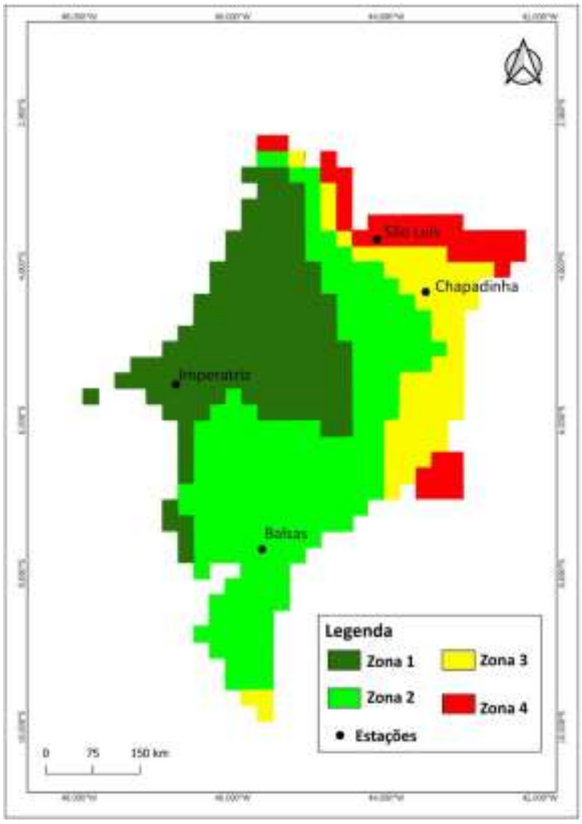

Figure 2 - Wind speed zoning map in Maranhão.

Initially, the main component analysis technique (PCA) was applied to reduce the dimensionality of the data and use the maximum spatial variation. Then, the application of the cluster analysis technique called k-medias generated a map composed of four Zones (classes). Through the analysis it was possible to perceive that the north of the State (zone 4) is the zone most favored by the climatic conditions, due to the coastal position. Zone 3, located in the east of the state, was the second region with the most predominance of winds due to its proximity to the Brazilian caatinga, as well as low levels of precipitation. While in the center-south region, two zones with lower values (Zones 2 and 1) were identified, one in the central part (Cerrado Biome) and another in the west (Amazon Biome) due to the high concentration of vegetation.

The time series of precipitation and wind speed were calculated considering the zones identified.

The highest wind speed value was identified in zone 4 with an average of 4.24 m/s and the lowest wind speed value was found in zone 1 with an average of 1.25 m/s (table 1).

Table 1. Maximum and minimum values of wind speed (m / s) in each identified zone.

	Month	**Min**	**Month**	**Max**
Zone 1	March	1.25	September	1.92
Zone 2	March	1.48	August	2.65
Zone 3	**April**	**1.82**	August	2.97
Zone 4	April	2.47	**October**	**4.24**

Table 2 shows the wind speed values over the studied time series (2000 to 2016) in Zone 1. Considering the annual average, in 2000 (0.84 m/s) the lowest values were observed and the highest occurred in 2010 and 2012 (1.36 m/s).

Table 2: Monthly variation of wind speed (m / s) in Zone 1 from 2000 to 2016.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual average
2000	0,67	0,61	0,63	0,61	0,94	1,00	0,96	1,25	0,80	0,92	0,79	0,96	**0,84**
2001	0,75	0,76	0,70	0,78	0,97	1,21	1,47	1,76	1,37	1,15	1,20	0,98	**1,09**
2002	1,14	1,14	1,19	1,10	1,18	1,38	1,49	1,62	1,42	1,37	1,29	1,12	**1,29**
2003	1,20	1,12	1,12	1,13	1,32	1,39	1,74	1,43	1,56	1,27	1,15	1,25	**1,31**
2004	0,97	1,07	1,19	1,30	1,45	1,69	1,67	1,67	1,64	1,33	1,36	1,06	**1,37**
2005	1,09	1,02	0,97	1,15	1,38	1,53	1,72	1,68	1,54	1,42	1,27	1,02	**1,32**
2006	1,08	1,10	1,05	0,86	1,08	1,62	1,66	1,67	1,52	1,27	1,17	1,13	**1,27**
2007	1,15	0,97	0,99	0,98	1,26	1,54	1,49	1,80	1,78	1,50	1,39	1,08	**1,33**
2008	0,95	0,96	0,89	0,96	1,08	1,43	1,66	1,71	1,69	1,66	1,36	1,05	**1,28**
2009	0,98	1,00	1,07	0,84	0,97	1,38	1,51	1,71	1,67	1,34	1,40	1,13	**1,25**
2010	1,04	1,08	1,15	1,00	1,14	1,61	1,65	1,81	1,83	1,51	1,34	1,15	**1,36**
2011	0,99	0,95	1,04	0,93	1,34	1,63	1,73	1,75	1,84	1,40	1,33	1,26	**1,35**
2012	1,20	1,10	1,13	1,25	1,39	1,47	1,65	1,92	1,65	1,38	1,15	1,09	**1,36**
2013	1,06	1,00	1,06	1,08	1,23	1,41	1,48	1,63	1,49	1,45	1,20	1,21	**1,27**
2014	1,11	0,99	1,02	1,02	1,22	1,60	1,72	1,70	1,60	1,47	1,27	1,27	**1,33**
2015	1,12	1,01	0,98	1,01	1,20	1,43	1,42	1,58	1,48	1,37	1,29	1,33	**1,27**
2016	1,14	1,23	0,97	1,07	1,20	1,39	1,45	1,51	1,26	1,26	1,22	1,14	**1,24**
Monthly average	**1,04**	**1,01**	**1,01**	**1,00**	**1,20**	**1,45**	**1,56**	**1,66**	**1,54**	**1,36**	**1,24**	**1,13**	**1,27**

Table 2 shows the wind speed values over the studied time series (2000 to 2016) in Zone 2. Considering the annual average, in 2000 (1.12 m/s) the lowest values were observed and the highest occurred in 2012 (1.71 m/s).

Table 3: Monthly variation of wind speed (m / s) in Zone 2 from 2000 to 2016.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual average
2000	0,85	0,80	0,80	0,77	1,05	1,15	1,11	1,47	1,23	1,34	1,51	1,39	**1,12**
2001	1,09	1,00	0,99	1,02	1,14	1,35	1,62	2,05	1,80	1,63	1,52	1,38	**1,38**
2002	1,29	1,42	1,36	1,24	1,36	1,57	1,68	1,81	1,80	1,67	1,59	1,39	**1,52**
2003	1,53	1,28	1,26	1,27	1,44	1,50	1,89	1,73	1,94	1,85	1,64	1,68	**1,58**
2004	1,28	1,20	1,24	1,33	1,54	1,83	1,86	1,93	1,94	1,92	1,94	1,64	**1,64**
2005	1,43	1,26	1,15	1,27	1,52	1,60	1,81	1,87	1,91	1,91	1,79	1,42	**1,58**
2006	1,44	1,40	1,35	1,05	1,27	1,79	1,81	1,82	1,83	1,63	1,51	1,54	**1,54**
2007	1,54	1,13	1,25	1,15	1,30	1,57	1,63	2,03	2,04	2,01	1,94	1,55	**1,59**
2008	1,29	1,35	1,11	1,10	1,22	1,45	1,75	1,86	2,05	2,03	1,77	1,52	**1,54**
2009	1,41	1,31	1,28	1,03	1,11	1,46	1,57	1,92	2,10	2,08	2,05	1,75	**1,59**
2010	1,44	1,47	1,45	1,20	1,24	1,63	1,73	2,00	2,13	1,88	1,78	1,59	**1,63**
2011	1,30	1,22	1,25	1,14	1,58	1,85	2,00	2,01	2,22	1,91	1,87	1,80	**1,68**
2012	1,63	1,51	1,46	1,48	1,64	1,66	1,92	2,25	2,01	1,85	1,63	1,48	**1,71**
2013	1,39	1,39	1,38	1,33	1,42	1,55	1,69	1,91	1,96	1,91	1,59	1,67	**1,60**
2014	1,45	1,30	1,37	1,30	1,38	1,73	1,89	2,00	1,96	1,85	1,77	1,68	**1,64**
2015	1,52	1,40	1,23	1,28	1,42	1,63	1,77	1,90	1,90	1,90	1,79	1,80	**1,63**
2016	1,50	1,54	1,29	1,39	1,44	1,68	1,79	1,87	1,73	1,72	1,63	1,47	**1,59**
Monthly average	**1,37**	**1,29**	**1,25**	**1,20**	**1,36**	**1,59**	**1,74**	**1,91**	**1,92**	**1,83**	**1,72**	**1,57**	**1,56**

Table 3 presents the wind speed values over the studied time series (2000 to 2016) in Zone 3. Considering the annual average, in 2000 (1.52 m/s) the lowest values were observed and the highest occurred in 2012 (2.30 m/s).

Table 4: Monthly variation of wind speed (m/s) in Zone 3 from 2000 to 2016.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual average
2000	1,06	1,04	1,03	1,06	1,45	1,73	1,80	2,12	1,70	1,87	1,78	1,59	**1,52**
2001	1,30	1,14	1,17	1,32	1,43	2,14	2,45	2,94	2,25	1,92	1,74	1,68	**1,79**
2002	1,59	1,59	1,60	1,54	1,82	2,45	2,37	2,60	2,19	2,13	2,02	1,67	**1,96**
2003	1,65	1,60	1,47	1,56	1,95	2,19	2,67	2,27	2,53	2,28	1,93	1,91	**2,00**
2004	1,54	1,44	1,46	1,65	1,97	2,53	2,50	2,56	2,55	2,20	2,27	1,93	**2,05**
2005	1,55	1,53	1,32	1,63	2,11	2,32	2,48	2,46	2,40	2,29	2,03	1,75	**1,99**
2006	1,76	1,51	1,50	1,24	1,69	2,55	2,46	2,45	2,31	2,00	1,87	1,83	**1,93**
2007	1,70	1,37	1,63	1,43	1,72	2,22	2,25	2,83	2,71	2,51	2,22	1,83	**2,04**
2008	1,52	1,52	1,29	1,35	1,65	2,11	2,49	2,46	2,61	2,62	2,19	1,76	**1,96**
2009	1,67	1,49	1,45	1,24	1,53	1,93	2,09	2,51	2,38	2,28	2,20	1,96	**1,89**
2010	1,60	1,63	1,54	1,55	1,49	2,23	2,52	2,68	2,83	2,24	2,01	1,84	**2,01**
2011	1,50	1,38	1,38	1,46	2,26	2,54	2,87	2,80	3,20	2,53	2,45	2,12	**2,21**
2012	2,03	1,96	1,75	1,88	2,21	2,34	2,86	3,34	2,89	2,54	1,97	1,79	**2,30**
2013	1,72	1,76	1,62	1,79	1,96	2,19	2,53	2,79	2,85	2,53	2,08	2,00	**2,15**
2014	1,83	1,76	1,68	1,67	1,99	2,57	2,88	2,93	2,75	2,63	2,21	2,08	**2,25**
2015	1,90	1,79	1,57	1,57	2,02	2,41	2,62	2,71	2,47	2,50	2,17	2,24	**2,16**
2016	1,87	2,07	1,71	1,88	1,96	2,28	2,58	2,63	2,38	2,36	2,15	1,97	**2,15**
Monthly average	**1,63**	**1,56**	**1,48**	**1,52**	**1,83**	**2,28**	**2,50**	**2,65**	**2,53**	**2,32**	**2,08**	**1,88**	**2,02**

Table 4 presents the values of wind speed over the studied time series (2000 to 2016) in Zone 4. Considering the annual average, in 2000 (1.89 m/s) the lowest values were observed and the highest occurred in 2014 (2.77 m/s).

Table 5: Monthly variation of wind speed (m/s) in Zone 4 from 2000 to 2016.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual average
2000	1,42	1,31	1,26	1,22	1,60	1,93	1,92	2,37	2,16	2,55	2,63	2,35	**1,89**
2001	1,76	1,51	1,49	1,56	1,81	2,45	2,78	3,29	2,70	2,68	2,65	2,77	**2,29**
2002	2,04	2,25	2,18	2,00	2,20	2,74	2,75	2,95	2,70	2,75	2,65	2,28	**2,46**
2003	2,21	1,92	1,89	1,89	2,11	2,31	2,82	2,46	2,80	2,72	2,47	2,53	**2,34**
2004	1,91	1,69	1,75	1,83	2,05	2,67	2,61	2,79	2,80	2,78	2,77	2,59	**2,35**
2005	2,13	1,95	1,70	1,87	2,22	2,49	2,70	2,74	2,77	2,86	2,55	2,13	**2,34**
2006	2,11	1,91	1,77	1,39	1,88	2,84	2,72	2,75	2,67	2,48	2,37	2,38	**2,27**
2007	2,27	1,63	1,93	1,67	1,98	2,48	2,41	3,15	3,11	3,03	2,87	2,43	**2,41**
2008	1,97	1,94	1,49	1,55	1,84	2,21	2,66	2,56	2,91	3,05	2,68	2,30	**2,26**
2009	2,16	1,86	1,85	1,45	1,55	2,17	2,31	2,74	2,86	2,90	2,85	2,60	**2,28**
2010	1,91	2,01	1,93	1,81	1,73	2,43	2,63	2,92	3,09	2,68	2,61	2,41	**2,35**
2011	1,94	1,77	1,81	1,70	2,63	2,86	3,17	3,01	3,41	3,01	3,02	2,88	**2,60**
2012	2,63	2,49	2,17	2,17	2,50	2,53	3,11	3,65	3,35	3,17	2,84	2,47	**2,76**
2013	2,31	2,47	2,35	2,28	2,39	2,59	2,80	3,21	3,36	3,21	2,66	2,73	**2,70**
2014	2,40	2,28	2,25	2,13	2,24	2,94	3,24	3,39	3,24	3,28	2,90	2,83	**2,76**
2015	2,59	2,35	2,06	2,07	2,40	2,86	3,22	3,34	3,08	3,17	3,00	3,06	**2,77**
2016	2,38	2,45	2,16	2,35	2,35	2,83	3,09	3,12	3,01	3,02	2,87	2,52	**2,68**
Monthly average	**2,13**	**1,99**	**1,88**	**1,82**	**2,09**	**2,55**	**2,76**	**2,97**	**2,94**	**2,90**	**2,73**	**2,54**	**2,44**

Wind Speed Seasonality

Figure 7 shows the average monthly wind speed (m / s) and precipitation (mm / h) values estimated over the year. The highest values of wind speed identified occur between October and November, during this period the lowest precipitation values were identified. In April, the minimum values of wind speed are verified (rainy season), consequently, in these months the maximum values of precipitation occur. In general, the climatic variable wind speed is inversely proportional to precipitation, since in the dry season the wind speed is higher. These differences are related to variations in the sun's declination throughout the year, which is associated with a set of astronomical factors such as the translation movement and the inclination of the Earth's axis (KRISHNAMURTHY 2018).

Through the comparison between the data of wind speed and precipitation it was possible to perceive that the maximum values of the wind speed were observed in the dry season and the minimum values in the rainy season, where possibly the cloudiness can explain this variation (PREM KC, 2018).

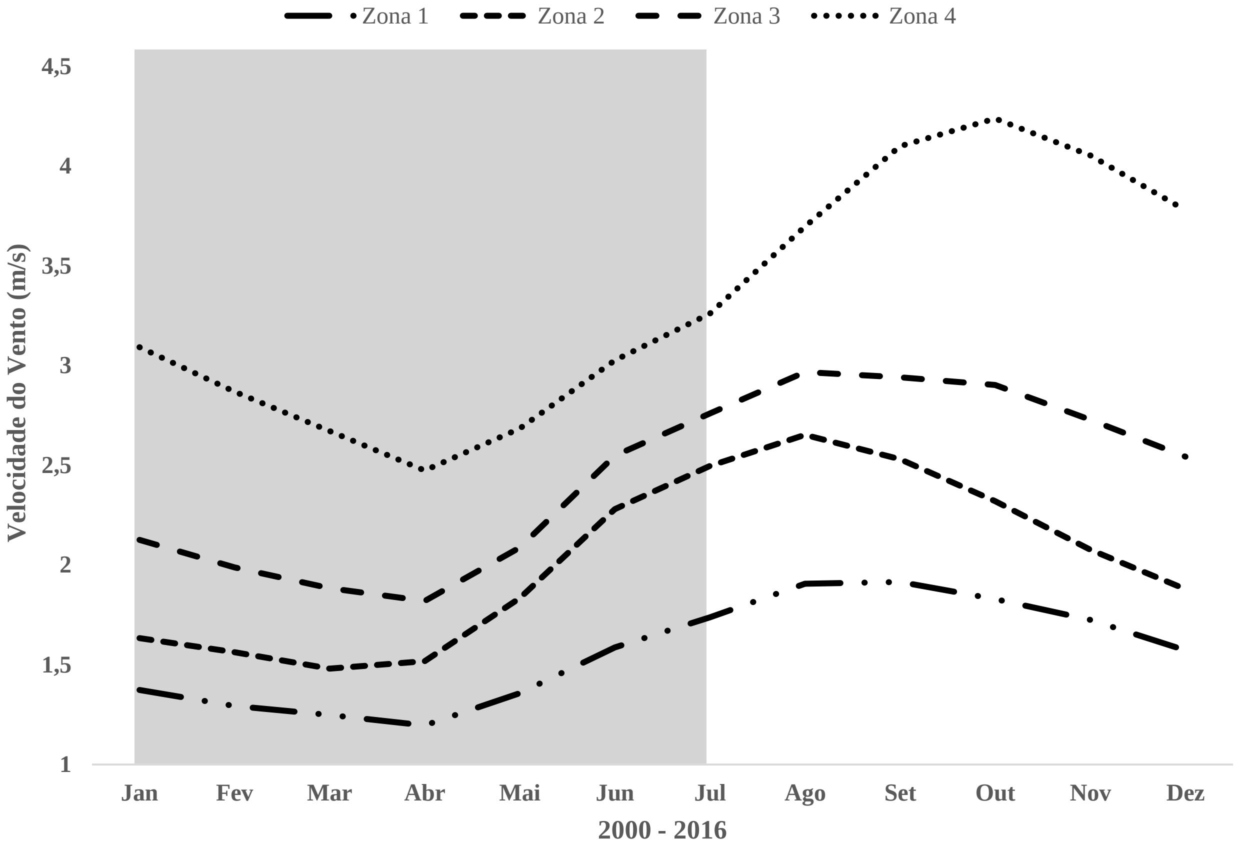

Figure 3 - Variation of monthly wind speed averages, highlighting the rainy season.

The area with the highest winds is located in the north of the state due to two factors: the influence of the sea—primarily the temperature variation between the continent and the ocean resulting in “sea breezes” and “land breezes”, and the proximity to the equator line, where are the trade winds.

Trend analysis

Using the Mann Kendall method, the wind speed data and the analyzed records were used. For trends, such as trends shown negative, but with a small and non-significant linear trend (p> 0.1). Hastenrath & Greischar (1993) and Silva et al. (1998) also did not identify significant trends in precipitation in the northeastern region of Brazil for wet and dry seasons. However, precipitation in this region is quite sensitive to extreme values of sea surface temperature in the Equatorial Pacific associated with ENOS, such as anomalies in the surface temperature of the Atlantic Ocean related to anomalies in the dipole temperature of the surface of the Atlantic Ocean (Moura & Shukla 1981).

About the annual wind speed in relation to the months (table 5), the trends were positive (with a common direction) and significant (p <0.1). For the analysis of the annual wind speed in Zone 1, the test showed a standard deviation of 28.1%, the minimum value was 0.605 m/s and the maximum were 1.915 m/s. For Zone 2, there was a standard deviation of 30.5%, 2.246 m/s the minimum value and 0.774 m/s, the maximum value. In zone 3, there was a standard deviation of 47.4%, the minimum value identified was 1.02 m/s, and the maximum was 3.34 m/s. Zone 4 has a standard deviation of 50.9%, with a maximum of 3.64 m/s and a minimum of 1.22 m/s.

The trend analyzes showed that the wind speed has been increasing over the 16 years studied, in relation to the analysis of precipitation, small decreasing trends were identified, but not significant.

Table 6 - Linear trends and significance for each zone and wind speed period using the Mann Kendall test.

Zone	Duration		Yearly	
	Start	End	Linear Trend	Kendall's tau
1	2000	2016	0,004	0,134
2	2000	2016	< 0,0001	0,190
3	2000	2016	< 0,0001	0,212
4	2000	2016	< 0,0001	0,257

Simulation of wind energy production in Maranhão

The wind turbine used as a model for storing the energy generated in each Zone, is manufactured by GE Renewable Energy in Brazil, has a capacity of 4MW and a rotor of 70 meters. From the simulation model of wind energy production, it was possible to identify that, for all the years analyzed, the total energy production was higher in the coastal region than in the interior of the state.

In figure 4, the minimum wind speed values were identified in April with 40.051,1 MWh (rainy season) and the maximum in October with 180,140 MWh (dry season).

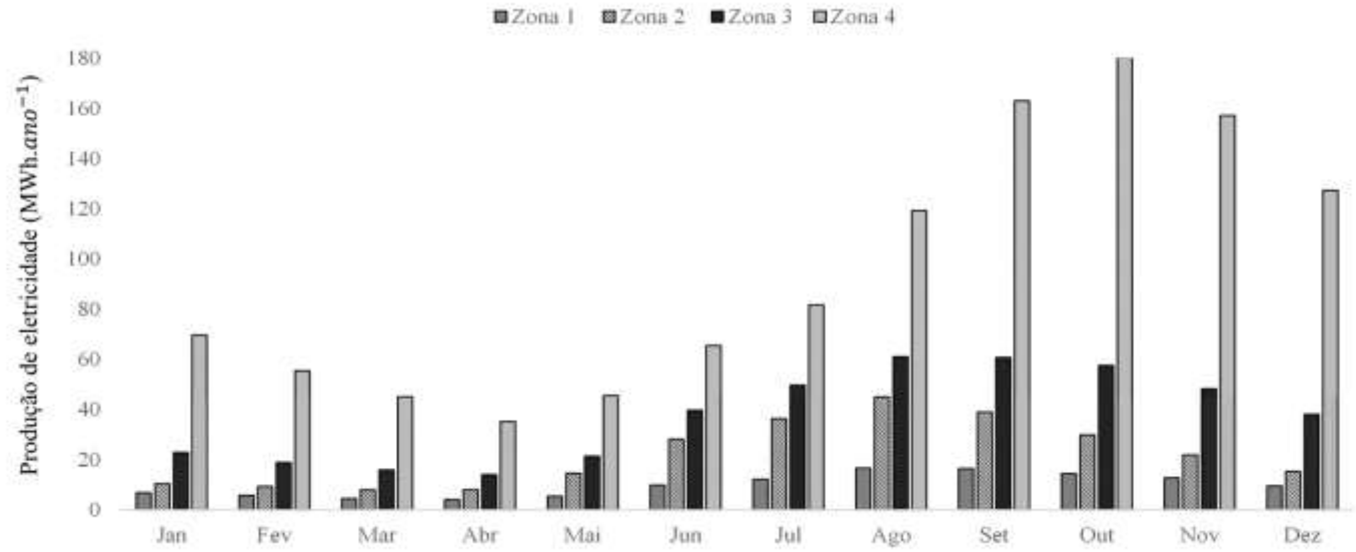

Figure 4. Simulation of the annual average electricity production from 2000 to 2016 in the 4 areas studied.

Climate Risks

Considering the correlation between precipitation and wind speed, wind speed values decrease with increasing precipitation values. According to an annual analysis, precipitation represented 50.1% of variation in the wind speed data in zone 1 (r2 = 0.5018).

In relation to the annual series, each 10 mm increase in precipitation data/month corresponded to a decrease of 1.46 m/s, producing 7,366 kWh less in power generation in zone 1 (Figure 5).

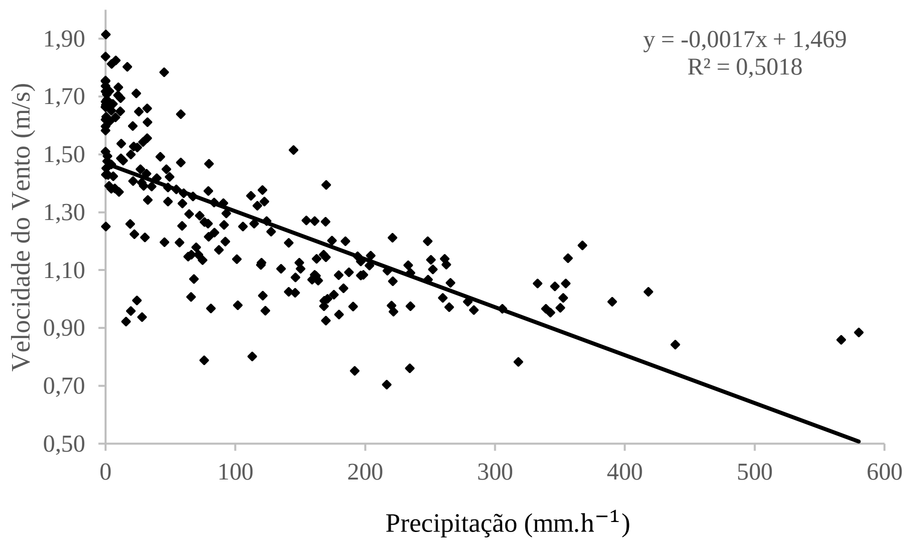

Figure 5 - Correlation of wind speed with precipitation in Zone 1.

In zone 2, in the annual period analyzed, precipitation accounted for 23.7% (r2 = 0.2375) of the variation in wind speed values. Analyzing these correlations, in the cerrado region, for every 10 mm increase in precipitation / month, a decrease of 1.69 m / s was estimated, producing 11,424 kWh less in energy generation (Figure 6).

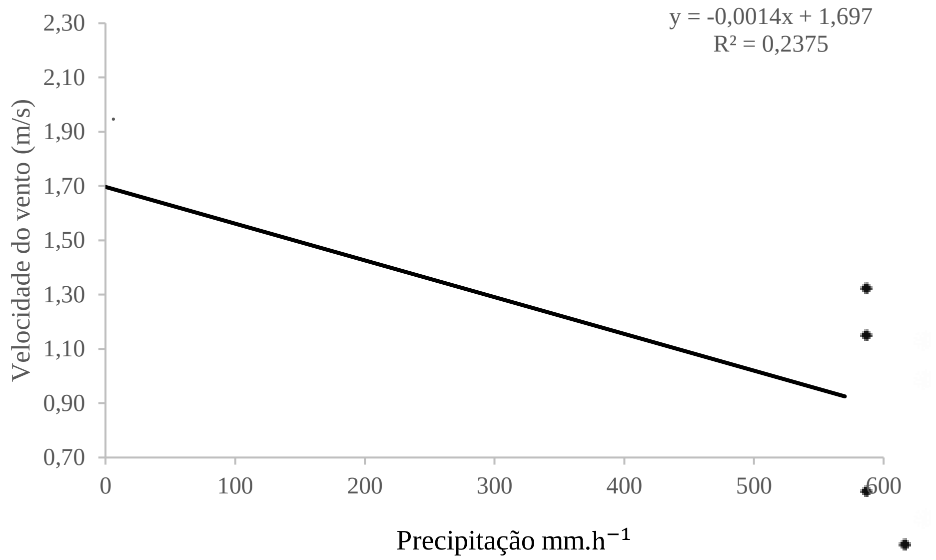

Figure 6 - Correlation of wind speed with precipitation in zone 2.

In zone 3, in the annual period analyzed, precipitation accounted for 52.5% (r2 = 0.5254) of the variation in wind speed values. Analyzing these correlations, in the cerrado region, for every 10 mm increase in precipitation / month, a fall of 2.32 m / s was estimated, producing 29,555 kWh less in energy generation (Figure 7).

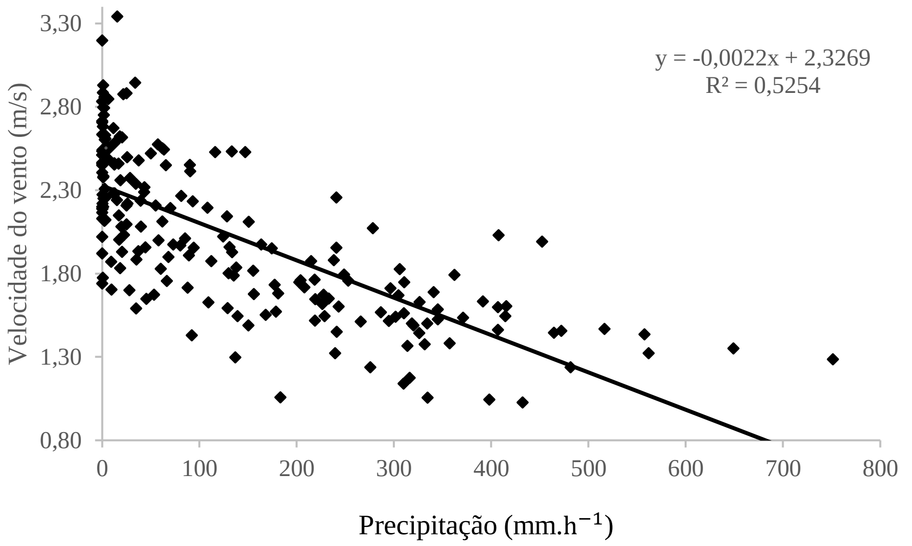

Figure 7 - Correlation of wind speed with precipitation in Zone 3.

In zone 4, in the annual period analyzed, precipitation corresponded to 61.72% (r2 = 0.6172) of the variation in wind speed values. Analyzing these correlations, in the cerrado region, for every 10 mm increase in precipitation / month, a decrease of 2.80 m / s was estimated, producing 51,956 kWh less in power generation (Figure 8).

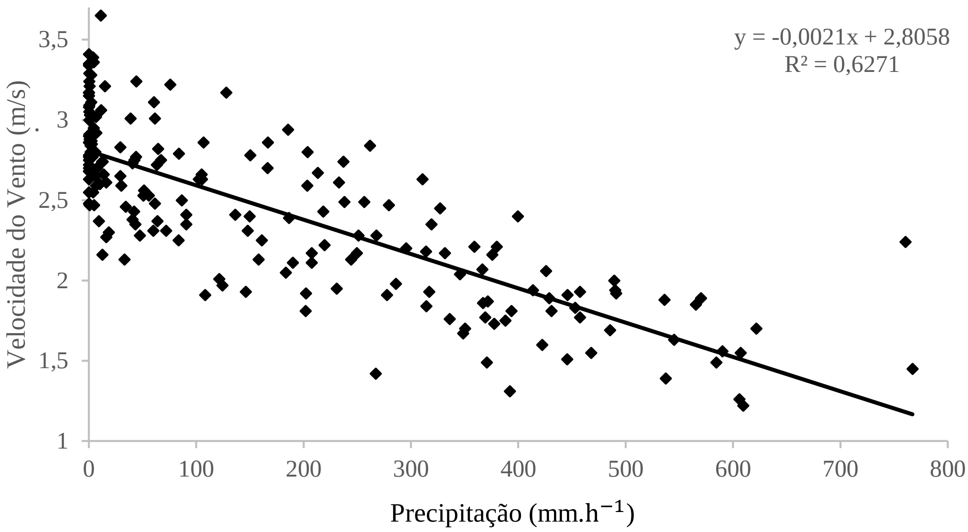

Figure 8 - Correlation of wind speed with precipitation in Zone 4.

Validation

Table 2 shows the validation between the estimated data in each zone and the data collected in each weather station. The station located in the municipality of Balsas has the highest precision with $R^2 = 0.92$. On the other hand, the Turiaçu station shows the lowest precision with $R^2 = 0.30$. From the linear regression analysis, it is possible to affirm that there is high precision of the data.

Table 7 - Parameters used for validation between the data estimated by the GLDAS base and data measured by the weather stations.

Stations	**Mean Absolute Error**	**Mean Square Error**	**Relative Quadratic Error**	**R²**
Alto Parnaíba	0,01	0,03	1,73	0,86
Bacabal	-0,27	0,16	7,87	0,62
Balsas	-0,05	0,02	1,22	**0,92**
Barra	0,23	0,09	5,97	0,86
Carolina	0,19	0,11	7,20	0,65
Caxias	-0,22	0,10	4,22	0,90
Chapadinha	-0,26	0,21	8,61	0,74
Colinas	0,11	0,07	3,43	0,87
Imperatriz	-0,04	0,68	43,85	0,74
São Luís	0,23	0,49	14,75	0,84
Turiaçu	-0,26	0,76	22,79	**0,30**
Zé Doca	-0,06	0,02	1,52	0,79
Average	-0,03	0,23	10,26	0,75

From the analysis, we realized that the north of the state (Zone 4) is the zone most favored by the climatic conditions, due to its coastal position. Zone 3, located in the eastern part of the state, was the second most favored region due to its low levels of precipitation and the low occurrence of nebulosity conditions. The south-central region had two zones that were identified with lower data values (Zones 2 and 1)—one in the central region (Cerrado biome) and one in the western region (Amazon biome).

Conclusion

According to the results obtained, it is understood that the areas most favored by the climatic conditions for the implementation of wind power plants are located in the northern region of the state, while the south-central area has the least favorable conditions. However, more research is necessary, as well as better experimental measures for wind speed assessment (such as a standard anemometer), as the parameters that were analyzed react differently to astronomical and climatic conditions.

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4 CONCLUSÕES

De modo geral, conclui-se que as áreas mais favorecidas pelas condições climáticas para implantação de usinas eólicas para geração de eletricidade localizam-se na região norte do Estado, enquanto no centro-sul encontram-se as áreas com condições menos favorecidas na proporção que se distancia do litoral.

No entanto, mais pesquisas são necessárias, assim como melhores medidas experimentais para avaliação da velocidade do vento (como anemômetro padrão), pois essas variáveis reagem de maneira diferentes às condições astronômicas e climáticas.

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Atividades Desenvolvidas no Período

Aprovação do artigo intitulado *“**Wind Speed Seasonality in a Brazilian Amazon-Savanna Region from the Global Land Data Assimilation System***”, pela Revista Ciência e Natura - ISSN:0100-8307, 2019.

Apresentação do trabalho intitulado “**ZONEAMENTO DA VELOCIDADE DO VENTO NO ESTADO DO MARANHÃO UTILIZANDO DADOS DA BASE CLIMÁTICA GLOBAL GLDAS**”. no XXI Simpósio Brasileiro de Sensoriamento Remoto, 2019.

Comissão de organização do “**III Fórum de Meio Ambiente do Maranhão**”, 2019.

Curso “**Uso de geotecnologias para identificação de conflitos hídricos em bacias hidrográficas**” ministrado no III Fórum de Meio Ambiente do Maranhão, 2019.

Pós-graduação em **Georreferenciamento de Imóveis Rurais** pela Faculdade Unyleya, 2020.

ANEXO A: Aprovação de artigo pela Revista Ciência e Natura

ciência e natura
Revista do Centro de Ciências Naturais e Exatas

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Santa Maria, RS, 24 de março de 2020.

CARTA DE ACEITE

Declaro para os devidos fins, que o artigo intitulado ***Wind Speed Seasonality in a Brazilian Amazon-Savanna Region from the Global Land Data Assimilation System*** *de autoria de* ***Leonardo Henrique de Sá Rodrigues, Marcos Aurélio Alves Freitas, Luan Victor Soares Pereira, Brunna Caroline Correia Dias, Vicente Marques Silvino, Janaque Nunes Passinho e Fabrício Brito Silva****, foi* ***ACEITO*** *para publicação na Revista Ciência e Natura da Universidade Federal de Santa Maria, RS.*

Prof. Marcelo Barcellos da Rosa
(Editor-chefe Ciência e Natura)

e- ISSN *2179-460X*, ISSN *0100-8307*, DOI *10.5902/2179460X*

ANEXO B: Atestado de apresentação no XIX Simpósio Brasileiro de Sensoriamento Remoto.

XIX SBSR

Simpósio Brasileiro de Sensoriamento Remoto

ATESTADO

Atestamos que no XIX Simpósio Brasileiro de Sensoriamento Remoto, realizado no período de 14 a 17 de abril de 2019, em Santos, SP, Brasil, foi apresentado o trabalho:

ZONEAMENTO DA VELOCIDADE DO VENTO NO ESTADO DO MARANHÃO UTILIZANDO DADOS DA BASE CLIMÁTICA GLOBAL GLDAS.

Leonardo Henrique Sá Rodrigues, Fabricio Brito Silva, Luan Victor Pereira de Sousa, Pedro Henrique Modesto de Aguiar , Marcos Aurélio Alves Freitas, Brunna Caroline Correia Dias

na sessão: Meteorologia e climatologia

Apresentador(a): Leonardo Henrique Sá Rodrigues

Santos, 17 de abril de 2019.

Douglas F. M. Gherardi
Coordenador do SBSR

Ieda Del'Arco Sanches
Coordenadora do SBSR

Luiz Eduardo O.C. Aragão
Coordenador do SBSR

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ANEXO C: Declaração de conclusão do curso de Pós-graduação em Georreferenciamento de Imóveis Rurais.

FACULDADE
Unyleya

DECLARAÇÃO

Declaramos para os devidos fins que **LEONARDO HENRIQUE DE SA RODRIGUES**, CPF n° 054.856.633-03, concluiu com aproveitamento satisfatório o curso de Pós-Graduação *Lato Sensu* em **GEORREFERENCIAMENTO DE IMÓVEIS RURAIS**, com início em 27 de abril de 2019 e término em 09 de julho de 2020.

A carga horária do curso é de 460 horas e atende à Resolução CNE/CES n° 01, de 6 de abril de 2018.

Os cursos de pós-graduação *Lato Sensu* oferecidos estão em conformidade com a legislação vigente e com o credenciamento do Ministério da Educação – MEC, concedido por meio da Portaria n.º 1.663 de 5 de outubro de 2006, Portaria SESu nº 727 de 31 de março de 2011 e recredenciamento pela Portaria nº 721 de 20 de julho de 2016.

Informamos que o processo de certificação encontra-se em andamento e que o Certificado de Conclusão de Curso será emitido após a devida tramitação burocrática.

A Declaração tem validade de 90 (noventa) dias a contar da data de emissão.

Rio de Janeiro - RJ, 17 de Agosto de 2020

Marcos Gonçalves

Direção Acadêmica

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ANEXO D: Certificado de participação no curso "Uso de geotecnologias para identificação de conflitos hídricos em bacias hidrográficas".


CEUMA UNIVERSIDADE

Universidade do CEUMA – UniCEUMA

Ato legal de credenciamento da universidade do CEUMA: Decreto MEC S/N de 27/03/2012, publicado no Diário Oficial da União em 27/12/2012.

CERTIFICADO

Certificamos que **LEONARDO HENRIQUE DE SÁ RODRIGUES** participou do(a) **USO DE GEOTECNOLOGIAS PARA IDENTIFICAÇÃO DE CONFLITOS HÍDRICOS EM BACIAS HIDROGRÁFICAS**, realizada **no dia 20 de março de 2019**, com carga horária de **4 horas**.

São Luís-MA, 17 de julho de 2020.

Fabrício Brito Silva
Pró-Reitor de Pós-Graduação, Pesquisa e Extensão

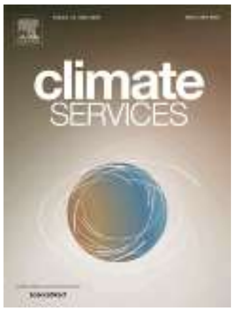
05485-20111-90709-36176-63303

ANEXO E: Normas para submissão na Revista

CLIMATE SERVICES

AUTHOR INFORMATION PACK

TABLE OF CONTENTS



ISSN: 2405-8807

DESCRIPTION

The journal *Climate Services* publishes research with a focus on science-based and user-specific climate information underpinning climate services, ultimately to assist society to adapt to climate change.
Climate Services brings science and practice closer together. The journal addresses both researchers in the field of climate service research, and stakeholders and practitioners interested in or already applying climate services. It serves as a means of communication, dialogue and exchange between researchers and stakeholders. *Climate services* pioneers novel research areas that directly refer to **how climate information can be applied in methodologies and tools for adaptation to climate change**.

It publishes best practice examples, case studies as well as theories, methods and data analysis with a clear connection to climate services. The focus of the published work is often multi-disciplinary, case-specific, tailored to specific sectors and strongly application-oriented. To offer a suitable outlet for such studies, Climate Services journal introduced **a new section in the research article type**. **The research article contains a classical scientific part as well as a section with** easily understandable **practical implications** for policy makers and practitioners.

The journal's focus is on the use and usability of climate information for adaptation purposes underpinning climate services.

The following topics are within the direct scope of the journal:
- The use of climate modelling and climate impact modelling to strengthen climate services;
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- Development of adaptation and mitigation strategies for climate services;
- Climate adaptation, governance, economic aspects and institutions in support of climate services;
- Climate services studies to identify and overcome barriers to climate change adaptation;• Evaluation of climate services;
- The role of climate communication strategies and use of climate information in decision making for climate services;
- Transdisciplinary stakeholder dialogues in connection with climate services; and
- Discussion of current practices (both regarding value creation and value protection - or risks and opportunities) and corresponding recommendations for climate services.

Climate Services, together with its excellent board members, aims to publish high-quality, novel and groundbreaking research pioneering the relatively new field of climate services. The journal ensures its high quality by a thorough peer review process, following international peer review standards. We invite all people working in the field of climate services to consider publishing their work, research results and experiences in the Climate Services journal.

In case you have questions, please don not hesitate to contact us; jclimateservices@hzg.de

What do we mean with climate services?
The journal adopted the definition of climate services from the European Commission's Roadmap for Climate Services (2015). According to this definition climate services cover *"the transformation of climate-related data - together with other relevant information - into customized products such as projections, forecasts, information, trends, economic analysis, assessments (including technology assessment), counselling on best practices development and evaluation of solutions and any other services in relation to climate that may be use for the society at large."*
Hence climate services providers develop science-based and user-specific information relating to past, present and potential future climate and therefore assists society to adapt to climate variability and change. Information about climate, climate change, and impacts on natural and human systems as well as mitigation and adaptation strategies is tailored to the specific user requirements. Climate service users include economic, administrative, political and scientific stakeholders, across sectors and disciplines in society.

Complementary journal
Intending authors should also note that there is a complementary journal: Climate Risk Management. *Climate Risk Management* focuses on the observation of relationships between climate conditions and consequences in human and/or natural systems across multiple space and time scales; risk assessment and risk management approaches for climate-sensitive sectors such as agriculture, forestry and fire management, health, mining, natural resources management, water management, the built environment, and tourism; analysis of relevant institutional developments and arrangements relevant to adaptation; and the exploration of connections between climate risk management, disaster risk management, and sustainable development.

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Man-environment systems from the perspective of environmental impacts and risks of rural and urban land use as well as their societal management and governance, covers the interrelations between process and system simulation, foresight, evaluation, decision support and management strategies of regional and local actors

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Climate change impact, hydrological cycle, rivers, water resources, climate change

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Climate Service research papers report the results of original research and its (potential) application. The article consists of a scientific research paper and an additional Practical Implications chapter.

In the **research paper** (max. 8,000 words excluding references) the scientific background to climate services is provided, consisting, e.g., of the description of methods, models, newly developed theories or the analysis of data.

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