International Journal of Multidisciplinary and Current Research ISSN: 2321-3124
Research Article Available at: http://ijmcr.com

Mapping of Wind Resources in different Geographical regions of Togo for 10m and 80m agl

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Receiver 02 May 2017, Accepted 01 July 2017, Available online 03 July 2017, **Vol.5 (July/Aug 2017 issue)**

Abstract

Togo is having around 232.5MW [1] of power-installed capacity from different sources and importing about 85% of its power requirement from neighboring countries (2015) [2]. As of July 2017, no wind turbine installation existed in Togo. Current Global wind energy installed capacity is 486.8GW [3]. It is right time for Togo to go for energy production from wind, which is clean and green source of power and wind resource assessment is the precursor for wind farm development, which has not been studied till now. This paper aims to showcase a study and evaluation of the wind energy potential of Togo at 10m and 80m and develop initial Wind Resource Map for the country. As per the study of IRENA [4], Annual average wind speed of Togo is ranging from 2.35-5.67 m/s at 80m and 2.3-5.46 m/s at 10m agl. More than 34226.66 Km², that is, 60.47% of the area of Togo, corresponds to areas where the average annual wind speed at 10m agl is between 3.5-5.5 m/s. The study demonstrates that 60.47% of Togo's total area is eligible for small wind turbine installation. However, the wind speeds allow for large wind turbines installation in approximately 2% of the country's available land.

Keywords: *Wind potential, Togo Wind resource Map, Wind energy.*

1. Introduction

The Global warming and the climate change issues has been considered as one of the biggest challenge of the Century and every government is working towards mitigating by implementing different kinds of efforts. One of the major efforts is to produce power from Renewable energy sources and the energy transition from fossil fuel to green energy started happening in many countries. Today, much of the world's energy production comes from fossil sources. The use of fossil fuels leads to emissions of greenhouse gases. The growing problem of global warming, combined with the reduction of fossil fuel sources, has aroused the public authorities to combine their actions through various international meetings including the COPs, to take the decision to "contain the rise in temperatures below 2 ° C compared to pre-industrial levels and continue the action to limit the elevation to 1.5 ° C ". Faced with this situation, the exploitation of renewable energies becomes an indispensable solution. Thus, all the countries have chosen to save the planet are investing in the development of renewable energy resources. It can be expected that any future sustainable energy system will be based on the use of renewable energy sources. In its strategy of developing renewable energy sources, Togo has a vision for the use of wind energy in its energy mix.

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The use of the wind resource in the production of electricity in Togo is an objective to be achieved from 2025 [2]. This study will make it possible to reassure the government of Togo and the officials in charge for the energy sector that Togo is having favorable wind source for the production of electricity of wind. It is also drawing the attention of the government to have weather stations on certain identified wind sites favorable to initiate a comprehensive study by direct measurement of meteorological data at different heights greater than 10m. The main objective of this study is to identify wind potential of different places in Togo to contribute to produce own electric power, identifying sites conducive for the development of wind energy production.

2. Study area description and methodology

2.1 About Togo

Togo covers an area of 56 600 km^2 and has the shape of a 600 km long corridor with a base that does not exceed 60 km of border on the Atlantic. It is between latitude 6° and 11° North and longitude 0° and 2° east of the Greenwich meridian. A country of plains, rather than high mountains, the territory is crossed from the south-west to the northeast by a long chain of mountains and plateaus alternating.

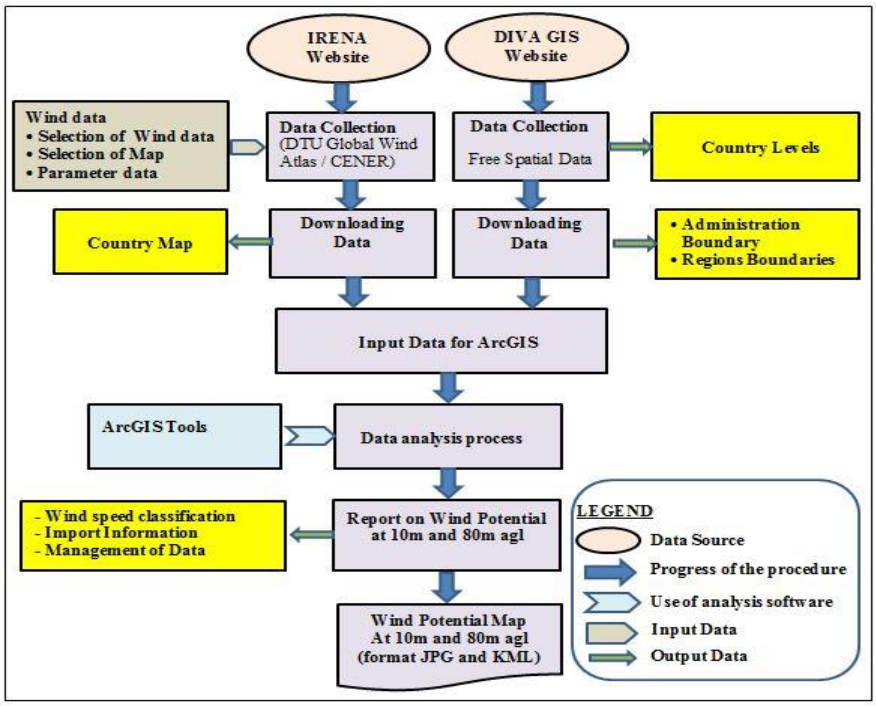

Figure 1: Methodology for data collection and analysis

Togo enjoys an inter-tropical climate due to its altitude. As regards to research on energy sources, at present, it is clear that it is devoid of non-renewable and polluting energy resources. However, it has an advantage in terms of renewable energy sources. Togo has large river network, where hydroelectric potential is estimated at 224 MW, which would correspond to an annual potential production estimated at 850 GWh[2]. Togo has significant solar potential varies from 4.4 KWh/m² to 5.5 KWh/m² with an average power density of 700 W/m². The potential of plant and organic biomass is very high due to the high proportion of the agricultural population, and more recently in 2012 the government approved to install a 25.2 MW capacity of wind power plant on 42 km^2 of unfit soil in the Lome port area[5]. Togo has not yet demonstrated its ability to use ocean energy and tidal power to produce electricity, so it can only thank the nature for its benefits. Energy consumption is increasing year after year, forcing the country to import more than 75% of its electricity consumption in 2010, compared to 85% in 2015[2].

2.2 Methodology

The data for this study has been collected from the website of the International Renewable Energy Agency (IRENA), Abu Dhabi. The data collection methodology was a series of steps that have led to the analysis and the steps of collecting meteorological data and the analyses have been presented in the diagram Figure 1. All the necessary information are compiled, recorded, tabulated and analyzed for making observations as indicated in the objectives of the study.

2.2.1 Data collection

The IRENA[4] website were accessed during May 2017 to download the data of CENER[6] for the period of three years from 2008 to 2010 and during January 2017 to download the data of DTU Global Wind Atlas[7] for the period from 1979 to 2013. The CENER output is Africa wind map, which is computed averaging 10m wind speed with the grid horizontal resolution of 10 km x 10 km and has 38 vertical levels [8]. The DTU Global Wind Atlas provides high resolution wind climatology at 80m, 100m, and 200m hub heights above the surface for the entire world. The data downloaded from CENER's data for the study, is the average annual wind speed of the ECOWAS's countries at the height of 10m with a resolution of 10km x 10km in ".tif" format. With this data, the data on the average annual wind speed of Togo at 10 m in height were extracted. The data downloaded from DTU's data is the annual average wind speed data of ECOWAS's countries at 80m with a resolution of 1km x 1km in *".tif"* format. For this study, the data relating to the average annual wind speed of Togo at 80m height was extracted.

2.2.2 Data analysis

ArcGIS (GIS software) was used to analyze the data downloaded from IRENA[9]. The input data files are in the format ".tif", this data from CENER and DTU Global Wind Atlas, respectively, is the average annual wind speed at 10m and 80m height for the ECOWAS countries. The ArcGIS software was used to extract data from the average annual speed for Togo, respectively 10m and 80m height. These data were processed using also ArcGIS tools, and then declassification of the zones of Togo, according to the average annual wind speed ranges. The data at the exit of this analysis are the wind maps of Togo at the height of 10m and 80m in JPEG image and in Google earth format.

3. Results and interpretation

The results of this study are wind maps of Togo at the height of 10m and 80m agl. These maps are represented respectively in Figures 2, 3, 4 and 5. The analysis of these maps will allow estimating the percentage of area of the Togolese territory favorable to the project of installation of wind farms. The wind maps obtained by analyzing with ArcGIS software shows that, the overall average annual wind velocities of Togo is between 2.3 - 4.72 m/s at 10m agl and 3.96 – 447 m/s at 80m agl.

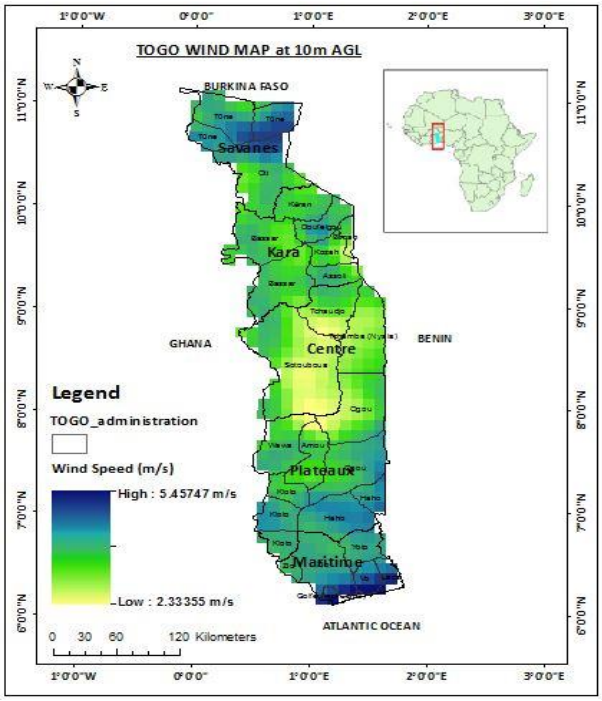

Figure 2: Togo's Wind map not classified at 10m

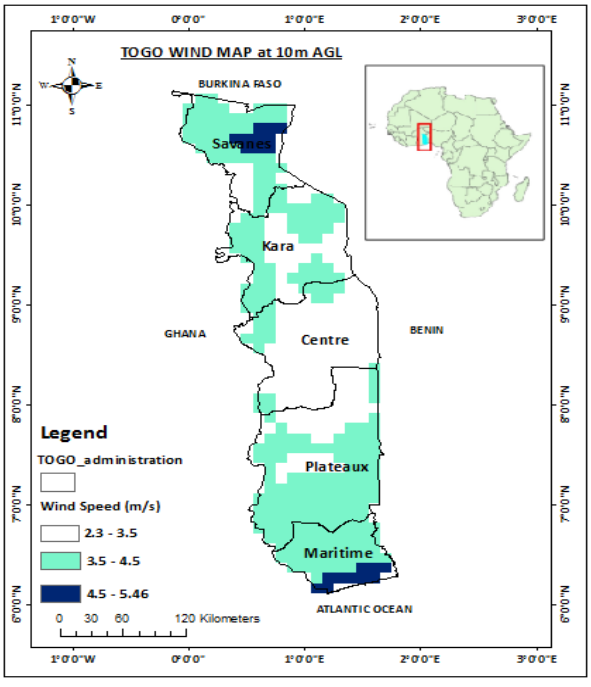

Figure 3: Togo's Wind Map reclassified at 10m

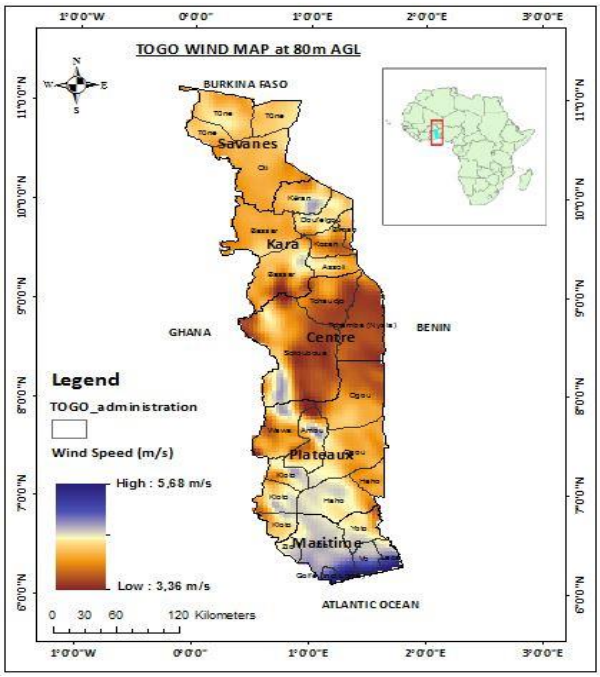

Figure 4: Togo's Wind map not classified at 80m

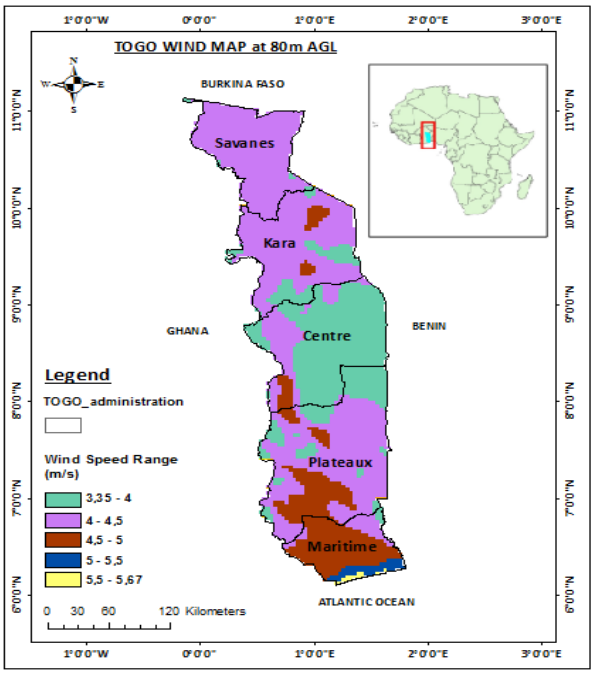

Figure 5: Togo's Wind Map reclassified at 80m

3.1 Togo wind map at 10m height

The map in Figure 2, shows the favorable zones for installation of Small Wind Turbines are indicated in the north and south of the country with average annual wind speeds of between 3.5 - 5.46 m/s and the favorable zones are estimated on the whole at more than 34226.66 Km² or 60.47% of Togo. High potential areas with average annual speeds of 4.5 - 5.46 m/s are blue colored areas in south, an estimated area of 575 km² and in north an estimated area of 544 km². The area of all high potential

areas is estimated at more than 1119 km², or 2% of Togo. The potential area indicated in the south of the country is the area along the coastline that covers the Gulf Prefecture, the southern part of the prefectures of Zio and VO and much of the prefecture of the Lakes.

3.2 Togo wind map at 80m height

The map shown in Figure 3, there is only a small favorable zone for the installation of Large Wind Turbines and this area indicated is located in the south of the country which is along the coastline with average annual wind speeds of between 5.0 - 5.67 m/s. The estimated surface area of less than 575 km² covering the large southern part of the Gulf Prefecture, South of the prefectures of Zio and of VO and the great southern part of the prefecture of the Lakes.

3.3 Suggestions for future studies

Today, in Togo, there are more than nine weather stations for the agricultural sector (Dapaong, Mango, Kara, Sokode, Sotouboua, Atakpame, Kouma Konda, Tabligbo and Lome Airport)[10]. The stations are with a height of 10m and can allow a study of wind potential on many sites in Togo, established in order to have a long-term meteorological database to study wind potential in Togo. It is therefore desirable that the Ministry in charge of Energy and the Ministry in charge of Agriculture together define the locations for the installation of these meteorological stations, which will be used for recording the wind data over a period of minimum one year. These stations are to provide a reliable database for optimal analysis and the proposed installation location for agricultural weather stations are provided in Figure 6.

The above study and analysis clearly indicates a reasonable wind potential at 10m height, which may be used for deployment of Small Wind Turbines for domestic use. Very little sites in the extreme southern part of the country are having acceptable wind potential for the installation of Large Wind Turbines at 80m height to go for economically viable wind projects.

The above study may be used for initial estimation for the large area screening for wind potential of the country. The result will be very useful for the government to plan and establish rule and guideline for countrywide wind power projects. Based on the result it is found that the southern tip of the country, which is costal area, is showing an annual average wind speed of more than 5 m/s, which leads to assume the fair possibility for good offshore wind projects. However, a detailed study has to be done before actually going for the wind farm projects.

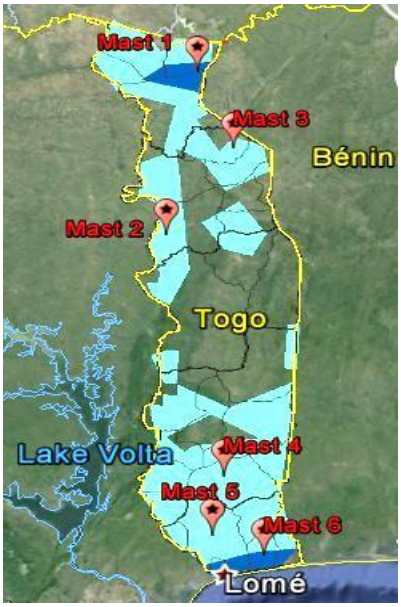

Figure 6: Agriculture Wind Mast location

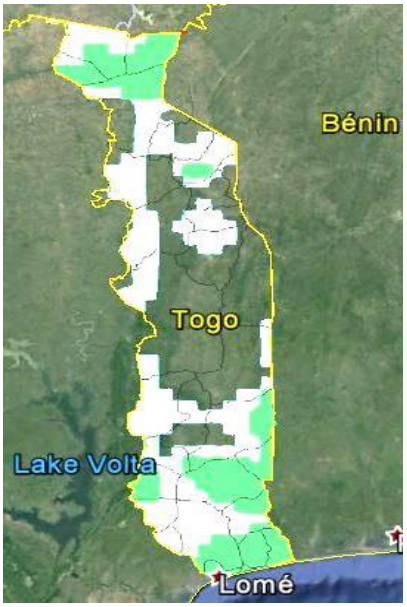

Figure 7: Map of areas favorable to micro-wind installations at 10m

The map shown in Figure 7, is the map of areas in Togo in which micro wind turbine technology is possible. The green parts on this map correspond to the zones in which the average annual wind speed at 10m agl is between 4.0 - 5.5 m/s and is estimated at more than 8928 Km² i.e 20.17% of the area of Togo.

Togo uses mostly petroleum products as primary sources for its own electricity production. By signing, in September 2016 in New York, the Agreement resulting from the United Nations Climate Conference - COP 21 - held in December 2015 in Paris[11], Togo demonstrates its spirit to combat climate change. The energy department in Togo has a mission to develop renewable energies to increase their share in the country's energy mix. This study will contribute to the improvement of the

knowledge about the wind potential of Togo. It is therefore possible to use wind turbine technology in Togo. To demonstrate the feasibility, the mapping of Togo's wind characteristics at 10 m and 80 m height above the ground level, has been done. An analysis of the results shows that Togo has a significant wind potential and has zones where the development of micro-wind technology is possible with little possibilities for installation of large wind turbine at higher heights.

Conclusion

In Togo, a study of the wind potential of the whole territory has not been done until today, because Togo is classified among the less windy countries, where no prospect of use of wind turbine technology is conceivable. According to this study, a contribution to the improvement of the knowledge of wind potential throughout the Togolese territory has been done. It should be noted that the overall mapping of the winds at 10 m and 80 m height above ground level in Togo was carried out. This study has shown that overall Togo is dominated by winds of average speed of 2.33 to 5.57 m/s throughout its territory. This study is part of a process to estimate wind potential in Togo and therefore a contribution to the assessment of wind potential across the country. Moreover, it is important to be able to quantify the wind potential at the height of 10m to decide on a possible use of wind turbines on the territory.

Acknowledgment

M. Samah Bawong TCHODOU, the main author would like to thank NAM S&T Centre, New Delhi through Research Training Fellowship for Developing Country Scientists (RTF-DCS) and National Institute of Wind Energy (NIWE), Chennai, for providing the financial support and necessary infrastructure facilities for undergoing the six months project study.

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