Identification of Potential Wind Farm Locations in Tirumangalam Taluk using Geospatial Information Technology

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ABSTRACT

The most favorable locations for wind farm were determined based on environmental landuse factors, wind resources and the layout of the electrical grid lines. In the study landuse map was prepared and updated by using Survey of India topographic sheet and ASTER satellite imagery in open source Quantum GIS & GRASS GIS software environment. Wind Power Density Layer was digitized by using Indian wind Atlas 2010. The electricity transmission grid layer was prepared by using GPS survey and topographic sheet. Potential wind farm locations were identified based on Geo-spatial Information Technology i.e. querying, buffering, proximity, closest facility available, and site suitability analysis for Tirumangalam Taluk of Madurai district, Tamil Nadu, India. From the study it is concluded that in the total area, the area lies in least potential one 13.54 km^2 (2.38%) followed by moderately potential zone 55.46 km^2 (9.78%) and highly potential zone 20.61 km^2 (3.63%).

Keywords - **Geographical Information System, Landuse, Quantum GIS, Site Selection, Wind farm.**

1. INTRODUCTION

Human being acknowledged power of wind energy 5500 years ago when they used it to propel sailboats and sailing ships. In addition, windmills were used for irrigation pumping and for milling grain. Now, they fitted multi-bladed wind turbine atop a tower with generators and battery banks to produce electricity as it is environmental friendly and non-exhaustible [1].

The worldwide wind energy industry will be worth USD 153 billion-up from USD 77 billion in 2011 - with an installed wind power capacity of 562.9 GW compared to 235.8 GW in 2011. The report also observed that this source is providing up to one-fifth of energy supplies in some countries. While the global economic slowdown affected the sector in 2010, turbine deployment activity remained strong [2].

The Chinese wind energy market represented more than half of the world market for new wind turbines, adding 18,9 GW. A sharp decline in new capacity was witnessed in the US whose share in new wind turbines fell down to 14.9 percent (5.6 GW), after 25.9 percent (9.9 GW) in 2009. Nine other countries that can be seen as major markets, with turbine sales in a range between 0.5 and 1.5 GW, are: Germany, Spain, India, United Kingdom, France, Italy, Canada, Sweden and Romania [3].

As for land availability, it is critical to systematically identify the ways high quality wind sites (e.g. with wind power density > 200 W/m^2) are being used and whether they are suitable for wind-farm development [4].

Wind energy options are plenty. The performance of wind mill depends on location-based variables, implying the need for geospatial information analysis to find the best fit for each segment. Geospatial information technology is therefore proving to be an essential component of decision making process in wind energy [1].

Geographical Information System (GIS) is one of the most efficient tools for development of any kind of decision support system. The main benefit of using the GIS is not merely the user-friendly visual access and display, but it also featured with data collection and integration capabilities, management, analysis and presentation of geographic and other spatially defined data [5].

It supports spatial analysis and modeling within the discipline of geography (e.g. location, proximity and spatial distribution), which makes it a vital tool for modern geography [6].

In the Indian Wind Atlas 2010, the authors, based on their expert judgment, state, "On a conservative consideration, a fraction of 2% land availability for Tamil Nadu has been assumed for installable potential estimation".

In contrast, this research used a Geospatial Information Technology based approach for excluding land that is not suitable for wind farm development using such industry-standard criteria as landuse, water-bodies, and urban/rural use in a systematic, transparent, and easily replicable manner.

2. STUDY AREA

Tirumangalam Taluk is in Madurai District, Tamil Nadu (India) with has an area of 563.65 square kilometer, the latitude and longitude extension of the study area is 9°37'32.89"N to 9°57'55.95"N and 77°48'55.17"E to 78°57'18.52"E respectively and is altitude range from 52m to 353m above mean sea level. The climate is dry and hot, with rains during October-December. Temperatures during summer reach a maximum of 40°C and a minimum of 26.3 °C. Winter temperatures range between 29.6°C and 18°C. The average annual rainfall is about 85 cm. As of the 2001 India census, Tirumangalam Taluk had a population of 196,642. Males constitute 98,877 of the population and females 97,765. The location of the study area is shown in figure 1.

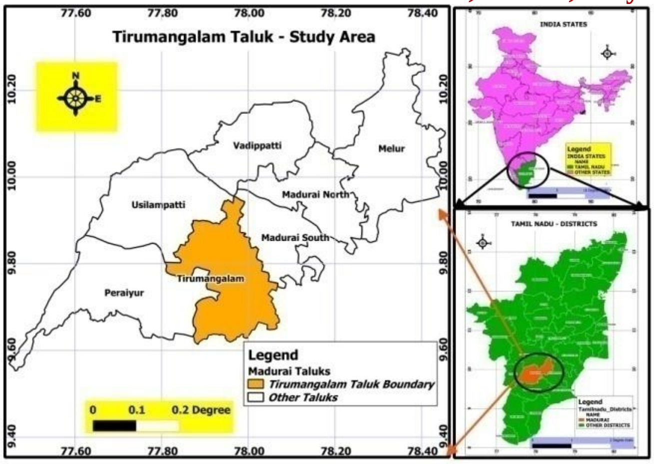

Fig 1: Map showing the study area – Tirumangalam Taluk

3. METHODOLOGY

QGIS and GRASS software were used to prepare and analyze the thematic maps. GIS functionalities such as buffering, proximity analysis, site suitability etc. were incorporated into the system to enhance the efficiency of most favorable locations for wind farms process. The methodology adopted can be subdivided into three main processes. First process was data collection and digitization in QGIS software environment. Secondly data was integrated such as unique coordinate system, topology building and attribute addition. Lastly Geospatial analysis such as buffering, overlaying etc. the entire methodology is depicted in the figure 2.

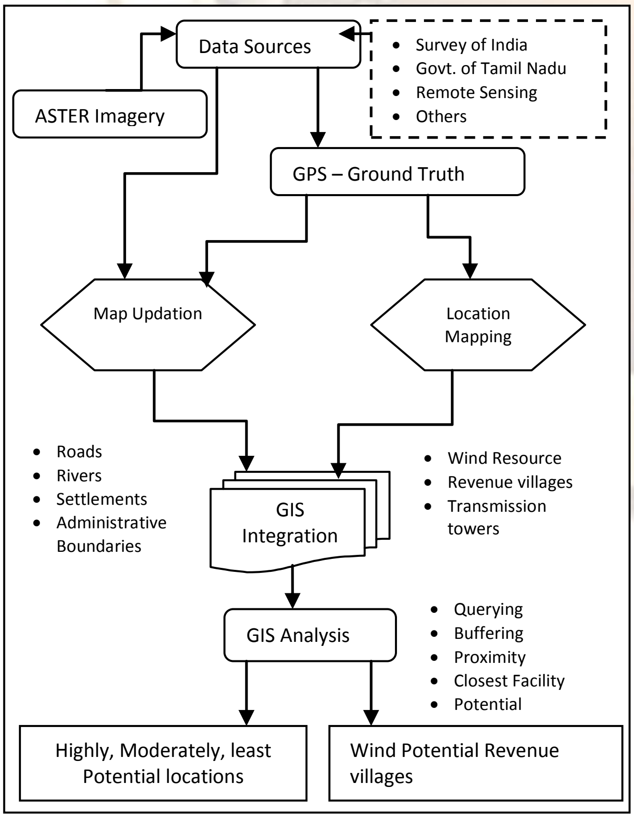

Fig 2: Methodology flow diagram of potential wind farm location

3.1 Data Collection

Data collection is a very important stage of GIS database creation and the standard of GIS database is purely dependents on the quality of the data used, there are two types of data acquired in this study, they are already existing data and GPS survey data that are illustrated in table 1. Collected data were geo-referenced by uniform coordinate reference system (WGS 84 UTM Zone 43N).

TABLE 1
Name of Layers and Source Details

Name	Scale/Resolution	Source
Topographic sheets	1:50000	Survey of India
ASTER Imagery	15m	USGS
Taluk Map	1:75000	Government of Tamil Nadu
Wind Power Density Map	5km	Centre for wind Energy Technology
Transmission Network		GPS surveying

3.2 Landuse map preparation & updation

Survey of India Toposheets 58G13, 58G14, 58K1NW, 58K1SW and 58K2 were collected.

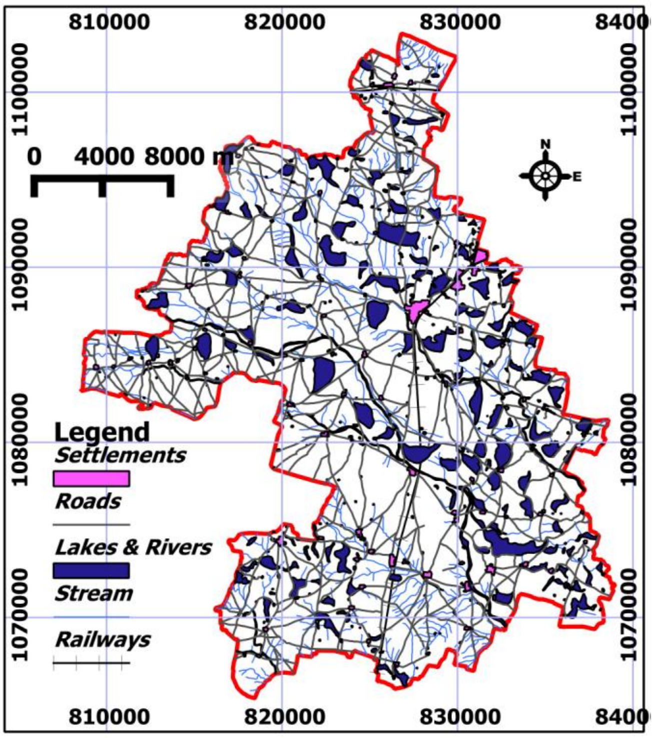

Fig 3: The landuse map of Tirumangalam (1972)

Geo-referenced toposheets were used to prepare landuse map of Tirumangalam (transportation layers, hydrographic layers and settlements) as on 1972 that is shown in figure 3. Remote sensing satellite images are quick and reliable source for different mapping tasks like map updating and base map preparation [7]. Availability of medium resolution satellite imagery from satellites like TERRA tremendously increased the use of remote sensing images for landuse mapping and applications like cartography. Terra satellite carries a payload of five remote sensors designed to monitor the state of Earth's environment and ongoing changes in its climate system. One among important sensor is ASTER (Advanced Space-borne Thermal Emission and Reflection Radiometer). Geometrically corrected multi-spectral data (2011) of ASTER sensor (TERRA satellite) with a spatial resolution of 15m (Fig.4) was used for updating of existing thematic layers such as road network, settlements, hydrographic features etc. The road network was classified in to National highway, State highway, major district roads and other village roads. The updated map (Fig.5) was used for further GIS analysis.

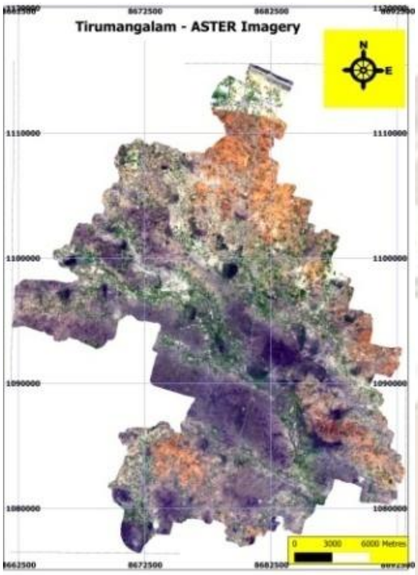

Fig 4: ASTER Imagery of Tirumangalam Taluk

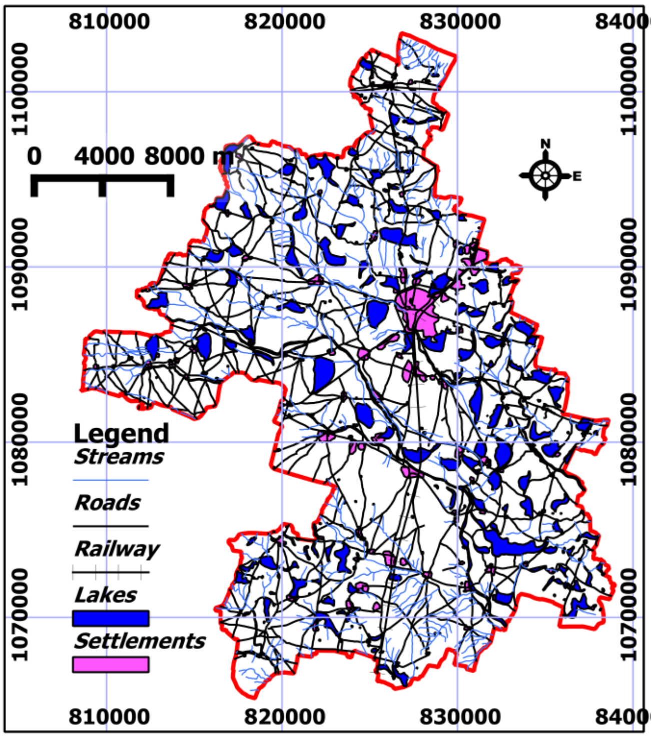

Fig 3: The landuse map of Tirumangalam (2011)

3.3 Revenue Village Map

Taluk map of Tirumangalam was collected from Survey and Land Records, Tamil Nadu with scale of 1:75000. Geo-referenced Taluk map was used to prepare revenue village boundary layer (Fig.6). In Tirumangalam taluk has 108 revenue villages.

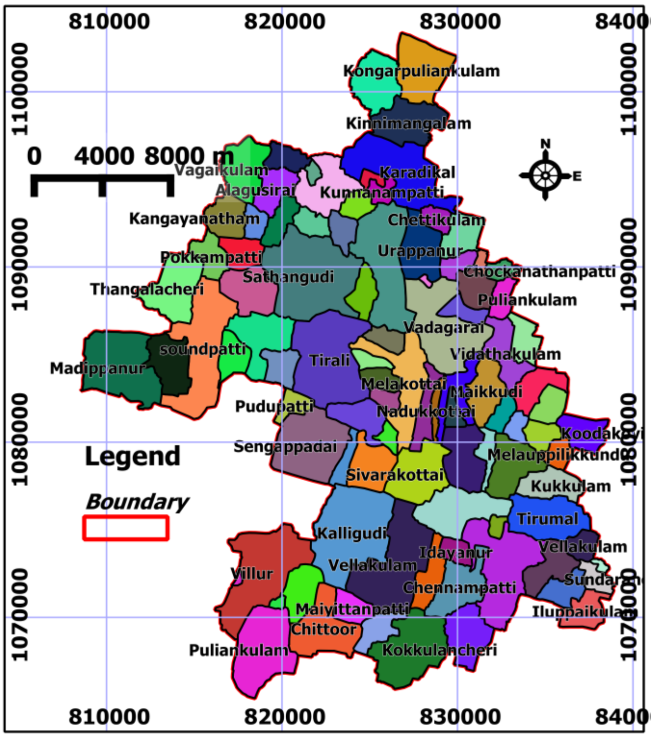

Fig 6: Map shows the revenue village boundary.

3.4 Tirumangalam Wind Power Density Map

The wind power density, measured in watts per square meter. Wind speed generally increases with height above ground. In order to tap the potential of wind energy sources, there is a need to assess the availability of the resources spatially [8]. Wind Power Density Map of India at 50m above ground level (Indian Wind Atlas) was collected from Centre for Wind Energy Technology (CWET 2010), Chennai.

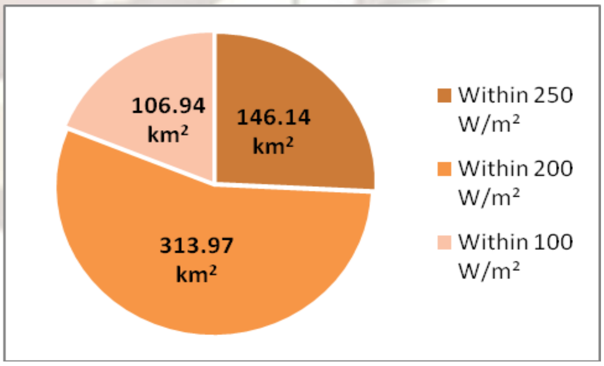

Fig 6: Wind power density with area occupied

The vector layer of wind potential has been prepared by using geo-referenced Wind power Density map (Raster format) at 50m above ground level and stored as esri-shape file (polygon) format, and added information about wind speed in attribute table which was classified into three categories. The area which contains 250 W/m², 200 W/m²and 100 W/m² were classified into highly potential, moderately potential and least potential respectively, distribution is illustrated in figure 6 ad also shown in map format in figure 7.

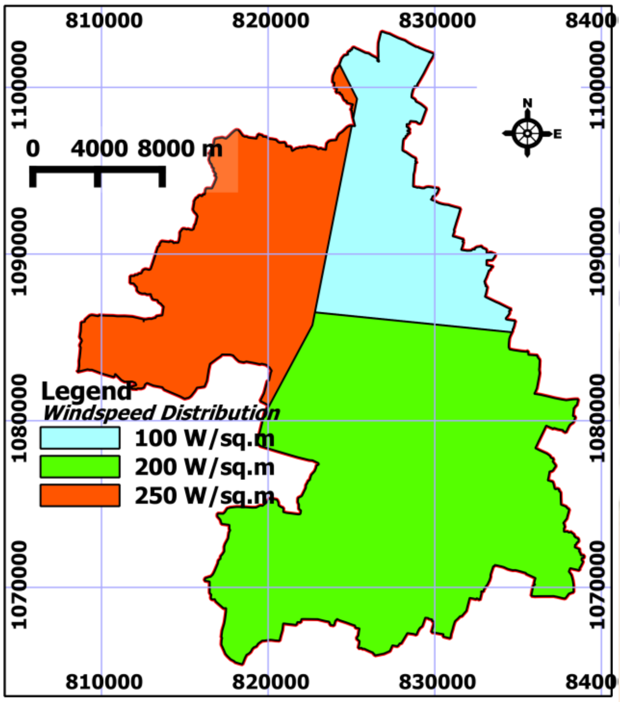

Fig 7: Wind power potential map of Tirumangalam

3.5 GPS Surveying

Global Positioning System (GPS) was extensively used for ground survey to prepare location specific thematic map such as Electrical Grid Transmission Network lines that was illustrated in figure 8. Also toposheets were referred.

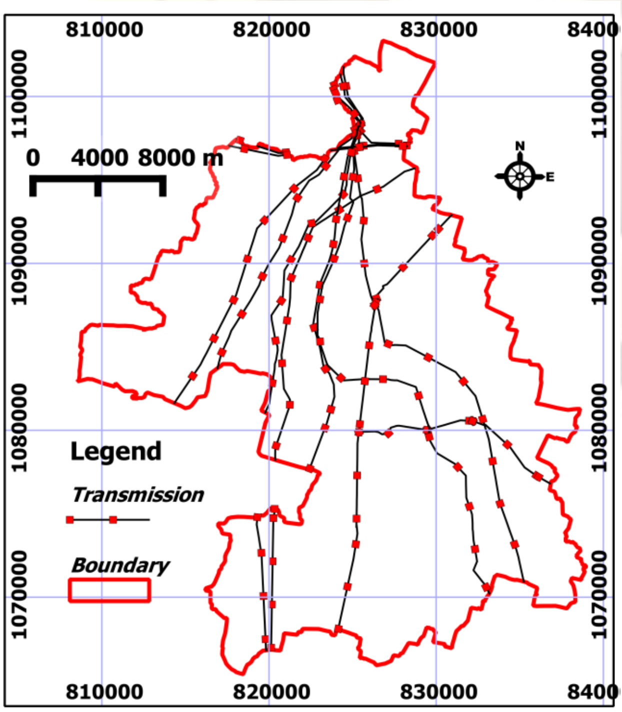

Fig 8: Power Transmission & Distribution Network Map

3.6 GIS Integration

The combination of data files from different functional units of the research (landuse, Revenue Villages, Wind power density, Transmission network) that were collected information about the same entities. In combining the data were imported into GRASS software environment. Topological representation of vector data helps to produce and maintain vector maps with clean geometry as well as enables certain analyses that cannot be conducted with non-topological. Topological errors can be corrected automatically [9] and the corrected layers were used in GIS analysis.

3.7 GIS Analysis

Land use and terrain data was used to eliminate geographical areas not suitable for wind developments. Multiple databases with land use and elevation data were evaluated for resolution, format, quality, and ease of use [4].

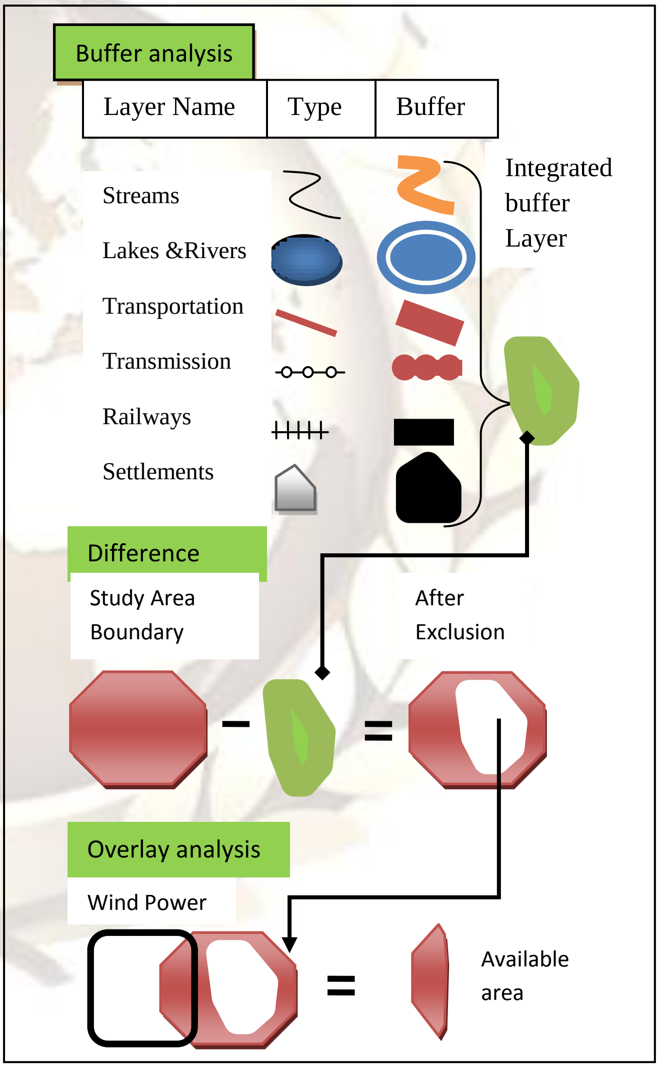

Fig 9: Steps used in various GIS Analysis

GIS analysis is the combination of operations like Querying, Buffering, Proximity, Closest Facility etc. that has been depicted in fig 9. The exclusion distance has been predicted based on environmental, safety and economic factors. The exclusion or buffer distance from the layer has been taken from various research articles [10], [11], [12]. That has been listed in table 2. Streamlines, lakes, roads, rails roads, settlements, and Transmission lines were buffered in QGIS software environment according the condition of exclusion buffer distance given in table 2. The buffer layer was merged into single polygon layer, named total area of exclusion i.e. not suitable for wind farm development. The difference between the study area boundary and total area of exclusion was called total available area. In overlay analysis, the total available area was classified into three according to wind energy potential classes. Total available area was 100% fell down in 10km buffer around transmission line, it shown total available area is economically feasible.

TABLE 2
Details of layer name, buffer distance and source details.

S. No	Layer name	Buffer Distance
1	Stream lines	100m [10]
2	Water body	100m [10]
3	Roads	250m [10]
4	Rail Road	250m [10]
5	Villages	500m [11]
6	Urban Area	500m [11]
7	Transmission lines	150m [12]

The total available area falling under highly, moderately and least potential wind power density were calculated and presented in table 3. Similarly the potential revenue villages for wind farms were identified based on the highly and moderately potential area falling under revenue village boundary.

4. RESULTS AND DISCUSSIONS

The map (figure 10) displays Geospatial Analysis results reclassified to show areas that are highly suitable or moderately suitable for wind farm development. These are the target areas that would be tagged for follow up investigation. All of the remaining areas have at least one piece of negative evidence that would preclude the site being suitable for a wind farm based on the parameters that went into analysis.

TABLE 3
Wind farm potential locations with area occupied

	Within Least Potential zone	Within Moderate Potential zone	Within Highly potential zone
Number of locations	109	307	184
Area in sq.km	13.54	55.46	20.61
Area in Percentage	2.38	9.78	3.63

Wind farm potential locations map has been prepared showing three zones namely highly potential, moderately potential and least potential (Figure 10). From the inventory concluded in the total area, the maximum area lies in least potential one 13.54 km^2 (2.38%) followed by moderately potential zone 55.46 km^2 (9.78%) and highly potential zone 20.61 km^2 (3.63%).

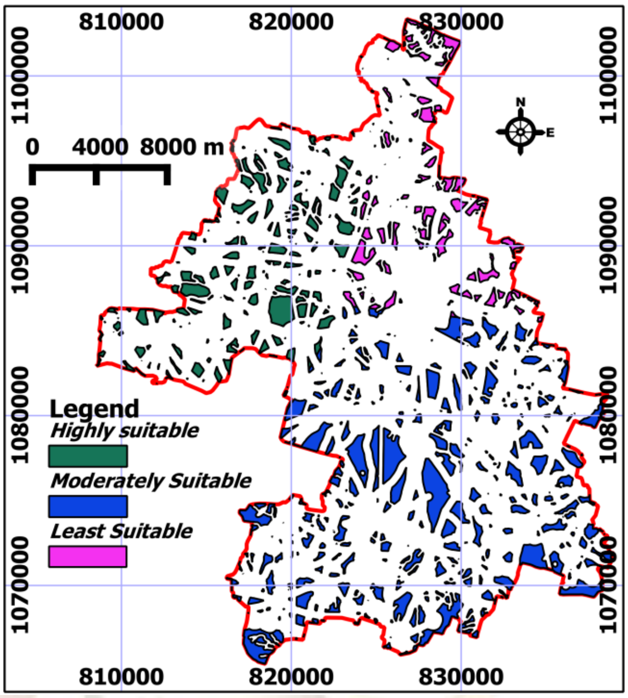

Fig 10: Potential wind farm location - zonation map of Tirumangalam Taluk

TABLE 4
List of highly potential revenue villages for wind farm development

Available area within highly potential zone		
Revenue village Name	Total Area in m^2	Potential area in m^2
Kilavaneri	8104563	2816121
Sathangudi	21238688	2612182
soundpatti	16630519	2012052
Thangalacheri	9017259	1781027
Madippanur	14426024	1523340
Kangayanatham	4799605	1196528
Tirali	18712768	1113484

TABLE 5
List of moderately potential revenue villages for wind farm development

Available area within moderately potential zone		
Kalligudi	19319256	3454205
Sengappadai	13643495	3146293
Puliankulam	13151697	3113032
Kokkulancheri	12918943	2815031
Saluppapillayarnatham	9807190	2771030
Villur	16870772	2532048
Karisalkalampatti	6180794	2449129
Vellakulam	16815086	2373891
Sivarakottai	9284181	2168047
Kurayur	15455278	2145860

Similarly, the revenue villages were categorized based on the potential area available in each of the revenue village. Out of 108 revenue villages few of them were recommended for further research as well as wind farm development that was listed out in table 4 and table 5.

5. CONCLUSION

The potential of wind power generation is immense, a historic source of energy, wind can be used both as a source of electricity and for irrigation and agricultural uses. In today's world, where a greener source of energy is the need of the hour, wind energy is a promising resource, waiting to be harnessed to its true potential [13]. This study investigates the importance of Geospatial Information Technology to identify the potential wind farm locations. The usage of open source Geospatial software QGIS and GRASS for the integration of thematic layers such as wind, landuse, revenue villages, Transmission network etc. through satellite imagery, field survey data and other attribute information enhances the study as well as its accuracy standards. Similar study could be attempted in western portion of Tamil Nadu.

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