Land Suitability Analysis for Wind Farm Development in Texas

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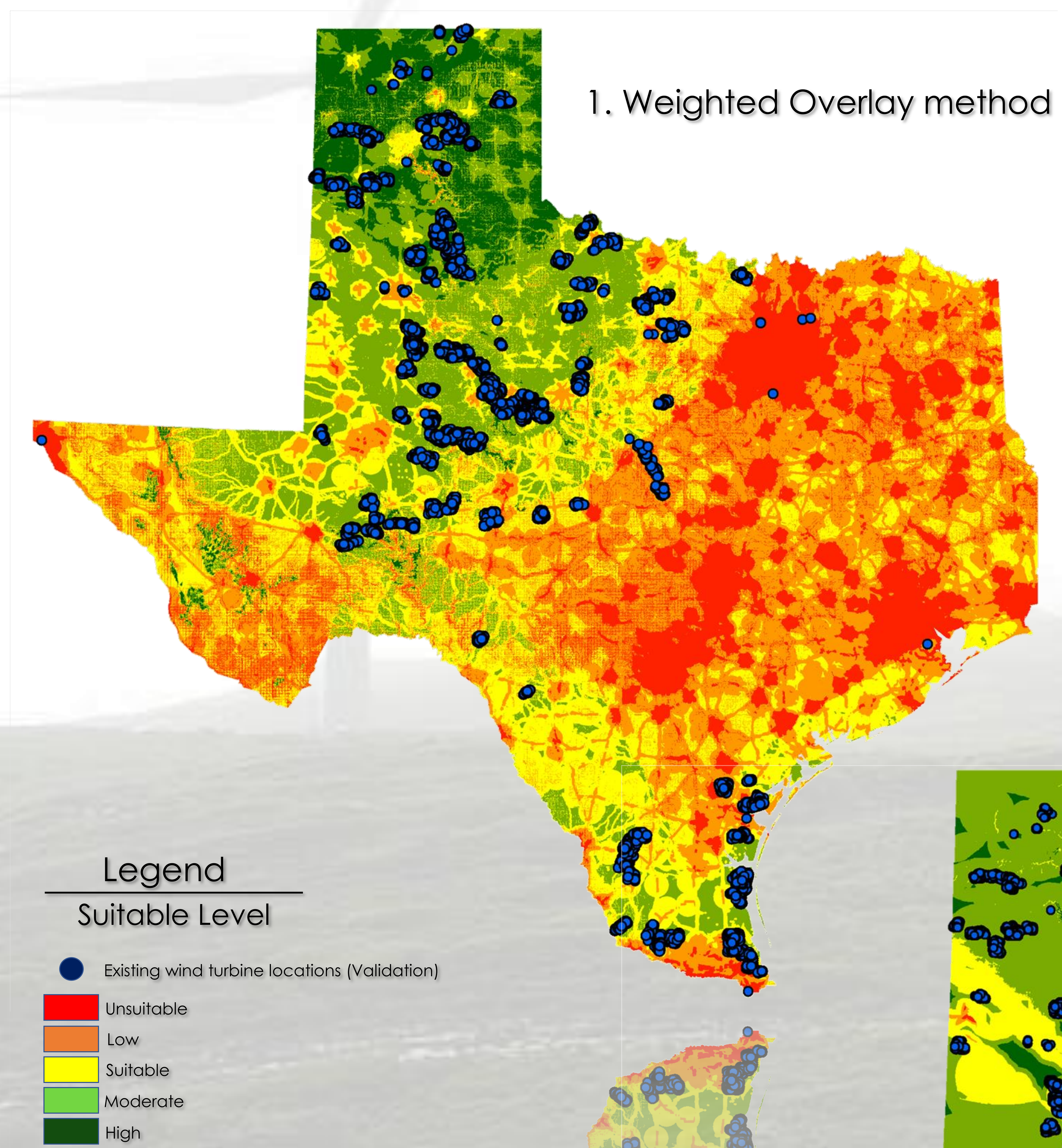
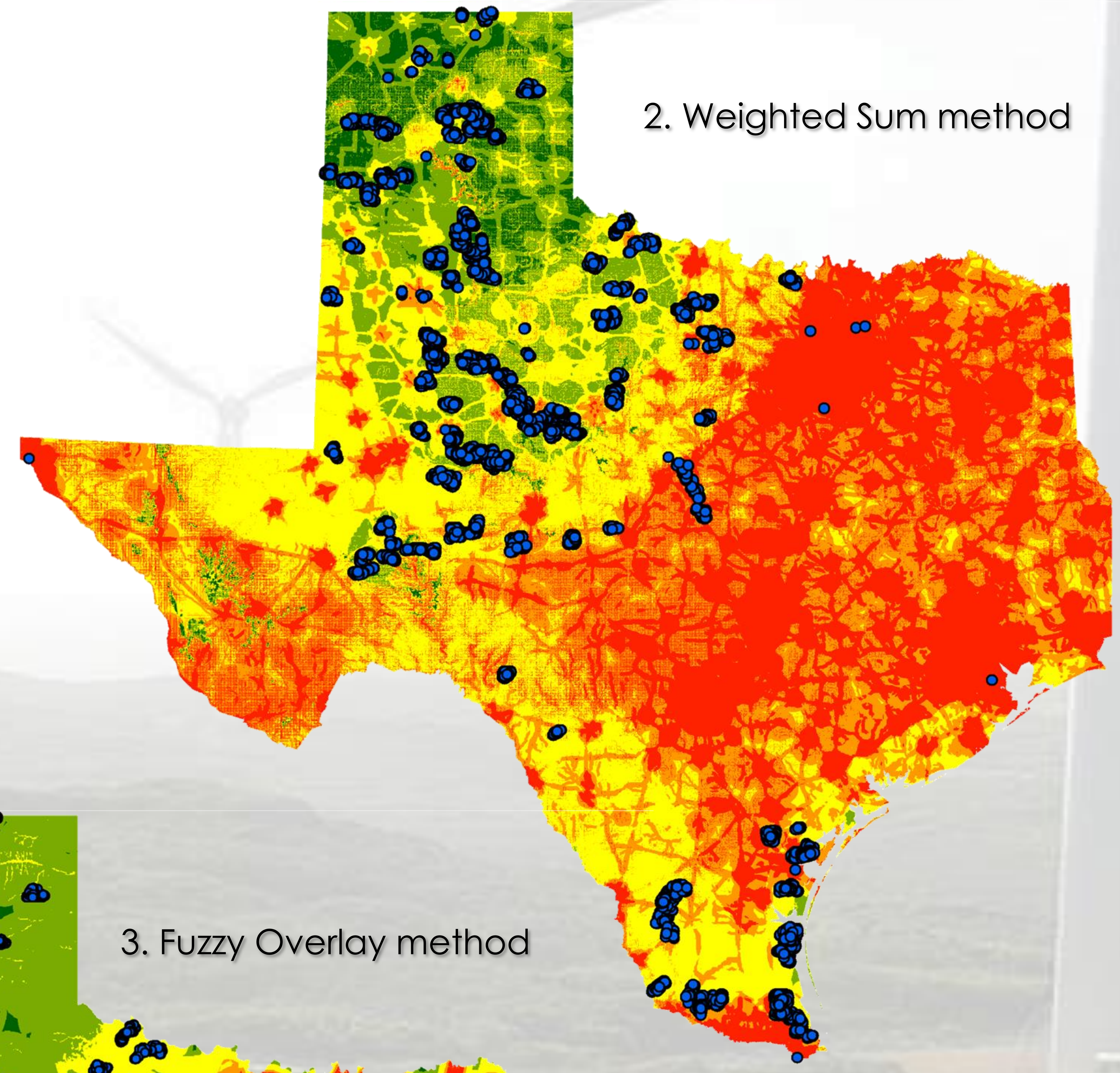
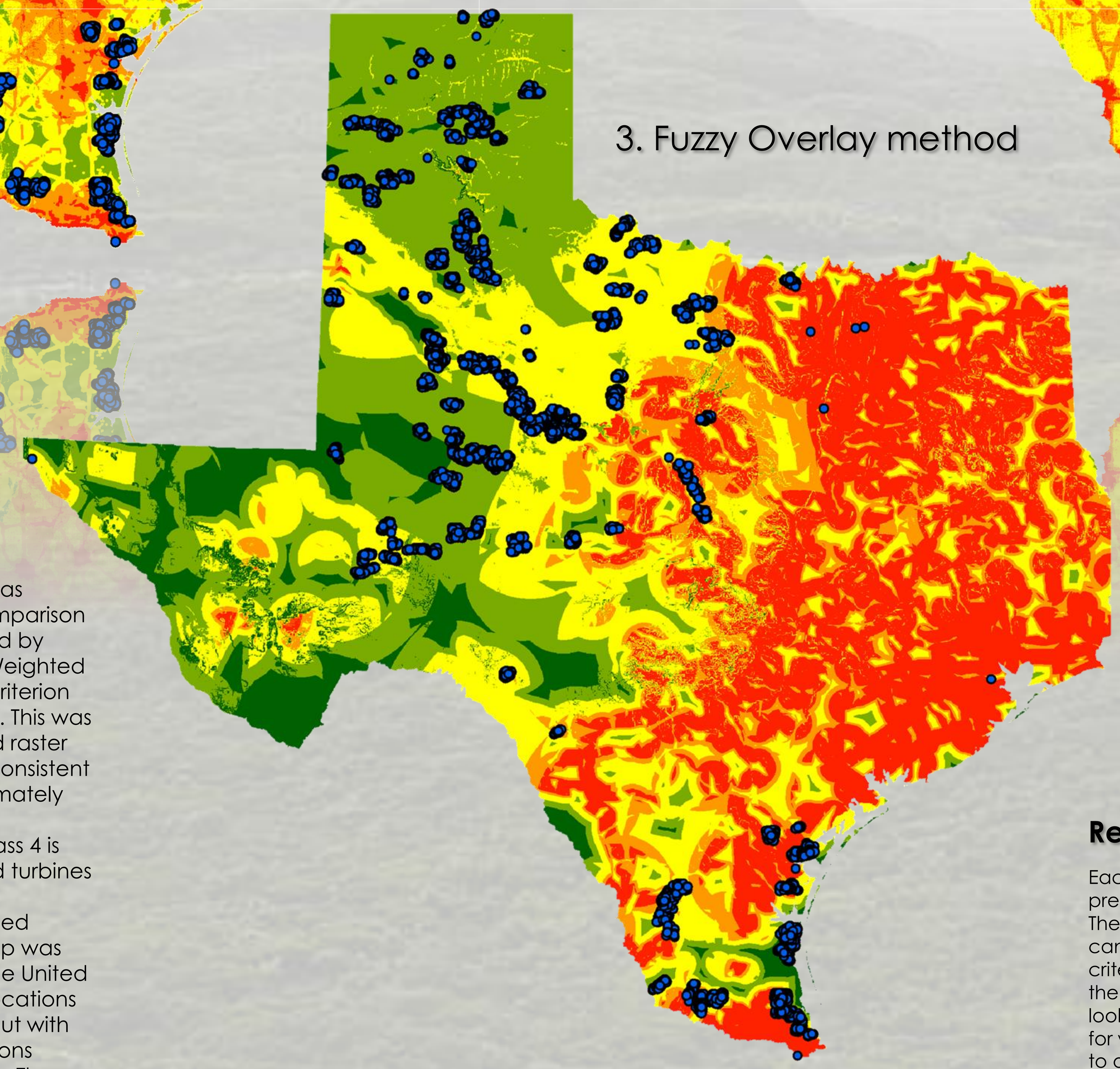
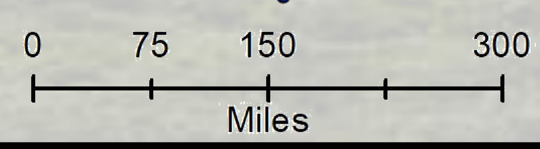
Abstract

The overall goal of this project is to apply geographic information system (GIS) integrated with multi criteria decision making (MCDM) for effective land suitability analysis for wind turbine in Texas. Factors taken into consideration included socioeconomic criteria such as distance to highways, proximity to airports and urban areas, localized environmental criteria such as terrain slope and distance to rivers, affected waterbodies, and wildlife management areas, as well as the most critical criterion, the wind power density defined by the National Renewable Energy Laboratory (NREL) integrating the abundance and quality of wind, the complexity of the terrain, and the geographical variability of the resource. GIS analysis involved building models by applying different map overlay techniques, including Weighted Sum, Weighted Overlay and Fuzzy Overlay based on input factors where each factor was classified and weighted through an Analytical Hierarchy Process (AHP). GIS model outputs indicated that the western and northwestern portion of Texas are the most feasible areas for wind turbine installation. These results were validated with existing wind turbine locations obtained from U.S. Wind Turbine Database.









Methodology

Eight different criteria were taken into account where each was weighted through Analytical Hierarchy Process (AHP). The comparison matrix assigned the greatest value to the wind classes followed by slope. The weights were used for the Weighted Overlay and Weighted Sum analysis. Besides the wind class and slope factors, each criterion was used to calculate the distance from the object of interest. This was a crucial step to result a suitability map from a distance-based raster analysis. Each raster layer was reclassified in order to have a consistent uniform scale for raster data input for the overlay process. Ultimately each criterion was classified into 5 classes. Class 1 represents unsuitable areas, Class 2 is low suitability, Class 3 is suitable, Class 4 is moderate, and Class 5 is the areas with high suitability for wind turbines application.

Three overlay models were built, Weighted Overlay(1), Weighted Sum(2) and Fuzzy Overlay(3) where each output suitability map was compared and validated through a dataset acquired from the United States Wind Turbine Database showing existing wind turbine locations in Texas. Overlaying the suitability map from each model output with the validation dataset, allowed to extract cell values at locations specified in a point feature class from the raster suitability map. These values were then used to build a frequency distribution to analyze the accuracy for each suitability map.

Results

Each GIS model output indicated that the most preferred region is the west and northern part of Texas. These results are specific to this project as the output can be altered by adding or removing one or more criteria. Weights are also playing an important role on the outcome of the suitability analysis. Although, looking at the maps provides an idea of the suitability for wind farms in Texas, further data analysis was done to obtain a more conclusive results.

Accuracy Assessment

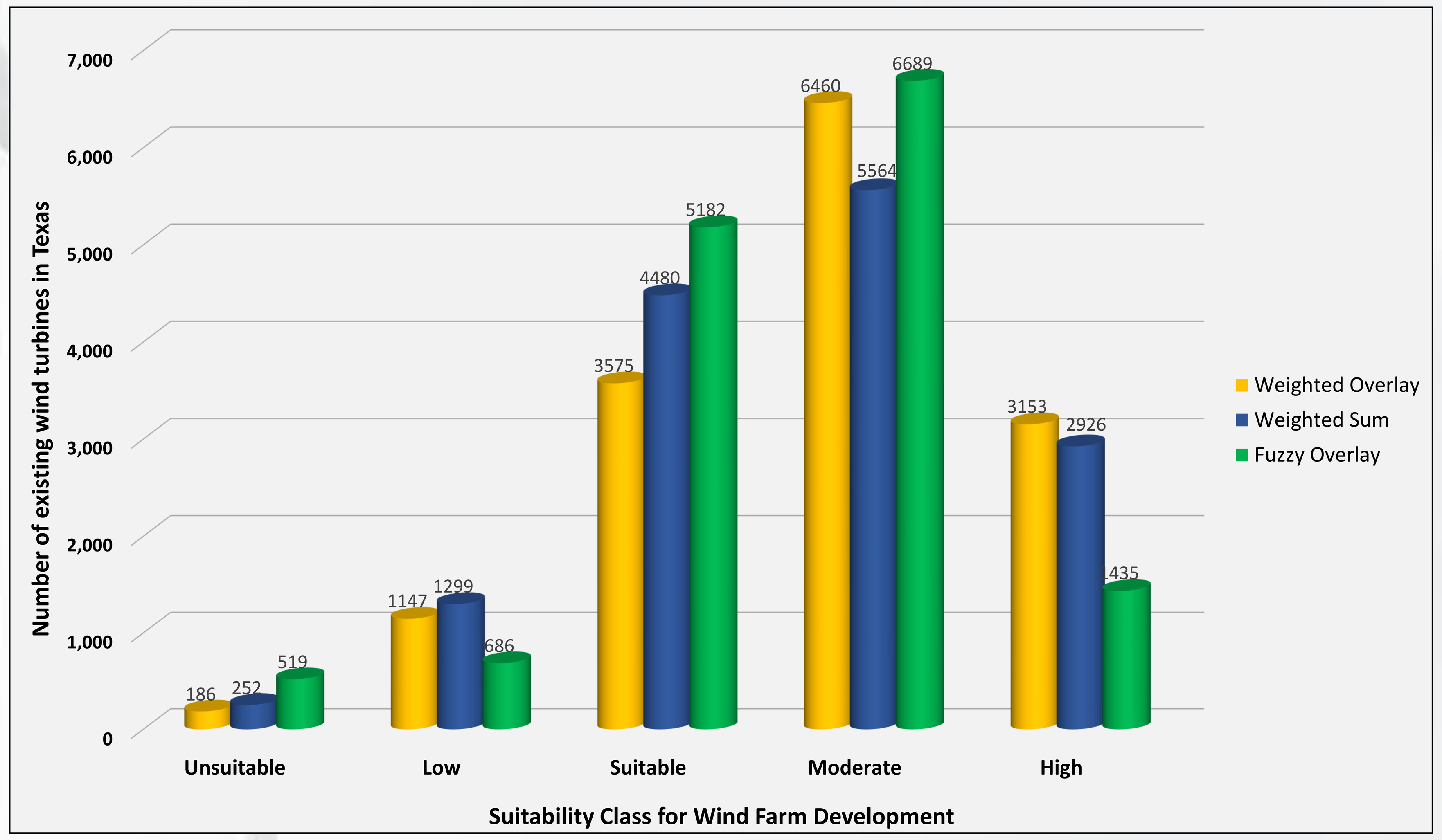


Figure 1. Frequency distribution of the existing wind turbines in each suitable class.

The accuracy assessment was done by overlaying each suitability map with the validation dataset. The dataset was obtained from the United States Wind Turbine Database. This is basically a point shapefile including 14,521 features where each point represents an existing wind turbine location in Texas. Ideally the more point we can observe in the higher cell values 4 (moderate) or 5 (high) the more accurate the output suitability map. Fuzzy Overlay generated the greatest number of points located in either the "Suitable" or "Moderate" class. 46% of the total points were in Moderate suitability areas, followed by 35.7% in Suitable areas. However, this overlay tool resulted the least amount of "High" suitability areas out of three. Weighted Overlay had given more control on assigning weights for each criterion. In this model we can observe an ideal frequency distribution resulting 6,460 points in "Moderate" class that equals to 44.5% of the total wind turbines in Texas. This model generated the greatest number of points (3,153) in the "High" suitability areas which takes up 9.8% of the total wind turbines installed. The last model, Weighted Sum, resulted an average but consistent values in each class. 1,299 points were in "Low" areas, 4,480 points were in "Suitable" areas, 5,564 in "Moderate" and 2,926 points in the "High" suitability areas.

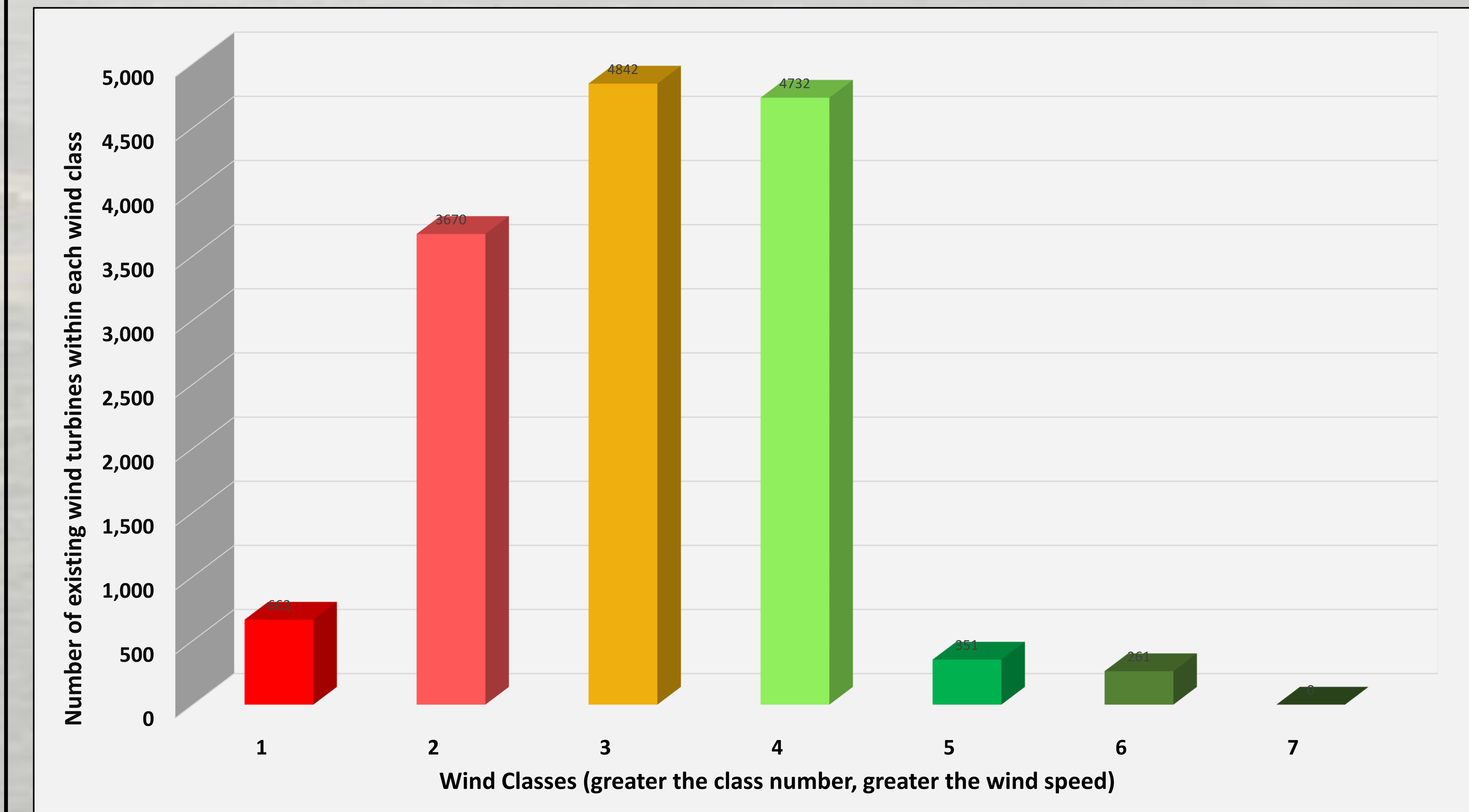


Figure 2. Frequency distribution of the existing wind turbines in regards to wind classes.

The accuracy assessment helped to provide an even more detailed idea about the accuracy of each overlay technique. However, observing a reduction in frequency in the "High" or Class 5 areas led to research the result further. There are some uncertainty regarding the existing wind turbine locations, due to the on-field circumstances that we can not really have an insight on. Thus, we overlayed the validation dataset with only the wind classes obtained from the National Renewable Energy Laboratory to seek an answer for the reduction in wind turbines in the Highest suitable class. Basically there are 7 wind classes defined by NREL, where wind class 1 is basically unsuitable for large scale wind turbine application. Figure 2 shows that wind Class 3 and 4 areas in Texas contains 62% of the total 14,521 wind turbines. As the wind speed increasing beyond Class 4, we can observe a significant reduction in wind turbines. Wind class 5 and 6 together takes up only 4.1% that suggest valid results in Figure 1. Since wind classes as a criterion received the greatest weight, the impact on each suitable map is significant. Ultimately, Texas does not have large areas where the wind speed exceed class 4, thus we can conclude that the reduction observed in "High" suitable areas now supported with the fact that the dominant wind classes in Texas are Class 3 and Class 4.