5.5 USING ENVIRONMENTAL DATA TO ATTRACT DEVELOPMENT: THE OKLAHOMA WIND POWER ASSESSMENT INITIATIVE

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1. INTRODUCTION

Technological advancements over the last two decades have transformed the wind energy market from a niche into a mainstream, competitive energy source. First introduced as a large-scale power source in the United States during the late 1970s, the price of wind energy production has declined 80% since then. It is now the fastest growing energy source worldwide, with an estimated additional 48,000 megawatts anticipated development by 2010 and an associated $45 Billion in capital investment (Source: American Wind Energy Association, 1999). In Oklahoma, three things have come together to capture a share of this market: the Oklahoma Mesonet, the Oklahoma Wind Power Assessment Initiative (OWPAI), and the Oklahoma Renewable Energy Council (OREC).

<u>The Oklahoma Mesonet</u>
The Oklahoma Mesonet is an automated network of 114 environmental observing stations (Brock et al., 1995). Each station is instrumented with a RM Young propeller vane (model 5103) at 10 meters. The wind data used by OWPAI includes the 5-minute averages of wind speed and direction. All data go through quality assurance procedures that are established to ensure high data quality in the Oklahoma Mesonet (Shafer et al., 2000).

Wind statistics were computed from data collected by the Oklahoma Mesonet over the period January 1, 1994 to December 31, 2000. Most stations collected more than 95% of the five-minute records possible during this period of time. This represents approximately 1.4 million combined observations of wind speed and direction for each station. These observations were processed to produce the wind inputs used in two models.

<u>The Oklahoma Wind Power Assessment Initiative</u>
In July of 2000, the Oklahoma Department of Commerce funded OWPAI using State Energy Program funds from the U.S. Department of Energy. OWPAI is a collaborative project involving researchers at the University of Oklahoma and Oklahoma State University. Additional funding for research was provided by OSU's Center for Energy Research.

While OWPAI's mission includes other activities such as educational outreach, policy study and solar energy study, perhaps its most important goal is to develop a wind resource assessment using modern software and input from 7 years of data from stations in the Oklahoma Mesonet.

OWPAI made use of two models to develop its wind resource assessment, the reasons for which will be discussed later. One model is an analytical model available commercially, called WindMap™ (Product of Brower and Company). Windmap uses wind point data, along with terrain and vegetative roughness grids over the area of study, to produce output grids of wind speed and wind power.

The second model is empirical in nature and was developed by OWPAI. This model correlates terrain, terrain exposure (or relative elevation) and vegetative roughness to calculated wind energy values at select Mesonet stations, and uses the relationship to develop a wind power grid for the entire state.

<u>Oklahoma Renewable Energy Council</u>
In addition to the analysis of potential wind energy, OWPAI engaged in a comprehensive education and outreach effort. These efforts culminated in the first statewide conference on wind energy, held in May 2001 in Oklahoma City and attended by 375 individuals and developers, an encouraging showing for a start-up industry in the state.

Following the success of the wind power conference, some participants formed the Oklahoma Renewable Energy Council (OREC). OREC brings together representatives from various sectors of energy generation, retail, and consumption for monthly meetings. It also provides a mechanism for briefing legislators and study panels on renewable energy. Although it started with wind as the initial focus, OREC has expanded to include representatives of other renewable energy sources, such as biomass and solar energy.

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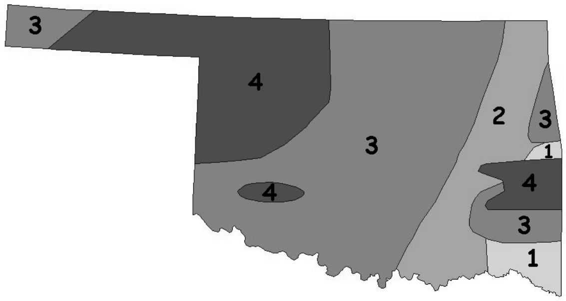

Figure 1. U.S. Department of Energy, Pacific Northwest Laboratory (DOE / PNL) estimation of wind resources in Oklahoma, 1987. Resolution: approximately 33 km. Resource potentials increase from 1 to 4. I.e., class 1 areas are a poor resource; class 4 areas are a good resource.

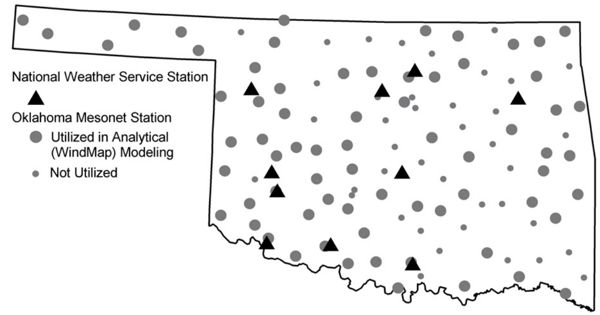

Figure 2. Triangles show locations of National Weather Service wind data used for the creation of the 1987 DOE/PNL resource map. Large dots indicate Oklahoma Mesonet stations used for inputs into OWPAI's empirical model.

2. ASSESSMENT

Wind farm developers target regions favorable for development by first looking at regional wind resource maps. More refined assessments are performed on these areas using instrumented tall towers (40 m AGL and up), as part of a process called "microsite" assessment. Until recently, the best resource map available for the Oklahoma region was that developed by the U.S. Department of Energy and Pacific Northwest National Labs (DOE/PNL; Elliott et al., 1987). ***Figure 1*** shows the resource map for Oklahoma, with an analysis grid resolution of 1/3 deg. longitude by 1/4 deg. latitude, approximately 33 km (20 miles) in each dimension. While the PNL model output has good resolution considering the small amount of wind data available (represented by triangles in ***Figure 2***), the high spatial resolution of the Oklahoma Mesonet offers an opportunity for the development of a much higher resolution resource map. Furthermore, the resolution of the OWPAI resource map is enhanced by using empirical and analytical models incorporating high-resolution terrain and vegetation data.

The availability of an abundance of wind data for an extended period (7 years) allows for the development of wind climatology products. These products are useful to developers for many reasons: 1) the heavy dependence of wind energy on wind speed; 2) the dependence of wind turbines on speed thresholds and direction of winds (so that they can be arrayed to minimize "wind shadowing" for example); 3) and the varying value of power depending on how it matches shorter term (e.g.: daily peaking) and longer term (e.g., seasonal) electricity demands. Developers may also use OWPAI's wind climatology products to benchmark their relatively short-term tall-tower wind data. During a micro-site evaluation, data is typically collected from tall towers for only a year or so before the tower is moved to a new location. This short timeframe is desired because of the need to make decisions on wind-farm planning in the area and because of the cost of collecting and analyzing data over a protracted period. However, it leaves open the question of whether their year of collection and study is in fact low, high, or about average. With the abundance of Oklahoma Mesonet sites and OWPAI's climatological products already developed, the wind farm developer need only compare data from nearby Mesonet stations, over the same collection period, to the long term trends for those stations, in order to judge the results of the shorter term tall-tower data.

<u>Selection of stations to use in wind resource models</u>
Because fetch conditions (i.e.: obstacles such as trees or buildings) are particularly important to wind applications, a subjective evaluation of all sites was first conducted to exclude stations from which data might bias a wind resource assessment. The following inputs were used to evaluate the sites:

- Panorama pictures of Mesonet sites, on the web at http://www.mesonet.ou.edu/siteinfo/
- Digital Orthophotos (geo-referenced aerial pictures)
- Landuse/landcover grids (from MIADs data)

Sites were rated 'poor', 'fair', 'good' and 'excellent', based on subjective criteria. For example, a site surrounded totally by trees approximately 10 m feet in height and within a radius of approximately 50 m was considered 'poor'. A site with a wind-break of trees about 10 m feet tall and approximately 40 m to the south was rated 'fair' in general, with a note of being 'poor' to the south (the direction of prevailing winds). Sites with only low to moderate obstacles in directions of non-prevailing winds (i.e.: not in the north or south quadrants) and no obstacles in the directions of prevailing winds were rated 'good'. Those with very little or no obstructions in any direction, and with vegetation representative of a larger area (a circular area with 10-km radius), were rated 'excellent'. Notes were also made of any special considerations for any of the sites, such as a sharp rise in terrain to the south of one site (which may lead to an underestimation of representative wind speeds for the area)

Sites with a 'poor' rating were not used as inputs into any of the resource models. Those rated 'fair' were not used except under special circumstances (such as a paucity of stations to use in a large region for the analytical model). For the most part, only sites with 'good' or 'excellent' ratings were used as inputs into

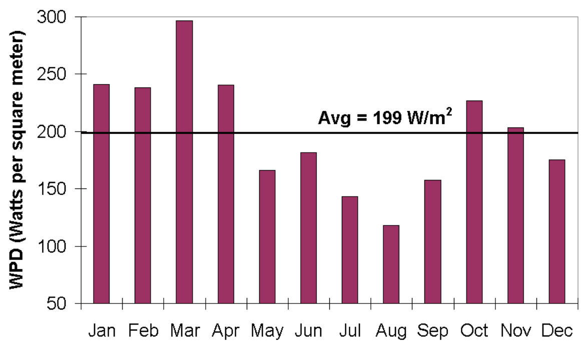

Figure 3. Monthly wind power density at 10 m for the Weatherford Mesonet Station. Monthly averages were computed over the period, 1994 to 2000.

models. Sixty-nine Mesonet stations were used as inputs for the analytical model (***Figure 2***). For the empirical model, only 76 stations with 'good' or 'excellent' ratings were used.

3. WIND CLIMATOLOGY REPORTS

OWPAI's wind climatology reports highlight the period of observation, wind power class, average wind speed, average wind power density (WPD), and site conditions for a station. However, the core of the wind climatology statistics is condensed into the following four figures:

1. bar chart of the average, monthly WPDs (***Figure 3***);
2. wind rose diagram (***Figure 4***);
3. bar chart illustrating the frequency distribution of the wind speeds; and
4. bar chart of the average, annual WPDs.

To compute wind power density, the equation:

$$WPD = \frac{1}{2 * n} * \sum_{i=1}^{n} (\rho_i * \nu_i^{\ 3}) \qquad (1)$$

was used, where ρ is air density and ν is wind velocity (scalar-average wind speed). Equation (1) was applied to all valid five-minute data for the time period (n = approximately 735,000). Air density was explicitly calculated using temperature and pressure data from the stations.

WPD is used as a "ruler" by the wind power community to assess the resource potential of an area. At a height of ten m, WPD values between 100 and 150 are considered a marginal resource; WPD values from 150 to 200 are considered a fair resource; and values exceeding 200 W/m^2 are considered good to superb resources (Source: National Renewable Energy Laboratory). The assignment of resource potentials was based on large, utility scale wind turbines available at the end of the 1990s.

Average monthly WPDs show seasonal trends in the wind. For example, Oklahoma predominately has weaker winds during the summertime. Average annual

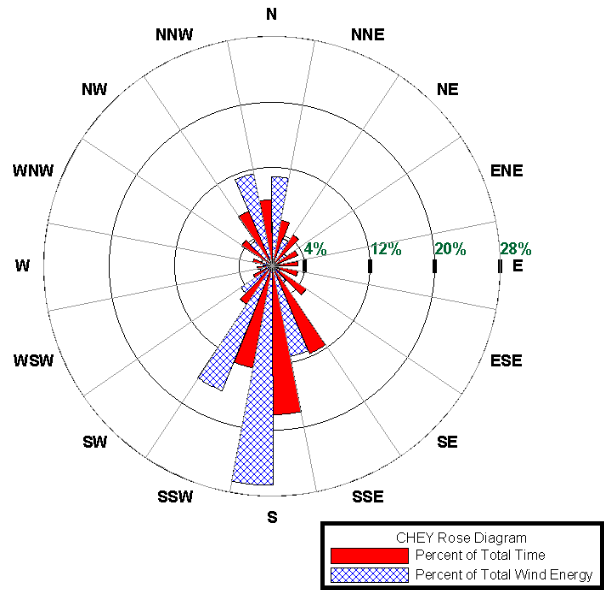

Figure 4. Wind rose for the Cheyenne Mesonet Station. Percentages represent averages over the period, 1994 to 2000.

WPDs, on the other hand, show long-term trends and variability between years. To an energy consumer or producer, a constant source of power is advantageous to a variable power source.

The wind rose diagram illustrates wind directional frequency as a function of both time and energy. The directional frequency can be an important factor in the placement of wind turbines in the vicinities of each other.

The frequency distribution of winds is illustrated with a bar chart where the ordinate is divided into wind speed bins and the abscissa represents the various frequencies. The average wind speed and the shape of the frequency distribution contribute to the magnitude of the WPD. A distribution with a longer tail (i.e., larger frequencies at high wind speeds) has a larger WPD value associated with it than otherwise. Such a chart can also be used to evaluate how turbines will perform.

4. WIND ASSESSMENT USING WINDMAP

In June 2000, when OWPAI began its assessment work, WindMap provided the most economical and practical method for performing a wind resource assessment for the state of Oklahoma. WindMap is a wind resource prediction and mapping software program for personal computers. The software has been used by several other states (i.e., Iowa, Massachusetts, Minnesota, etc.) in the assessment of their wind resources.

WindMap uses a mass-conserving model for predicting and mapping the wind over an area. In other words, the software seeks to find a divergence-free wind velocity field that departs by the smallest possible amount from some initial wind field derived from observations. The model can ingest four types of data: elevation, roughness, surface, and upper-air data. For this project, the following data sets were used as inputs into the model: Oklahoma Mesonet Data, Topography DEM Data, and Land Use/Land Cover Data. Wind data from 69 of the 114 Mesonet stations were included in the model.

Land use/Land cover (LULC) data was obtained from the Oklahoma Gap Analysis Program (GAP). The GAP LULC data is a 30-m resolution GIS map of natural cover types. Although GAP data does not include measures of surface roughness, knowledge concerning the different vegetation categories was used to derive values of surface roughness.

Digital topographic maps in DEM format at 1:250,000 scale were obtained from the U.S. Geological Survey (USGS). The basic resolution unit is 3 arc seconds or approximately 90 m. A resolution of 90 m was deemed adequate for the beginning work at the statewide level. The data were re-sampled cell-by-cell to a resolution of 30 m to match the resolution of the LULC data set.

Because OWPAI's version of WindMap operated only on gridded data sets of no more than 300 rows by 300 columns, the state was divided into 23 blocks of 90,000 grid cells where each grid cell is 372 x 372 m. Both the surface roughness and DEM data sets had a mean filter consisting of a 12 x 12 grid cell kernel applied to them in order to produce averages for cells with a resolution of 360 m. Using nearest neighbor analysis, these larger cells were resampled to cell sizes of 372 m. The size of the grid cells and the blocks provide a sufficiently rigorous scale of examination in order to detect important landscape differences in topography and surface roughness while maintaining a reasonable computation time.

Two factors have a large effect on WindMap's predictions. The initial wind field is one of the key factors. This field is created from observations so the data must be accurate and representative of conditions throughout the region. Fortunately, Oklahoma Mesonet stations provide a dense coverage of the state.

A second key factor is the relative weights given to the vertical and horizontal adjustments to the wind field. The stability ratio, the ratio of the vertical to the horizontal wind field, is a key parameter in the model. It provides a measure of the thermal stability of the atmosphere. A stability ratio of one corresponds to a thermally neutral atmosphere while values less than one corresponds to a stable atmosphere. The results presented in this paper are based on the model default, or a stability ratio of 1.0.

4.1 Wind Assessment at 10 Meters

Figure 5 illustrates the output grid from WindMap at a height of 10 m. Note, only a small area of the state has class 3 or 4 winds. Previous wind resource assessments by the National Renewable Energy Laboratory (NREL) and Pacific Northwest Laboratory suggest that a much larger area of class 3 and class 4 winds exist across the state ***(Figure 1)***.

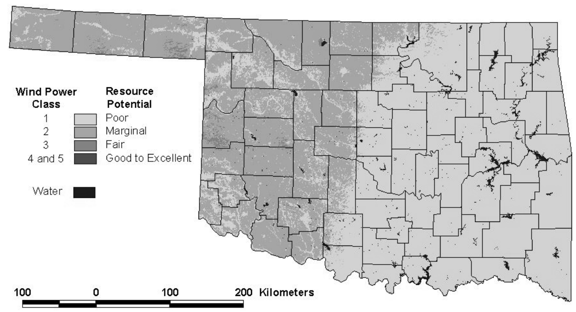

Figure 5. WindMap estimation of Oklahoma wind resources at 10 meters, not adjusted.

Additional evidence that the model output underestimates the wind resource for western Oklahoma was observed in the data collected from an instrumented tower located in northwest Oklahoma. During January 2001, a 40-m tower south of Buffalo, Oklahoma was instrumented with cup anemometers and directional vanes to measure the wind at three heights. After the first six months, wind speeds at 10 meters averaged 6.38 meters per second. According to the Wind Energy Resource Atlas (Elliott et al., 1987), an average wind speed between 6.0 and 6.4 m/s at 10 m is typically associated with Class 5 winds. In comparison, WindMap classifies the same area as having Class 2 winds. Such a significant difference suggests that WindMap is underestimating the wind resource for northwest Oklahoma, with input parameters as set.

The WPDs computed by WindMap were compared to the calculated WPDs for the Oklahoma Mesonet. WindMap underestimated the WPDs at roughly 60% of the stations. Unfortunately, the majority of underestimation occurred at stations located in the western half of the state. For example, Windmap underestimated WPD for all six Mesonet stations located in the Oklahoma panhandle. For these six stations, the WPDs were underestimated by an average of 14 W/m^2.

The apparent underestimation likely results from the following factors:

1. WindMap has several parameters (e.g., stability ratio, elevation adjustment coefficient, Weibull coefficient, boundary layer height) that can be adjusted by the operator. However, the choice of these parameters is subjective. Parameters are chosen by trial and error until a best fit with the data is found.
2. Oklahoma Mesonet stations are not located on tops of hill or ridges because of siting criteria. Consequently, stations are generally not located at sites with the strongest winds.
3. The physics of the WindMap model are limited compared to the full-physics models used in today's numerical weather prediction models (this is not surprising, given the modest cost of WindMap). Mass-conserving models such as WindMap have

trouble reproducing the wind field across complex terrain, especially in areas with few or no observations available.

4. The variety of topography and vegetation that exist across Oklahoma may provide problems for the model. Oklahoma has a wide variety of climate conditions (from humid subtropical to middle latitude steppe) and topography (low lands to high plains to mountains). Parameters for the model may have to change for each area of the state. To date, our study has used identical WindMap input parameters throughout the state.

In an attempt to increase the model's estimation of wind power density, wind statistics were computed from the data collected at the south Buffalo tower and used to help initialize the model. The results suggest that more surface data are necessary for the initialization of the model.

Unfortunately, the amount of surface data is finite, so methods for adjusting the output grid were investigated. The simplest method to compensate for the underestimation is to multiply the grid cells by a correction factor. To determine the correction factor, a linear regression was performed between the predicted and calculated WPDs for Mesonet stations. The reciprocal of the resulting slope is the correction factor (1.33). The resulting output is shown in ***Figure 6***. Although the resulting grid overestimates the WPD values at nearly 90% of the Mesonet stations, the results agree better with the statistics from the south Buffalo tower and the DOE/PNL wind assessment.

OWPAI hypothesizes that the new grid does a much better job estimating the wind power for western Oklahoma. However, further testing including the collection of more verification data is needed before the wind resource assessment map is finalized.

4.2 Wind Assessment at 50 meters

Typically, 10 m AGL is suitable for placement of small turbines. However, large utility-scale turbines must be placed at a much higher height. WindMap can produce maps at three levels above ground, so a 50-m map was also generated. The grid output at 50 m has significantly more area of class 3 winds than at 10 m, and a few isolated grid cells of class 4 winds.

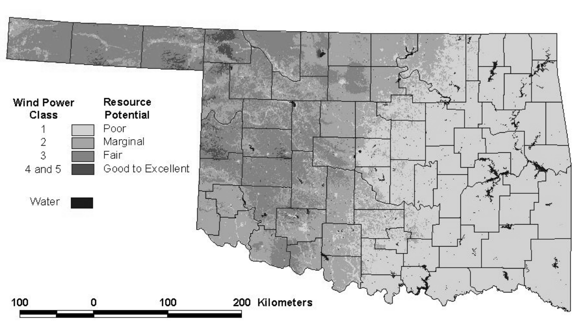

Figure 6. WindMap estimation of Oklahoma wind resources at 10 meters with Buffalo Tower data added and correction factor of 1.33 applied.

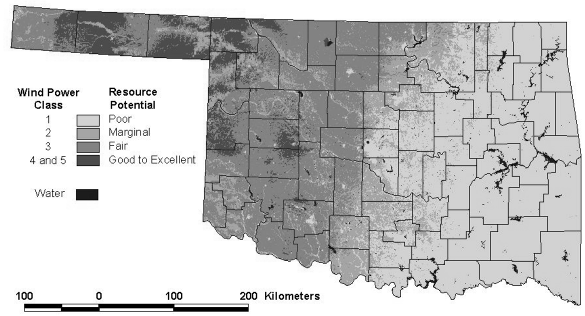

Figure 7. WindMap estimation of Oklahoma wind resources at 50 meters with Buffalo Tower data added and correction factor of 1.33 applied.

General knowledge and data from the south Buffalo tower suggests that the modeled results at 50 m are not realistic. The underestimation likely results from a lack of 50-m data in the initialization of the model. As a temporary solution, the corrected (multiplied by 1.33) 10-m grid from WindMap was extrapolated to 50-m using the $1/6^{th}$ power law.

The power-law is a method for extrapolating the wind speed between heights:

$$U/U_r = (Z/Z_r)^m \qquad (2)$$

U_r represents the wind speed at the reference height Z_r (10 m), while U represents the estimated wind speed at height Z (50 m). The exponent, m, is dependent upon the values of surface roughness and stability. Typically, the exponent is chosen based upon long term averages of measurements collected at two different heights. At the time of this writing, data from only one tall tower (south Buffalo) was available to the study. Based upon these data and intuition, an exponent of $1/6^{th}$ was chosen.

Figure 7 represents the long-term wind power density at 50 m based upon the extrapolation of the corrected 10-m grid output from WindMap using the $1/6^{th}$ power law. It suggests a considerable area of western Oklahoma suited to large turbine farm development. Eastern Oklahoma is generally poor for this purpose although some of the ridge tops of the southeastern mountains might be suitable.

The 50-m map provides much more information than previous assessment maps for Oklahoma. The new assessment map provides much finer detail than the DOE/PNL map, but more importantly, the overall spatial variation in wind energy remains the same (wind power increases from southeast to northwest). The resolution of a wind resource assessment map is important for the wind power industry. The placement of wind turbines is critical because a small increase in wind speed results in a much larger increase in power output from a turbine. In general, the power output from a turbine varies almost with the cube of the wind speed.

The other large discrepancy between maps is the classification of the Ouachita Mountains in southeastern Oklahoma. The DOE/PNL map places class 3 and 4 winds in this region, while the results from WindMap categorizes the entire region as class 1 winds. Unfortunately, verification data does not exist for these mountains; hence, two different conclusions are drawn. However, OWPAI favors the earlier assessment by DOE and PNL because the ridges in this mountain range are significant (i.e., greater than 100 m above the average elevation for the region).

While the accuracy of the model output must still be quantified, the adjusted model output provides the best guess approximation of the wind field across Oklahoma. Future work will concentrate on the development of an objective method for choosing a correction factor, as well as obtaining more validation data. Currently, OWPAI has one 40-m tower in operation, but future plans are to instrument more towers. The locations of these towers will likely be in areas with the greatest potential for development of wind energy, but attempts will be made to have these towers spread evenly across the state.

5. WIND ASSESSMENT USING AN EMPIRICAL MODEL

A neural network model was developed to relate five parameters quantifying elevation, terrain and vegetative roughness to calculated WPD values at 76 Mesonet stations. Neural networks are a form of artificial intelligence first practically used in the late 1950s. Advances in neural networks and computers have allowed their successful application to a wide range of problems in such areas as pattern recognition, signal processing, and control systems. One advantage over linear regression is that neural networks can fit to as well as generalize non-linear relationships.

5.1 Data inputs to model

Inputs for the empirical model were derived from the following:

- Oklahoma Mesonet wind data at 10 m;
- Oklahoma Mesonet air temperature and pressure data;
- a 200-m resolution Land Use/Land Cover (LULC) grid, derived from the USDA/NRCS MIADS data for Oklahoma; and
- a 60-m resolution Digital Elevation Model (DEM) derived from 1:100,000 scale digital topographic maps.

WPD was calculated by the same method as outlined in Section 3. All other calculations and data analyses were completed using ESRI GIS software ArcView vers. 3.2.

Through a process called training, wind power density (WPD) values for 50 of the 76 stations were related to elevation, terrain exposure, and roughness lengths in order to formulate a model that would output WPD over the entire state. This set was chosen randomly; however, the points are spread somewhat evenly across the state of Oklahoma. The WPD values for the 26 other stations were then used to validate the model output in order to optimize the model performance.

The elevation and terrain exposure for each Mesonet station were computed from the DEM data for Oklahoma. "Terrain exposure" is defined as the distance a point sits above or below the average elevation of the surrounding area, typically circular. OWPAI varied from this practice in its use of terrain exposures relative to north and south "pie-wedge" shaped areas out to a distance of 10 km. The north wedge extended from northeast to northwest (34° to 146°), and the south wedge extended from southwest to southeast (214° to 326°). [These degree readings correspond to Cartesian degree coordinates rather than compass degrees, since ArcView requires the former as inputs.] The average 10-km elevation was then subtracted from the actual elevation of the site to calculate terrain exposure. A positive number represents a point that sits above an adjacent wedge area on average; a negative number represents a point that sits below an adjacent wedge area on average.

Use of the wedge method described above was justified after creating and analyzing an average wind rose diagram for the 76 sites (***Figure 8***). The wind direction distributions on the wind rose diagram were calculated using 7 years of Mesonet wind data. This diagram displays the mean percent time and mean percent energy of the wind in 16 compass directions for the sites with ‘excellent’ and ‘good’ fetch ratings. From this diagram, the wind was from the north and south 77% of the time while 89% of the wind energy was from the north and south. Thus, it was concluded that the surface terrain and vegetation characteristics to the north and south of most points have the greatest impact on the measured winds and calculated wind energy.

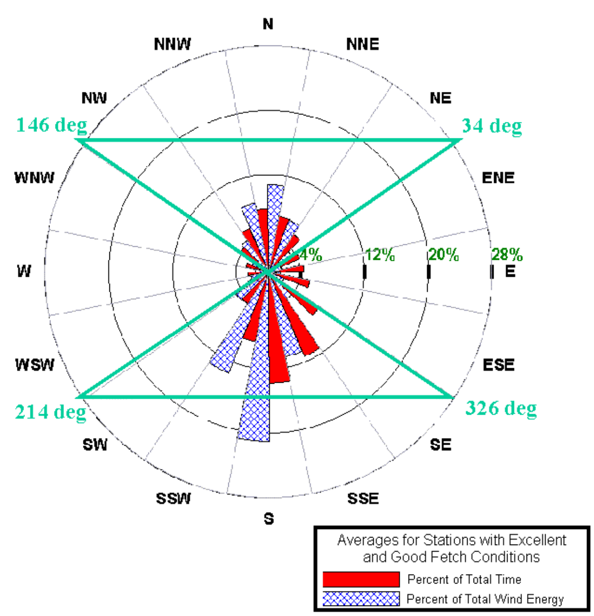

Figure 8. Average wind rose for stations with good and excellent fetch conditions.

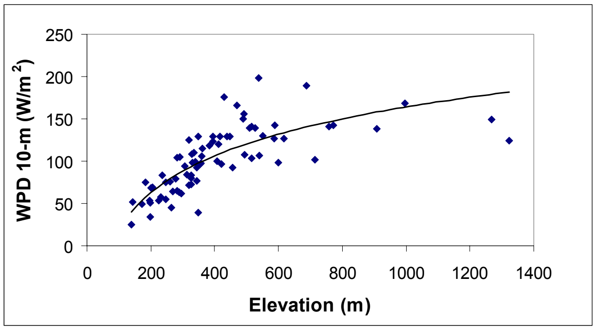

Figure 9. Elevation vs. Wind Power Density.

This conclusion was the basis for the development of the wedge method.

Similar to the GAP LULC data used for the WindMap model, the 200-m resolution LULC grid based on MIADS shows land use practices and natural vegetation cover. The LULC grid was converted by assigning roughness values to each class, then re-sampling the 200-m resolution roughness grid to match the 60-m resolution DEM grid. Average roughness values were calculated over the north and south pie-wedge areas out to 10 km (relative to Mesonet stations used), as described above for terrain exposure.

5.2 Methodology

In general, an increase in elevation corresponds to an increase in wind speeds. Moreover, it can be concluded that an increase in elevation would correspond to an increase in wind power. For Oklahoma, a logarithmic relationship is often assumed to exist between wind power and elevation (***Figure 9***). Hence, the relationship between elevation and wind power provides justification for including it in the neural network model.

Similarly, terrain exposure has a proportional relationship to wind power. That is, points that are above a surrounding area on average generally have higher wind speeds while points that are below the surrounding area on average generally have lower wind speeds. Although a distinct relationship does not exist between terrain exposure and wind power (***Figure 10***), several Mesonet stations imply that a relationship exists (especially Weatherford, Minco, and Cheyenne).

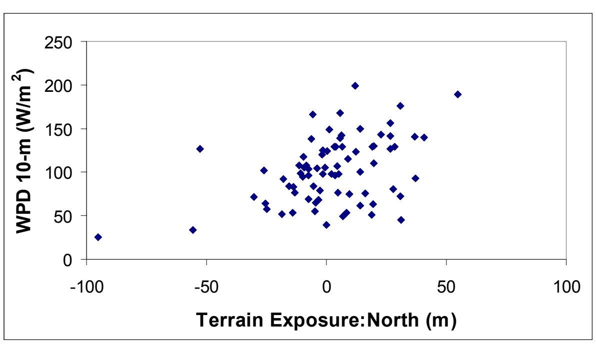

Figure 10. Terrain Exposure (north wedge) vs. Wind Power Density.

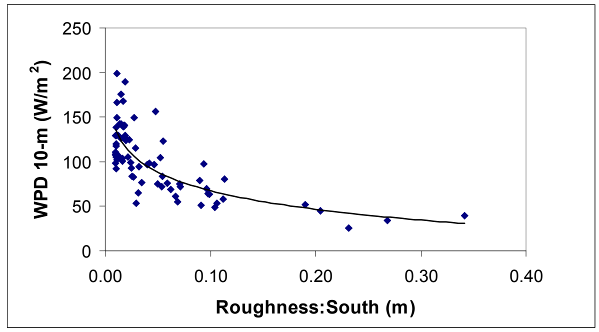

Figure 11. Roughness (south wedge) vs. Wind Power Density.

Wind power is also dependent on friction. For example, a rough surface, such as a forested area, tends to impact wind speeds more than a smooth surface, such as the ocean. In other words, tall, dense vegetation has a significant impact on surface wind speeds whereas short, sparse vegetation has little impact on surface wind speeds. From ***Figure 11***, it appears that an inverse logarithmic relationship exists between roughness and wind power; therefore, roughness was a parameter included in the development of the neural network model.

5.3 Results

Using the above data and methods, a long-term 10-m wind power map was produced (***Figure 12***). At 10 m, the neural network model does not predict any class 4 winds.

Using a 1/6th power law, the modeled 10-m wind power output was extrapolated to 50 m (***Figure 13***).

The 50-m output shows several areas of class 4 winds in Northwest Oklahoma and the Panhandle. This correlates well with the DOE/PNL model. Several differences are evident, though, when comparing the two methods. First, the DOE/PNL model predicts one broad area of class 4 winds in Northwest Oklahoma whereas the neural network model depicts several smaller areas corresponding to ridge and hilltops, within that same broad area. Secondly, the class 4 winds in Southeast Oklahoma shown in the DOE/PNL model are not evident in the neural network model.

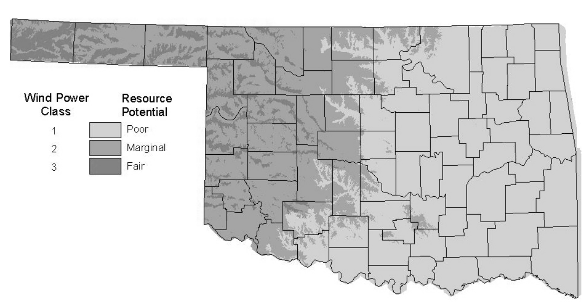

Figure 12. Modeled 10-m Wind Power Density using Neural Networks (W/m^2).

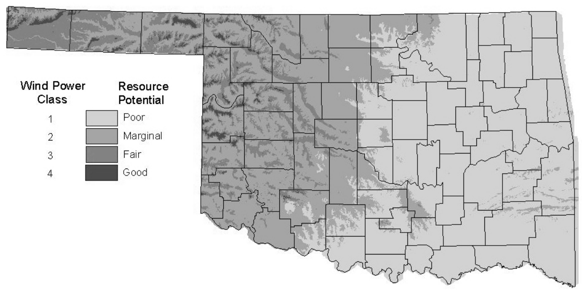

Figure 13. Modeled 50-m Wind Power Density using Neural Networks (W/m^2).

In all, the neural network model provides an indication of areas that have excellent exposure to the wind. These could be areas with low roughness values or areas that on average are several meters above an adjacent area. Regions that have a good complement of both these factors have better potential for the development of wind power.

As with WindMap, it is believed that the neural network model is underestimating the wind potential in Oklahoma. In order to determine this, more validation data is needed at the 50-m level throughout western Oklahoma. As validation data becomes available, adjustments will be made to improve the model performance.

6. SUMMARY

Oklahoma serves as a good test bed for these types of model validation and development studies. Because of the existence of a long-term permanent mesoscale observation network, it is possible to feed detailed local data into models to test their sensitivities. Results from these studies demonstrate how sensitive WindMap is to initialization and the limitations of the empirical model. Aside from these factors, though, the studies show the incredible detail that is available because of high-quality input data. The sensitivities of the models discussed here may be helpful to organizations in other states that are interested in evaluating their region's wind power potential.

Another benefit of the work done here is that the results are directly relevant to those outside of the science community. Landowners may use the maps and products produced by OWPAI to assess the likelihood of wind power development in their area, hence strengthening their bargaining positions when negotiating lease payments. Policy makers can get a better feel for how much energy can be generated from tapping these resources, and the economic benefits that result. OWPAI has used these data to show economic development potential in rural parts of western Oklahoma – an area that has been losing population as agricultural communities fade away. Given the finite supplies of oil in Oklahoma, wind power may become the next big energy boom for this major energy-exporting state.

The OWPAI team has taken the scientific results described here and produced several briefing papers for legislators and study committees. In particular, OWPAI representatives have input into two key committees – the energy deregulation review committee and an interim study on renewable energy. Our findings pertaining to economic development potential will help guide decisions to capitalize upon creating new markets in targeted areas of Oklahoma.

Those interested in viewing OWPAI's resource maps and other products may visit our web site at:

www.seic.okstate.edu/owpai

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