Blowing in the Wind: Evaluating Wind Energy Projects on the National Forests

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ABSTRACT

The 650 million ac of federal lands are facing increased scrutiny for wind energy development. As a result, the US Forest Service has been directed to develop policies and procedures for siting wind energy projects. We incorporate geospatial site suitability analysis with applicable policy and management principles to illustrate the use of a Spatial Decision Support System (SDSS) for evaluating the potential for wind energy development in the national forests. The SDSS is applied in a case study of the Nantahala and Pisgah National Forests (N&PNF), ranked by the National Renewable Energy Laboratory as one of the top 25 national forests for wind energy development based on wind power, distance from transmission lines, distance from major roads, inventoried roadless areas and other specially designated areas, distance from urban areas, and topography (Karsteadt, R. et al. 2005. *Assessing the potential for renewable energy on National Forest Systems lands.* National Renewable Energy Laboratory and the US For. Serv. Available online at www.nrel.gov/wind/pdfs/36759.pdf; last accessed Mar. 14, 2009). Our analysis further evaluates the N&PNF potential for wind energy development using 16 environmental, construction, land designation, and policy variables. We find that the majority of the N&PF is highly sensitive or exclusionary to wind energy development. Recommendations include the need for agencywide clarification of evaluation criteria for wind energy projects and prioritization of variables for evaluating future wind projects.

Keywords: wind energy, geo-spatial analysis, national forests, spatial decision support system

With the United States' wind power capacity [1] growing 29% annually since 2003, utility scale wind projects are currently being developed in 34 states (American Wind Energy Association 2009). This surging interest in wind energy is now focused on the 650 million ac of federal lands as potential sites. The majority of wind energy projects on federal lands are located in the West, on Bureau of Land Management (BLM) lands. As of 2005, there were 22 production and 63 site testing and monitoring authorizations on BLM lands (Bisson 2008). The BLM is leading the federal development of renewable energy policy. In 2008, the BLM issued its Wind Energy Development Policy Instruction Memorandum, formally instituting the use of a Programmatic Environmental Impact Statement (PEIS) for wind development. The PEIS addresses direct, indirect, and cumulative impacts from proposed wind energy development and required analyses before, during, and after construction.

The US Forest Service wind energy development policy is currently in a state of flux as reflected in the existence of only one environmental impact statement (EIS) for a wind project on US Forest Service land—the Deerfield Wind Project in the Green Mountain National Forest (Bayer 2008). Several recent policy directives have expanded the US Forest Service's role in promoting the use of renewable energy. In 2001, the President's National Energy Policy directed the US Forest Service to increase energy production from woody biomass, geothermal, wind, and solar power. The 2003 Healthy Forest Initiative Act authorized the US Forest Service to offer woody biomass grants, and the 2005 Energy Policy Act emphasized the US Forest Service's role in renewable energy development. In 2007, the Advanced Energy Initiative authorized funding for wind and solar research and expanded access to federal lands for wind energy development. Although the US Forest Service has developed a strategic plan for renewable energy development, the plan primarily focuses on identifying opportunities to use woody biomass from the national forests to produce bioenergy and bioproducts. The 2008 USDA Inspector General's Audit Report on the US Forest Service Renewable Energy Program concluded that although the US Forest Service has had some success in promoting renewable energy production (primarily woody biomass), it needs to develop a national strategy for renewable energy, particularly wind, solar, hydropower, and geothermal (USDA 2008).

In 2007, the US Forest Service issued proposed directives (US Forest Service 2007) for siting wind energy projects, processing wind energy proposals and applica-

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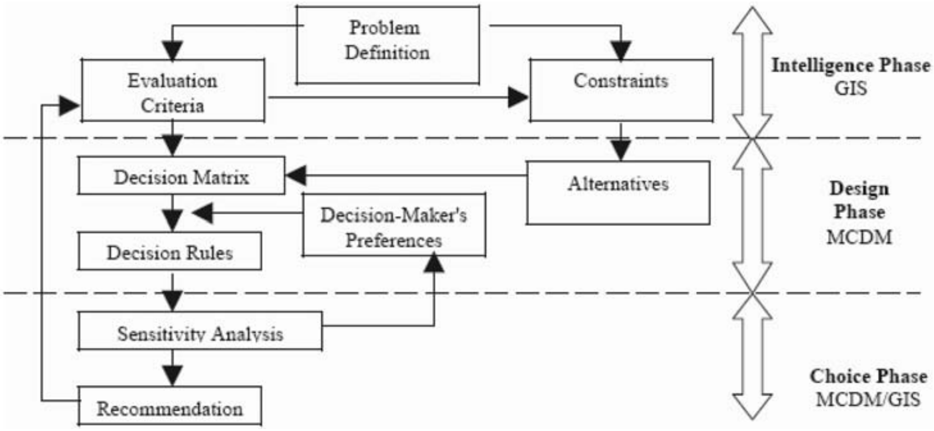

Figure 1. Spatial decision support system flow. (From Ozen et al. 2003)

tions, and issuing wind energy permits. Specifically, the directives provide guidance on siting wind energy turbines, evaluating a variety of resource interests, and addressing issues specifically associated with wind energy in the special use permitting process. These issues include potential effects on scenery, national security, significant cultural resources, and wildlife, especially migratory birds and bats. While the proposed directive and public comments are processed, wind energy projects on US Forest Service lands are evaluated under special use authorizations (SUA; US Forest Service 2008). SUA proposals must be consistent with National Forest System (NFS) regulations, federal laws, relevant state and local health and sanitation laws, and the standards and guidelines in the applicable Forest Land and Resource Management Plan (US Forest Service 2008). SUA proposals may not conflict or interfere with administrative uses, other scheduled or authorized existing uses, or use of adjacent non-NFS lands (US Forest Service 2008). A SUA requires wind energy projects to shown that the site is a viable wind source capable of effectively producing wind energy within the forest's management goals and could not be accomplished on non-US Forest Service land.

We illustrate the use of a geographic information system–based spatial decision support system (SDSS) for analyzing land-use suitability for wind energy on national forestlands. With the Green Mountain National Forest Deerfield EIS (Bayer 2008) as a starting reference, we incorporate existing techniques of site suitability analysis with US Forest Service management principles to illustrate an analytical approach to evaluate wind energy projects applicable to any national forest.

We use data on construction requirements, land designation, and environmental and policy constraints to evaluate suitability of wind turbine placement and the potential for wind energy development. An SDSS has three phases: the intelligence phase, the design phase, and the choice phase as illustrated in Figure 1 (Ozen et al. 2003). Geospatial analysis is the backbone of the intelligence phase of an SDSS, which uses constraints and evaluation criteria to produce potential alternatives for development. The design phase incorporates decisionmakers' preferences by allowing them to run iterations of the intelligence phase with varying combinations or factors or weight factors and comparing the impact of these changes on the output. The choice phase consists of sensitivity analysis and final decisionmaking. For land-use suitability assessment, the design phase of an SDSS can be used to identify the most appropriate spatial distribution for land uses according to specific requirements, preferences, or predictors of activity (Malczewski 2004, Hansen 2005, Lejeune and Feltz 2008). Map overlays to assess suitability are created by adding different layers of constraint and suitability criteria to represent cumulative development potential.

Next, we review the literature on criteria for siting wind energy projects and potential impacts associated with wind energy development. Then, we illustrate the intelligence phase of an SDSS via a case study examining the potential for wind development potential in the Nantahala and Pisgah National Forests (N&PNF) in North Carolina.

Criteria for Siting Wind Energy Projects

Feasible wind energy sites must satisfy a range of devolvement criteria that can be used in an SDSS as constraint variables. First, a site must have a wind power class rating between 3 and 7. [2] Land requirements vary considerably but mostly depend on (1) the developer's goals for wind potential and project capacity and (2) landscape characteristic and existing patterns of land use and ownership (Global Energy Concepts 2005). Most developers prefer areas that can site enough wind turbines to produce a minimum capacity of 30 MW of electricity, and preferably more, with an existing electric transmission grid in close proximity (Global Energy Concepts 2005). Site terrain must be favorable for construction and accessible by heavy-duty vehicles and cranes. Excessively steep slopes or ravines can be difficult to access and safety risks and soil conditions must be supportive for road construction and the installation of underground facilities (i.e., turbine foundations, communications lines, and electrical conductors; Global Energy Concepts 2005).

Landscape dictates project design through topography, land cover, human populations, and environmental sensitivities. Ridges and open plains usually have the highest wind power potential compared with valleys or rugged terrain, which can create turbulence and decrease wind potential. Topography and surface cover combine to affect the level of aerodynamic surface roughness, which affects wind speeds and the amount of turbulence (Renewable Energy Research Laboratory 2006). Higher roughness values refer to landscapes with many buildings or trees, whereas lower roughness values refer to flat, open spaces such as fields or water bodies (Danish Wind Industry Association 2003).

Included in the generic siting process is an analysis of potential environmental impacts such as proximity to parks and federally designated conservation areas (e.g., roadless areas, wilderness areas, critical habitat, or migration corridors). Land use in the project area is also evaluated to assess populations affected by the project. Turbine placement requires a variety of setback distances, which is the minimum distance a wind turbine is permitted to be constructed in relation to existing infrastructure or boundaries. Setback distances relevant to this analysis included residences, property lines, and roads. Setback distances from property lines vary locally according to building codes and structure height and are usually 1.5 times the turbine height, or 3 times the hub height from residences for

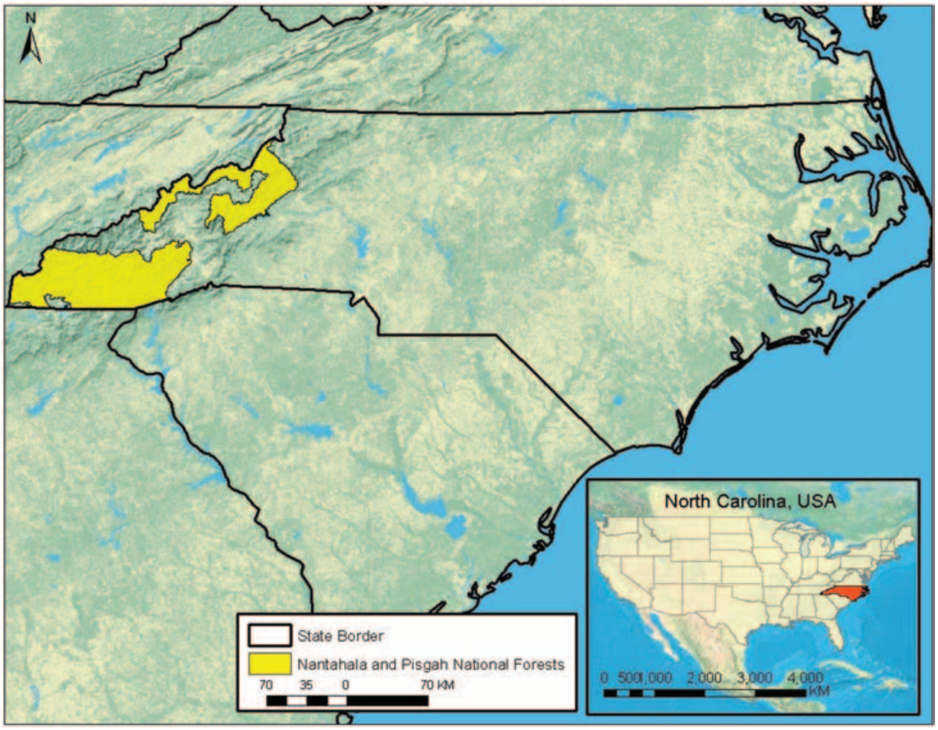

Figure 2. Location of the Nantahala and Pisgah National Forests in North Carolina.

noise reduction. Ice throw dangers require setback distances of two to four times the blade-tip height (Renewable Energy Research Laboratory 2006).

Wind turbine arrangement depends on the size and shape of the landform; turbines are placed in rows as perpendicular to the prevailing wind direction as possible. Single rows are used for sites with high wind power potential but limited space, such as ridgelines. Larger, more open spaces can accommodate multiple rows or a grid setup. Turbines must be spaced far enough apart to avoid downwind interference, known as wake or array effects, which reduce turbine efficiency in the same way as surface roughness (Global Energy Concepts 2005). Wide turbine spacing maximizes energy production but requires more land and infrastructure. In locations with unidirectional winds, turbines can be spaced closer together in rows, typically 3 to 4 rotor diameters apart, compared with areas with multidirectional winds, where turbines are usually placed 5 to 7 rotor diameters apart. On ridges, spacing of 2 to 3 rotor diameters is often used (Renewable Energy Research Laboratory 2006).

Terrain complexity also influences turbine layout to take advantage of high wind potentials. The goal is to balance higher wake effects and lower costs associated with tighter spacing (Global Energy Concepts 2005). Project facilities include the turbines and their foundations, service roads, crane pads, electrical equipment, and any associated buildings and typically occupy about 5% of the total project area (Global Energy Concepts 2005).

Potential Impacts from Wind Energy Development

A number of potential impacts from wind project construction should be included in an SDSS, especially on public lands. Wind energy development can produce a number of social, economic, and environmental impacts that create conflicts between the desire to protect the local environment versus national goals of reducing dependence on fossil fuels for economic, national security, and climate change benefits (Woods 2003); a classic case of the not-in-my-backyard syndrome (NIMBY). Damborg (1998), however, found that NIMBY is strongest where there is no or very little knowledge about wind power. With increased levels of information, public acceptance increased. Furthermore, community resistance to wind projects is usually not directed at the project itself, but against the decisionmaking method and those proposing the project. Higher involvement of local populations, a transparent planning process, and high levels of information increased overall project support.

Environmental concerns arise primarily from the disturbances associated with deforestation and land clearing for turbine placement (Forman and Godron 1981, Franklin and Forman 1987, Yahner 1988, Luken et al. 1991, Zipperer 1993, Conn 2003, Natural Resources Committee of the Highlands Council [NRSCHC] 2006). The most common deforestation pattern is internal line-corridor deforestation, classified as induced edges or as abrupt manmade junctions between a deforested area and the natural habitat (Forman and Godron 1981, Yahner 1988, Zipperer 1993). Impacts may include irreversible loss or degradation of habitat, changes in microclimate, reduced water quality, and increased flooding (Zipperer 1993, NRSCHC 2006). Species loss due to edge forest conditions and fragmentation may be the result of unsuitable changes in the microenvironment, competition with new invasive species, or an insufficient total area of suitable foraging habitat (Franklin and Forman 1987). Avian communities, for example, acutely feel the effects of edge forest creation as the removal of overstory vegetation creates new habitat and changes the range of species that find the habitat suitable (Franklin and Forman 1987).

Forest management plans also address cultural and archeological resources located on national forest lands. Cultural and archeological resources are regulated under the National Historic Preservation Act and should be considered in development proposals. In this analysis, these issues were not included because of lack of geospatial data.

Case Study: N&PNFs

In 2005, the National Renewable Energy Laboratory (NREL) released a report assessing the potential for developing industrial wind energy power facilities on national forests and grasslands. The N&PNFs in North Carolina (Figure 2) ranked in the top 25 national forests with large potential for wind energy development. Based on wind power, distance from transmission lines, distance from major roads, inventoried roadless areas and other specially designated areas, distance from urban areas, and topography, the N&PNFs in North Carolina were found to have 34,707 ac with suitable wind classes and a development potential of 702 MW (Karsteadt et al. 2005).

Nantahala and Pisgah Forest National Forest Management Plan

The local forest policies referred to by the US Forest Service wind energy directive are the management goals of individual national forests. Amendment 5 of the Land and Resource Management Plan for the N&PNF sets the most current goals for forest management (US Forest Service 1997). Ecological goals include conservation of biodiversity, establishing old-growth and forest interior areas, recovery of threatened and endangered species, and managed continuous tree canopy. Aesthetic goals focus on reducing visible clearcuts, especially within sight of the Appalachian Trail and Blue Ridge Parkways to retain high visitation rates. Management areas in the N&PNF range from administration for timber and recreational activities to "semiprimitive nonmotorized" areas, which must meet standards regarding size and isolation, lack of development, and potential for wildlife habitat and old-growth forest (US Forest Service 1997).

Methods

Data were collected from a number of sources including the US Forest Service, US Geological Survey (USGS), US Fish and Wildlife Service, and the North Carolina State Energy Office. All files were imported to ArcMap; raster files were resampled to 30 × 30 m cell size. [3]

Ridge Creation

Ridges with potential for development were created by digitizing and cleaning subwatershed hydrologic unit code (HUC) 14 boundaries. HUCs represent unique hydrologic units across the nation, which are subdivided into four classes: regions (the largest units), subregions, accounting units, and cataloging units (the smallest units). A cataloging unit is a geographic area representing part of a surface drainage basin, a combination of drainage basins, or a distinct hydrologic feature (USGS 2009). These units subdivide the subregions and accounting units into smaller areas, (i.e., HUC-14 areas), which represent watershed boundaries such as ridges. In this analysis, the USGS HUC file (Steeves and Nebert 1994) was used to create the ridge file by clipping the HUC-14 boundaries to areas of wind power potential class 3 or greater, a requirement for utility scale wind energy development. This resulted in watershed boundaries (i.e., ridge segments) only in areas with potential for development.

The final ridges were created by over laying the ridge segments created from the HUC-14 boundaries over a high-resolution topographic 7.5-minute USGS map (USGS 2008). For each HUC-14 boundary segment representing a ridge, side stream branches were deleted from the HUC-14 files to create ridge files, which only included ridgetops. Ridges were selected based on their directional attribute, which was determined based on spatial prevailing wind data from the National Climatic Data Center (2002). Turbine placement and project design depends on ridge direction to minimize downwind disturbance effects; turbine spacing was determined by the number of rotor diameters assuming General Electric 1.5-MW turbines, with rotor diameters of 77 m (Rosenbloom 2005).

Buffers were created using a radius of 30.8 m around turbine locations to account for areas cleared for construction. Ridge buffers were 6 m on each side of the ridge, to account for the area cleared for transmission lines and maintained for maintenance access. These measures are based on requirements of similar size projects on US Forest Service land (Paulson 2008). A 300-m buffer of the ridge containing the proposed turbines simulates the amount of edge forest

Table 1. Variable reclassified cost and constraint level for geospatial analysis.

	Attribute	Reclassified cost	Constraint level
Construction/infrastructure variables			
Percent slope	Slope, >20%	1	Sensitive
	Slope, <20%	0	No constraint
Roads	Distance, <40 m	1	Sensitive
	Distance, 40–7,000 m	0	No constraint
	Distance, >7,000 m	1	Sensitive
Blue Ridge Parkway	Road	10,000	Exclusion
	Road setback	100	Highly sensitive
	Nonroad	0	No constraint
Utilities	Distance, <7,000 m	100	Highly sensitive
	Distance, >7,000 m	0	No constraint
Trails	Distance, <225 m	1	Sensitive
	Distance, >225 m	0	No constraint
Appalachian Trail	Trail	10,000	Exclusion
	Trail setback	100	Highly sensitive
	Nontrail	0	No constraint
Blue Ridge Parkway viewshed	Viewshed within 5 mi	100	Highly sensitive
	Non–viewshed area	0	No constraint
Appalachian Trail viewshed	Viewshed within 5 mi	100	Highly sensitive
	Non–viewshed area	0	No constraint
Wind variables			
Wind power potential (W/m^2)	Potential, <300	100	Highly sensitive
	Potential, 300–400	1	Sensitive
	Potential, 400–500	1	Sensitive
	Potential, 500 to >800	0	No constraint
No. of turbines/ridge	2–10	1	Sensitive
	10–299	0	No constraint
Land designation variables			
IRA	IRA	10,000	Exclusion
	Non-IRA	0	No constraint
Specially designated areas	ERNA	10,000	Exclusion
	NWS	10,000	Exclusion
	WSA	10,000	Exclusion
	NWS	10,000	Exclusion
	OCD	10,000	Exclusion
	Nondesignated	0	No constraint
Private land	Private land with setback buffer	100	Highly sensitive
	Public land	0	No constraint
Environmental variables			
Wetlands	Wetlands	10,000	Exclusion
	Nonwetland	0	No constraint
Tree cover[a] (%)	Existing tree cover	100	Highly sensitive
	No tree cover	0	No constraint
Threatened species habitats			
Adler fly catcher	Habitat with 150-m buffer	100	Highly sensitive
	Nonhabitat	0	No constraint
Hermit thrush	Habitat with 150-m buffer	100	Highly sensitive
	Nonhabitat	0	No constraint

Low costs represent areas with development potential and higher values indicate areas unsuitable for development.
[a] ERNA, Experimental Forest and Natural Resource Area; IRA, inventoried roadless areas; NWSR, national wild and scenic river; OCD, other congressionally designated area; WSA, wilderness study area.

created by the clearing of forest on each ridge.

Cost Layers

In the intelligence phase of an SDSS, a cost layer is a tool used to geospatially represent development potential. High costs represent unsuitable areas, and low costs represent areas with greater potential for development. Cost layers are used to create a cost surface, which summarizes the general potential for an area.

At this point in the analysis we have identified all possible ridges that would be acceptable for wind energy development based on the simple criteria that they have a wind class designation of class 3 or better. This first part of the analysis extends the NREL study, because NREL did not identify specific ridges but identified whole forests without site-specific analysis. We used the wind power criteria from the NREL study to determine which ridges to include in our analysis. These ridges have different characteristics that need to be considered to make a final decision about their acceptability for development. To do this, we created a series of cost layers to assess the impact of variables such as construction requirements, existing infrastructure, environmental variables, and land-use and ownership. To create the cost layers, each variable was converted to raster form and buffered to form a constraint zone, which accounts for higher constraints closer to the feature and which diminish as distance to the turbines increase (Lejeune and Feltz 2008). Buffer distances and constraints are determined by quantitative (technical and regulatory requirements) and qualitative (visual impact) considerations. In our analysis, constraint zones represent the gradient zone of impact, where the constraint impact is highest adjacent to the constraint and decreases over distance away from the constraint.

Cost surfaces were constructed by then reclassifying the constraint zones so that cost surfaces with higher costs are less favorable or inappropriate for development. In this exercise, the primary motivation for using the specific values assigned to costs was to be able to clearly identify areas where wind development is inappropriate and should be excluded. Therefore, costs were assigned on a scale of 0 to 10,000, where 0 represents the highest development potential (i.e., no constraints present), 1 is assigned to sensitive areas, 100 highly sensitive conditions, and 10,000 represents areas that are completely restricted from development (i.e., exclusionary). Definitions for the condition constraint levels are as follows (Hansen 2005):

- *Exclusion*, the installation of wind turbines should be prohibited (value = 10,000).
- *Highly sensitive*, single-wind turbines may be permitted as long as an impact study indicates that the stated constraint does not exist at the exact location of the site proposed for the wind turbine (value = 100).
- *Sensitive*, authorization for building a wind turbine is conditional on a detailed impact study on the stated constraint (value = 1).
- *No constraints present* (value = 0), areas with highest development potential.

Cost Layer Variables

Cost layers were created for each SDSS constraint variable influential in turbine siting, including construction requirements, existing infrastructure, wind power potential, policy, environmental variables, and land designation and ownership. Table 1 shows the variables, reclassified cost, and constraint levels. These cost layers were combined to create a cost surface for each variable set and one final cumulative cost surface using the single output map algebra tool (Malczewski 2004, Hansen 2005). The cost layers are the final output of the SDSS intelligence phase. The cumulative cost surface is comprised of the four constraint levels that were defined by the following ranges: exclusionary areas with values greater then 10,000; highly sensitive areas with values less then 10,000; and sensitive areas with a value less then 100. No constraint areas are areas with a value of 0.

Assigning variable weights and constraint levels is one of the most difficult and interpretative aspects of an SDSS (Hansen 2005). In our analysis, no weights were applied to the layers and all were considered of equal importance. This is the phase in an application of an SDSS that a decisionmaker would be able to emphasize certain factors by weighting them greater than other less important factors in the analysis and running multiple iterations for sensitivity analysis.

Construction variables include roads, power lines and substations, park trails, and slope using data from the Southern Appalachian Assessment Online Database (Hermann 1996, 2001) and the USGS (USGS 1999). Landownership refers to federally designated areas such as roadless areas, wild and scenic rivers, wilderness areas, wilderness study areas, and private ownership. Private ownership is an important variable in this analysis because a number of private landholdings exist within the N&PNF boundaries. These in-holdings were classified as exclusionary areas as well as areas that would require setbacks for wind turbines developed in close proximity. Figure 3 displays the landownership variables cost surface created from the North Carolina Center for Geographic Information and Analysis (2006) and US Forest Service (Thompson 2000, 2008) data.

The proposed US Forest Service wind energy directive requires the use of a Scenery Management System to assess the value of scenery, the experience scenery provides rel-

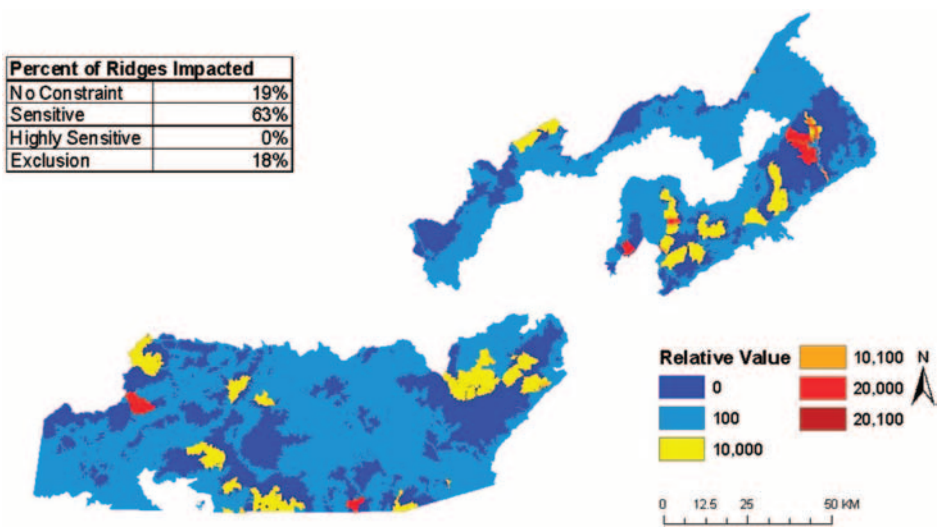

Figure 3. Land ownership variables cost surface for the Nantahala and Pisgah National Forests Wind Development Suitability.

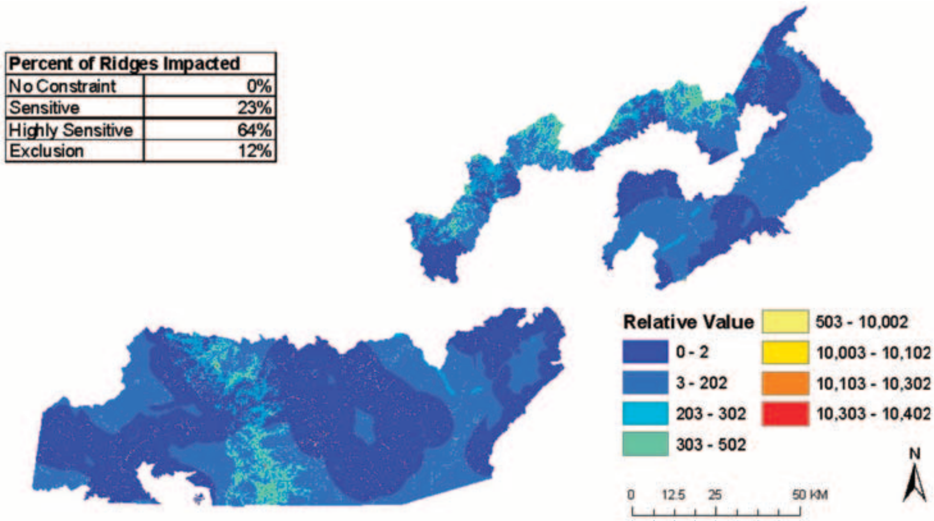

Figure 4. Construction variables cost surface for the Nantahala and Pisgah National Forests Wind Development Suitability. Note that cost values are relative and do not have an assigned unit.

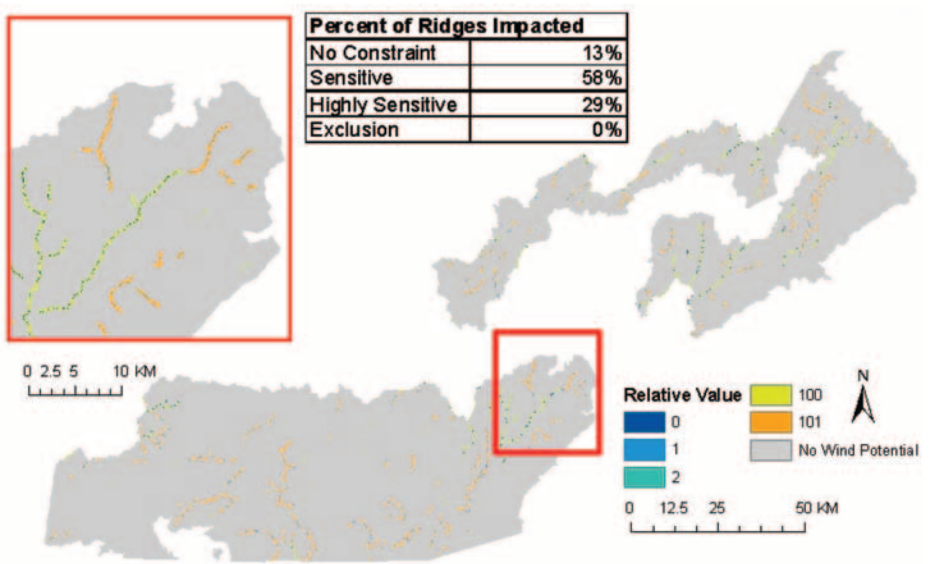

Figure 5. Wind power potential variables cost surface for the Nantahala and Pisgah National Forests Wind Development Suitability. Note that cost values are relative and do not have an assigned unit.

ative to competing resource demands, and the impacts on scenery associated with project construction and operation (US Forest Service 2007). Amendment 5 of the Nantahala and Pisgah Forest Management Plan specifically references the importance of maintaining the scenic views of the forest. Therefore, a geospatial viewshed analysis was performed along the Blue Ridge Parkway and the Appalachian Trail to analyze visual impacts associated with wind energy development. Viewshed analysis estimates the area within sight of a given location to determine how visible a constructed element is from surrounding areas (ESRI 2008). The basis of viewshed analysis is the visual threshold, the maximum distance at which an object is visible, which depends primarily on topography (Shang and Bishop 2000). For example, an object on a flat plain can be seen from all directions, whereas an object in mountainous terrain may be visible only from certain directions. The result from a viewshed analysis is a binary visible/not visible representation for the area surrounding the object.

Moller (2007) found that wind turbines become practically invisible at distances greater than 10 km because of slender construction, atmospheric haze, and the Earth's curvature. We used a threshold value of 5 mi based on the Renewable Energy Policy Project's (Sterzinger et al. 2003) extensive literature review on defining visual threshold values for wind energy projects and the USDA handbook, "National Forest Landscape Management" (Sterzinger et al. 2003). The handbook states that little texture or detail is apparent for objects more than 5 mi away, and if visible at all, the objects are perceived mostly as patterns of light and dark.

Viewshed analysis uses observation points, in this case the trail and parkway, and elevation data to determine which surrounding features are visible. The 5-mi threshold value constrained the viewshed to be calculated within 5 mi of both the parkway and the trail. The viewshed output identifies ridges within the 5-mi boundary, which are visible from the parkway and the trail. Figure 4 shows the construction requirement variables cost surface.

Using data from the North Carolina State Energy Office (2005), wind power was determined by wind speed potential and turbine spacing to maximize ridge development potential. The number of turbines per ridge was determined using ridge length and the required turbine spacing distances to estimate the number of turbines that could be constructed per ridge. Spacing distance was estimated based on rotor diameter and wind direction as previously discussed. Ridges were ranked in terms of their maximum turbine number, from 2 turbines to 229/ridge, to account for generation potential of 30 MW. Figure 5 displays the wind power variables cost surface.

Environmental variables such as known habitats of protected species, wetlands and tree cover percentage were evaluated with data from the North Carolina Gap Analysis Project (McKerrow 2008) and the Fish and Wildlife Service (Dahl 2008). Section 72.31e ("Wildlife, Fish, and Rare Plant Considerations") of the US Forest Service Proposed Directive (US Forest Service 2007) prohibits locating all stages of wind energy development in sensitive habitats or in areas where ecological resources are known to be sensitive to human activities. Our analysis includes the habitat for two threatened bird species, the alder fly catcher and hermit thrush, because they are species whose habitat preferences are particularly susceptible to edge forest creation. The environmental variables cost surface is shown in Figure 6.

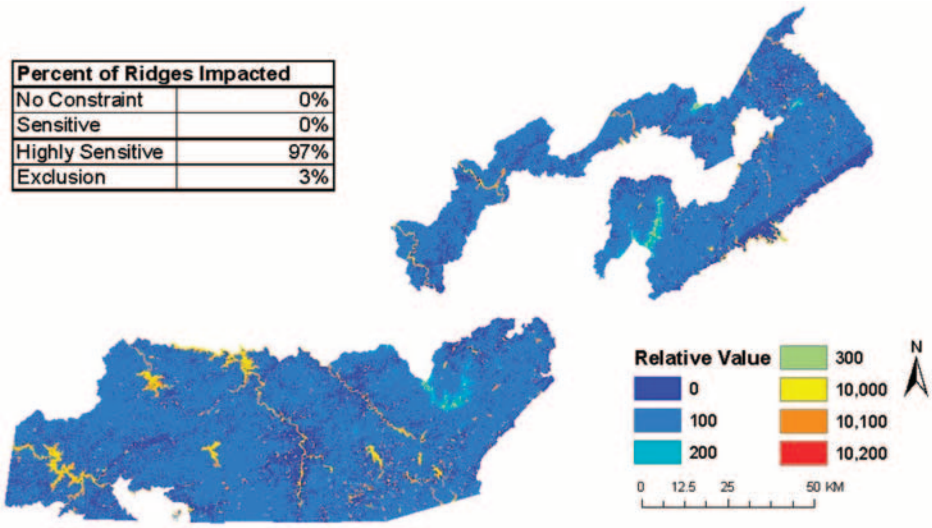

Figure 6. Environmental variables cost surface for the Nantahala and Pisgah National Forests Wind Development Suitability. Note that cost values are relative and do not have an assigned unit.

Table 2. Results of geospatial analysis cost surface by variable showing the percent of ridges impacted by each class variable.

	Percent of ridges impacted by variable cost surfaces			
Constraint level	Environmental	Land designation	Wind	Construction
No constraint	0	19	13	0
Sensitive	0	63	58	23
Highly sensitive	97	0	29	64
Exclusionary	3	18	0	12

Table 3. Results of the geospatial analysis cumulative cost surface: Area of constraint for the four constraint levels, percentage of the total study area, and the percent of ridges impacted by each constraint.

			Percent of ridges impacted by cumulative cost surface
Constraint level	Area of constraint (ha)	Total study area	Cumulative cost
No Constraint	2.97	0.0003%	
Sensitive	0.18	0.0000%	
Highly Sensitive	744,207.66	74.30%	
Exclusion	257,364.09	25.70%	
No Constraint			0%
Sensitive			0%
Highly Sensitive			71%
Exclusionary			29%

Results

Tables 2 and 3 show the percentage of ridges impacted by the environmental, land designation, wind, and construction variables and cumulative surfaces. Figure 7 displays the cumulative cost surface, where higher cumulative costs indicate ridges with more potential restrictions or exclusionary areas. Lower cumulative cost surfaces indicate less sensitive or no constraint areas more suited for development. In total, there are 346 ridges, approximately 1,106 km, with wind class of 3 or greater in the N&PNFs.

Although pressure for development of renewable energy sources is strong, many areas in the national forests are inappropriate for development because of unique or sensitive resources, and our results emphasize this for the N&PNFs. Our analysis rated 29% of ridges classified as exclusionary for development, and 71% of ridges as highly sensitive to development. Land designation has the largest exclusionary impact on ridge development within the study area, excluding 18% of ridges and only 19% as no constraint. Construction requirements exclude the second largest amount of ridges, 12%. The environmental variables identified by the Forest Management Plan result in large areas classified as sensitive to development, with the environmental variable cost surface ranking 3% of ridges as exclusionary and 97% of ridges as highly sensitive to development.

Although the NREL found wind energy potential for the N&PNF to be among the largest for national forests in the East, the conclusion was based on a coarse spatial analysis at the level of the national forest. Our more fine grained analysis finds that the majority of ridges have significant constraints that would have to be overcome to develop wind energy in the N&PNF. A major factor for this finding is the inclusion of the land cover constraint in our analysis: all ridges were located at least in part in forested areas. One of the goals of the N&PNF Land and Resource Management Plan is to maintain continuous tree canopy (US Forest Service 1997). This formed the basis of our restrictive land cover constraint and is a major factor accounting for the differences between our results and the NREL study, which did not base any of its analyses on constraints provided by the individual Forest Management Plans. In our case study, the N&PNF Management Plan specifically requires the US Forest Service to manage for continuous tree cover. This may not apply to all national forests; if other national forests do not include "continuous tree cover" as a management goal, wind energy development may be appropriate for those forests. Although clearing for turbine construction is unavoidable, the NFS is founded on the basis of multiple use. National forests' management strategies reflect this principle and in specified areas allow for activities such as hunting, recreation, timber extraction, and mining. Management plans can be amended, and in the future, multiple uses could incorporate wind development. If these types of management areas coincide with ridges with potential for development, in those locations analysis could be run without inclusion of the land cover constraint, potentially opening more areas to development potential. With spatial data on the different management areas within the N&PNF, it may

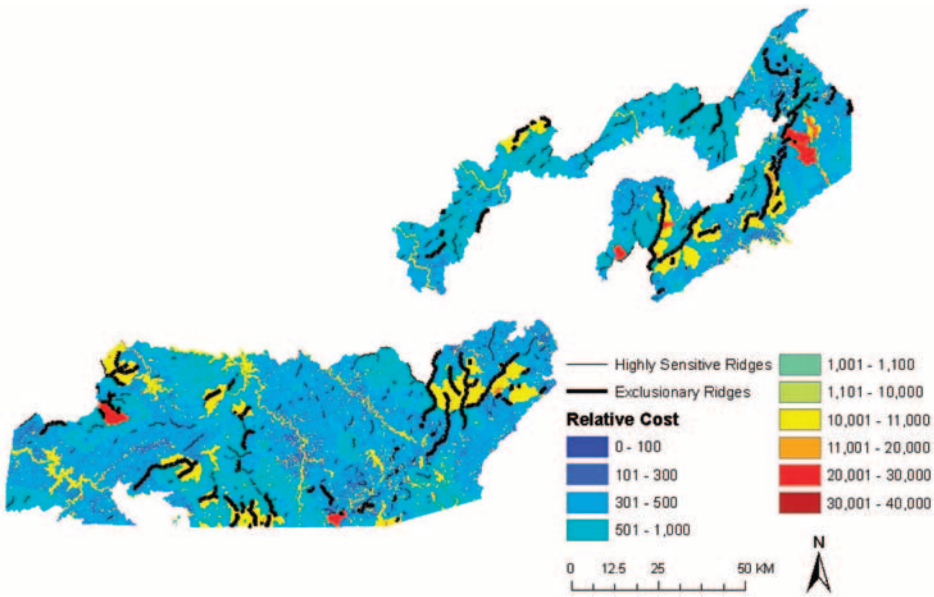

Figure 7. Results of the geospatial analysis showing cumulative cost surfaces and constraint level classification for the Nantahala and Pisgah National Forests Wind Development Suitability. Note that cost values are relative and do not have an assigned unit.

be possible to identify certain ridges in areas that are currently being managed in a way that clearing for turbine construction would be consistent with management goals.

Conclusions

Our analysis of the N&PNF emphasizes that wind development is not appropriate in all national forests. Wind development on the N&PNF, as well as on all national forests, is complicated and constrained by current management plans. The constraints arising from a particular forest's management plan may render development improper even when large-scale analysis ranks the area as physically capable of supporting wind farms.

Using the SDSS framework allows decisionmakers to identify areas with the highest potential for development. In addition, the SDSS framework allows decisionmakers to reevaluate the intelligence and design phase evaluation criteria with alternative forest management goals and incorporate input from forest managers on adding, removing, or weighting constraints to better represent the public's preferences for wind energy development in certain national forests. The final phase of an SDSS, the choice phase, includes a sensitivity analysis from which recommendations are based. This iterative process in turn produces development recommendations that are reflective of the decisionmakers' objectives and that can be adjusted to fit different development priorities.

US Forest Service wind energy policy will determine the agency's role as a renewable energy producer. The US Forest Service, however, faces several obstacles in developing its wind energy policy. In choosing a directive over a PEIS, the US Forest Service currently requires developers and field offices to evaluate projects case by case. Those opposing the directive warn that it will result in inconsistent requirements for wind energy projects, set a negative precedent for other permitting authorities in the United States, and potentially make US Forest Service land economically infeasible for hosting wind energy projects. Some believe that creating a more exhaustive directive or PEIS based on the BLM's programmatic best management policies would support the expansion of the knowledge base surrounding wind project development, limiting the potential for duplicate analyses (Lejeune and Feltz 2008).

Our illustration of an SDSS begins to address many of the concerns over the proposed wind energy directive and would allow unification of US Forest Service project evaluation without a PEIS. An SDSS for wind energy would not be unprecedented as the US Forest Service already uses spatial decision support tools for a variety of purposes from modeling forest planning tradeoffs in response to fire (Butler 2005) to analyzing national environmental threat assessments (Brewer 2008). For the US Forest Service, an SDSS could provide consistency and comparable project analyses while encouraging wind energy development in the most suitable areas.

As the number of wind power proposals on US Forest Service land increases, the ability of regulation to address the multitude of concerns associated with wind energy development is integral for maintaining support and positive perceptions of wind energy. In this article, we incorporate existing techniques of geospatial site-suitability analysis with applicable policy and management principles to illustrate the use of an SDSS for analyzing suitability of siting wind turbines in national forests. Using SDSS analysis of existing regulations and environmental and social impacts would provide an efficient and effective method for the US Forest Service to ensure continued conservation of protected areas while supporting renewable energy development under specific management scenarios. Clarification of US Forest Service objectives and standards would aid in assessing development impact and suitability analysis. The Department of the Interior has taken initiative to identify renewable energy zones suitable for development through the creation of a BLM energy and climate change task force (Quimby 2009). The SDSS analysis and methodology presented here is one approach the US Forest Service could use to begin taking steps to do the same.

Endnotes

[1] Capacity is the amount in megawatts (MW) of installed wind projects.

[2] Wind power class ratings are measured in watts per meter squared, where class areas 1 and 2 are generally unsuitable for utility scale wind turbine applications (NREL 2008).

[3] Contact authors for additional details on data sets used in the analysis.

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