CFAES

SCHOOL OF ENVIRONMENT AND NATURAL RESOURCES

The Spatial Relationship between Agriculture and Wind Energy

Joshua T. Fergen & Jeffrey B. Jacquet

INTRODUCTION

Wind energy development in the United States occurs primarily on private land in agriculturally-intensive areas, yet relationships between the wind and agricultural sectors are not well understood. In this study, we combine wind turbine location data with agricultural production regions and the U.S. Census of Agriculture to examine spatial patterns and relationships between wind turbine densities and agricultural characteristics.

CONTEXT

The number of farms and the number of farmers has declined precipitously in the United States over the past several decades, dropping from nearly 7 million farms in the 1930s to around 2 million today (USDA ERS 2019). Of these remaining farms, scholars have denoted a declining of the farming "middle class" as over 84% of these 2 million farms are small hobby farms, retirement operations or low-sales farms that provide only supplemental income (if any) to their operators and produce only 15% of agricultural products produced in the United States. Meanwhile, large-scale family (annual gross cash income greater than $1 million) or corporate farms comprise only 5% of farms in operation but produce over 52% of agricultural products sold in the U.S. (USDA ERS 2019). With farming no longer a common livelihood strategy, its abandonment has left limited economic opportunities and population decline in rural communities (Lobao and Meyer 2001).

Meanwhile, over 59,000 wind turbines have been constructed in the United States, and landowners not only have the primary decision-making authority over the construction of wind turbines (Jacquet 2015), but also stand to benefit from wind leases and energy production royalties (Fergen and Jacquet, 2016). Wind energy development has been one tool community developers and university extension offices have pitched to alleviate the negative transformation seen in rural communities (Bowen-Ellzey 2011).

AIM

1. What is the distribution of wind energy on private lands?
2. What factors of agriculture are most associated with turbine count?
3. Are there significantly differentiated clusters of turbines in the contiguous U.S.?
4. What regional variations exist?

METHODS

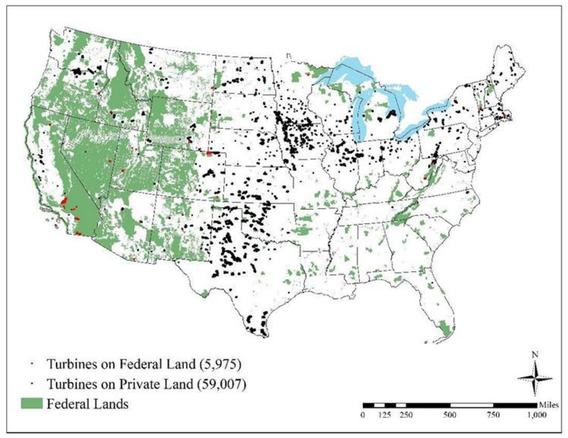
Data from the following sources were merged using ArcMap GIS:

- USDA-National Agricultural Statistics Service (NASS) (2017)
- The U.S. Wind Turbine Database (USWTD) (2020)
- USGS Protected Areas Database (2020)
- USDA Farm Resource Regions map (2020)

RESULTS

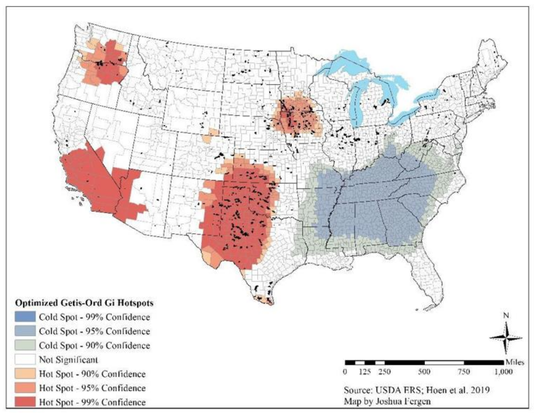
Wind Turbines on Public VS. Private Land

As of April of 2019, there are 53,350 turbines located in the contiguous United States on private land (90% of U.S. turbines), primarily in areas associated with agriculture.



Optimized Getis-Ord Gi Hotspots of Wind Turbines

To assess the spatial distribution of wind energy, two techniques were implemented in ArcMap 10.3. First, using the values of private turbines calculated at the county level, a Getis-Ord Gi Hotspot Analysis from ArcToolbox's spatial statistic tools was conducted to see whether clustering of turbines occurs, using a z-score for each county



Agriculture and Wind Turbine Correlations

Controlling for all other covariates, the strongest positive associations between turbine count and agricultural characteristics including the amount of land operated by partnership farms (Std. β = 11.991), the amount of land rented for agriculture (Std. β = 4.918), and producer income (Std. β = 2.089) at the county level. Negative relationships exist between the amount of land operated by family farms (Std. β = -3.405) and the amount of land operated by female producers (Std. β = -3.857). Together, these characteristics explain 23.66% of the variation in the number of private wind turbines in counties in the contiguous 48 states.

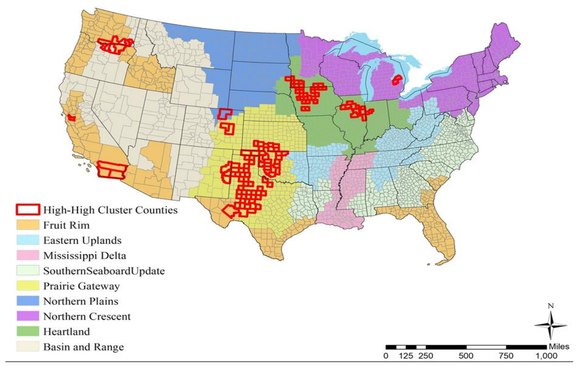
	Coeff.	Std. Error	z-value	Prob.
Acres	-.001	.002	-.677	.498
Private	0	.004	-.053	.958
Wind Class	.431	1.21	.356	.722
Avg. Farm Size	.001	.001	.961	.337
Production Expenses	.002	.007	.236	.814
Income	**.07***	**.034**	**2.089**	**.037**
Rented	**.119*****	**.024**	**4.918**	**.000**
Off-Farm Producer (%)	.053	.122	.439	.661
Family	**-.082****	**.024**	**-3.405**	**.001**
Partnership	**.366*****	**.031**	**11.991**	**.000**
Female Operated	**-.054*****	**.014**	**-3.857**	**.000**
White Operated	-.009	.009	-1.029	.304
Lambda (error)	**.404*****	**.025**	**16.447**	**.000**

Diagnostics	OLS	Spatial Lag	Spatial Error
Moran's I	19.27***		
Robust LM (lag)	2.91		
Robust LM (error)	63.005***		
Log Likelihood	-17222	-17152.3	-17126.194
AIC	34470	34332.6	34278.4
BIC	34548.3	34417	34356.7
Adjusted R	0.1384	0.2162	0.2366

**=p<.05; **=p<.01; ***=p<.001*
Variables measuring acreages under production regimes are calculated per 1,000 acres. Average farm size is measured in acres.
Variables measuring dollar amounts are calculated per $1,000

Wind Turbines and Agricultural Resource Regions

To assess regional variation in the mean scores of agricultural characteristics of the high-high clusters, ANOVA analysis were conducted between the Heartland, Prairie Gateway, and Fruit Rim produce regions. Correlation analysis reveals some trends that vary by region. The strongest correlations between turbine count and agricultural characteristics at the national level include the amount of land operated by partnerships (.333), land rented (.286), land operated by female producers (.204), production expenses (.155), and percent of off-farm producers (.150) The relationship between cluster county status and selected characteristics are strongest for land rented (.257), land operated by female producers (.227), average farm size (.213), land operated by partnership (.208), and percent of land operated by operators residing off farm (.205).



Ag & Wind Correlations by Agricultural Region

	US		*Prairie Gateway*		*Heartland*	
	Turbine Count	High-High Cluster	Turbine Count	High-High Cluster	Turbine Count	High-High Cluster
County Size	.004	**.047****	-.030	.065	.140	.033
Private Acres	.027	**.048****	-.003	.085	.007	.004
Wind Class (1-6)	**.080****	**.094****	**-.111****	**-.151****	**.169****	**.212****
Avg. Size Farm	**.143****	**.213****	**.206****	**.267****	**.181****	**.248****
Production Expenses	**.155****	**.165****	.038	**.135****	**.304****	**.320****
Net Income	**.140****	**.119****	.069	.098	**.208****	**.258****
Rented Acres	**.286****	**.257****	**.139****	**.260****	**.357****	**.312****
Off-farm Op. %	**.150****	**.205****	**.190****	**.276****	**.201****	**.205****
Family Acres	**.145****	**.173****	.002	.009	**.196****	**.204****
Partnership Acres	**.333****	**.208****	**.216****	**.270****	**.119****	**.180****
Female Acres	**.204****	**.227****	**.139****	**.215****	**.278****	**.253****
White Acres	**.252****	**.202****	**.120****	**.299****	**.210****	**.182****

***=p<.01; *=p<.05*
Pearson's R Correlation for Turbine Count; Spearman's Rho for High-High Cluster

CONCLUSIONS

U.S. wind energy development is overwhelmingly located on private land, with statistically significant spatial clustering that occurs with variables associated with large-scale agriculture. Regional agricultural variations are associated with spatial patterns in wind energy development. The association with land rented for agricultural production may be a sign that wind farms are being sited where local residents have less say in the development process, especially in the Prairie Gateway region, where absentee rates are higher (45%) for cluster counties compared to for the Heartland (34%). Numerous limitations to the data and conclusions exist; however, the results suggest wind turbines disproportionately benefit larger farming operations, with implications for the agricultural system and community development in rural areas. While these projects bring in extra revenue to rural counties struggling to finance local government, this revenue may flow disproportionately to non-local landowners, depending on the specific organization and tenure of these partnerships.

BIBLIOGRAPHY

Bowen-Ellzey, N. 2011. "Wind Energy Development as an Economic Development Strategy for Rural Areas." Ohioline: Ohio State University Extension Fact Sheet 11-CMD-849. https://ohioline.osu.edu/factsheet/11-CMD-849.

Fergen, J., and J. Jacquet. 2016. "Beauty in motion: Expectations, attitudes, and values of wind energy in the rural U.S." Energy Research and Social Science 11: 133-141. https://doi.org/10.1016/j.erss.2015.09.003

Jacquet, J. 2015. "The rise of 'private participation' in the planning of energy projects in the rural United States." Society & Natural Resources 28 (3): 231-245. https://doi.org/10.1080/08941920.2014.945056

Jacquet, J. B. and J. Fergen. 2018. "The Vertical Patterns of Wind Energy: The Effects of Ownership on Rural Communities in the Prairie Pothole Region of the United States." The Journal of Rural and Community Development 13 (2): 130-148. https://journals.brandonu.ca/jrcd/article/view/1527/351.

Lobao, L. and K. Meyer. 2001. "The Great Agricultural Transition: Crisis, Change, and Social Consequences of Twentieth Century US Farming." Annual Review of Sociology 27: 103-124. https://doi.org/10.1146/annurev.soc.27.1.103

Mills, S. B. 2018. "Blowing in the wind: The answer to farmland preservation." Michigan Planner May/June issue. Retrieved from The Center for Local, State, and Urban Policy (CLOSUP): http://closup.umich.edu/wind/wind-energy-and-farmland-preservation.php

ACKNOWLEDGEMENTS

The Authors recognize The Ohio State University's Center for Energy Research, Training, and Innovation (CERTAIN) for funding that supported this study.