USING GIS TO ESTIMATE THE SPATIAL DISTRIBUTION OF WIND-POWER ROYALTIES IN WEST TEXAS

A Thesis

by

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ABSTRACT

Wind energy is one of the fastest growing sources of renewable energy in the United States, particularly in the Great Plains region. This remarkable expansion has been attributed to high social acceptance, a simple permitting system, renewable portfolio standards, and tax incentives. However, the extent of financial benefits of wind energy (royalties) to landowners is poorly known, and scholars have not yet estimated how royalties are distributed spatially. This research utilizes land parcel information in conjunction with County Appraisal District records for Nolan and Taylor Counties in west Texas; wind turbine (n = 1,746) location, name and nameplate capacity; and a royalty estimation. The research examines the spatial distribution of royalties, to compare local and absentee benefits, and to estimate the disparity in estimated royalty payments between landowners with turbines and those without who receive no direct financial benefits. The mean estimated royalty payment per turbine per year is $7,404 and total royalties for the wind-farms in the two counties is more than $11 million annually which is captured by approximately 3% of all rural landowners. Non-resident landowners with turbines, defined as those landowners who live more than twenty miles from their tax addresses (approximately 46% of total landowners), receive 47% of total royalties, with the majority (70%) of royalties received by non-residents in Texas, and 61% of royalties remaining in the two-county study area. When key components of the wind contract depress, the total mean estimated average royalty for the study site also depresses, with capacity factor having the most effect on royalties. More than 30% of landowners with turbines have some land tenure in effect, and 45% of royalties are distributed to this faction. Turbines, and therefore, royalties appear to be distributed unequally amongst rural landowners and parcel size is highly correlated to number of turbines and royalty payments. Many residents continue to welcome wind power despite the inequality of benefits, but more research is needed to determine what factors may affect public perceptions and how royalties may affect spending in the area. Future research should focus on how royalties are used.

DEDICATION

This thesis is dedicated to my husband for his encouragement and support throughout all stages of graduate school, but most importantly, his patience with the writing process and insistence that I am capable of completing this arduous task. It may have taken longer than expected, but I did it! I would also like to dedicate this thesis to my family for being my cheerleaders and understanding every time I pushed my deadline. Your unfailing support means the world to me.

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NOMENCLATURE

US	United States
KW	Kilowatts
KWh	Kilowatt hours
MW	Megawatts
MWh	Megawatt hours
GW	Gigawatts
GWh	Gigawatt hours
CF	Capacity Factor
NIMBY/PIMBY	‘Not In My Back Yard”/”Please In My Back Yard”
AWEA/WWEA	American/World Wind Energy Association
PTC	Production Tax Credit
RPS	Renewable Portfolio Standard
RES	Renewable Energy Standard

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CHAPTER I

INTRODUCTION

This chapter presents the topic of wind energy and its benefits, usage, and potential. It outlines what is known about wind energy at both the global scale and local scale, and identifies the gaps in the literature which will be addressed in this thesis.

Wind energy is an economically and ecologically valuable resource, capable of benefitting everyone from an individual to the world, and with an established market on all continents and in many places offshore, its value is perceptible. Modern wind-generated electricity has its roots in a worldwide objective of reducing carbon emissions and concerns about the high cost of fossil fuels, and it has truly thrived in the last decade as a socially, economically, and ecologically lucrative source of renewable energy. Among the myriad reasons that wind energy has been so successful are its price competitiveness with other conventional energy sources such as natural gas, capability of producing energy without hazardous byproducts or greenhouse gas emissions, CO_2 emissions reduction, creation and sustainability of jobs, and tax incentives. Moreover, various factors may determine the success of a particular wind development including public perceptions of wind energy or wind farms, type of benefits offered to residents affected by the wind development, and whether energy mandates or standards and subsidies from county, state, and federal governments are in effect.

Globally, wind energy is produced on land in over 100 countries, and offshore of eight countries. The world's leader in installed capacity is China, which constitutes nearly 30% of the global capacity, followed by the US with 18%, Germany with 11%, Spain with 7%, and India with 6% (WWEA 2014). Worldwide wind capacity is currently 392 Gigawatts (GW), powering approximately seventy million homes. Wind energy is the fastest-growing source of energy in the world and it is the largest source of electricity in some countries, supplying as much as 20% of total electricity. Still, wind energy comprises only 4% of the world's electricity demand, though it could potentially supply more than forty times the current worldwide consumption of electricity (Lu *et al.* 2009). Other energy sources are coal, nuclear energy, natural gas, hydroelectricity, petroleum, or other renewable energy sources. In many of the top wind-producing countries, wind energy is cost-competitive with natural gas, nuclear power, or hydroelectricity.

In the United States, wind energy has been employed in 39 states as well as Puerto Rico, however, the US is only fulfilling a fraction of its vast wind potential. At maximum capacity on land and offshore, wind could supply enough electricity to power the US thirteen times over (AWEA 2014). Though only 4% of total electrical energy in the United States is supplied by wind power, 32% of renewable energy is wind-generated. In the past decade alone, the US wind industry has experienced exponential growth in terms of installed capacity, rocketing from around 6,600 Megawatts (MW) in 2004 to 61,300 MW in 2014 (AWEA 2014), enough to power approximately 15.5 million homes. This remarkable expansion of wind energy in the Great Plains has occurred on mainly private landholdings as a result of high social acceptance, aggressive building campaigns, tax incentives and subsidy programs such as the Federal Production Tax Credit (PTC), and cost-effectiveness relative to electricity derived from coal, nuclear power, or natural gas (Bohn and Lant 2009). Texas is the US leader in installed capacity with 12,755 MW, more than California and Iowa combined, and has a capacity of more than one-fifth of the national capacity. Texas ranks second, after California, for number of wind turbines installed, and is home to six of the ten largest wind farms in the US. The largest wind farm in Texas is the Roscoe Wind Farm, which is located in Nolan County, and has a capacity of 781.5 MW from 634 turbines.

Development of wind energy has been crucial in the United States and globally to reduce carbon emissions by reducing reliance on coal-burning power plants. Moreover, wind energy has increased economic activity in otherwise declining communities in the form of construction, operation and maintenance, and royalty payments to landowners. Although scholars have begun to analyze employment impacts of wind-power development, little is known about the destination and distribution of royalty payments. The actual impact of royalties on communities supporting wind farms is therefore also not known, nor is the total of non-resident landowners collecting royalties. This research will address the issue of distribution of royalties from a spatial perspective to assess the financial status of the study sites in central Texas. In most instances, turbines are sited on private property; more than 90% of US wind capacity is on private land. To compensate landowners for the use of the land to accommodate a turbine or several turbines, wind firms may offer a land rent or royalty. Generally, an ideal piece of land for a turbine would be in a rural location with an area of several hectares, a suitable wind resource, access to existing electrical transmission lines, and adjacent to similar parcels so that an array of turbines could be installed. If a particular property meets these criteria, a contract is negotiated between a wind operator and a landowner for the use of the land and payment of royalties for a period of twenty years or more. Long-term contracts are offered by wind firms in order to recuperate the cost of the original investment of the wind turbine, which is usually between $1 and $2 million per MW at the commercial scale. Only a handful of scholars have approximated the amount in royalties generated by wind energy, which is estimated to be around $5,000 per turbine per year (Pasqualetti 2004; Sowers 2006; Pasqualetti 2011; Ellis 2012), but this amount varies with the actual amount of electricity generated (*i.e.* the Capacity Factor or CF), the royalty rate offered by the wind firm, and the wholesale price of energy per Megawatt hour (MWh).

Nolan County and its eastern neighbor Taylor County in west Texas offer an ideal case study for analysis of the value of wind energy because they are home to the Roscoe Wind Farm, the Horse Hollow Wind Energy Center, the Sweetwater Wind Farm, and the Buffalo Gap Wind Farm, four of the five largest wind farms in Texas. Many studies have been conducted in this area; some about the social perspectives of wind energy (Brannstrom *et al.* 2011; Slattery *et al.* 2012; Jepson *et al.* 2012; Kahn 2013) or its political intricacies (Fischlein *et al.* 2010; Jepson *et al.* 2012), and considerably more on wind's economic impacts (New Amsterdam 2008; Slattery *et al.* 2011; Blair 2012; Kahn 2013). A great deal is known about the social perspectives of wind energy in this area, specifically residents' opinions about wind energy, wind farms, wind turbines, and economic benefits (Brannstrom *et al.* 2011). Non-peer-reviewed studies have ventured into the realm of estimating the economic benefits of wind energy in the form of employment and wind royalties (New Amsterdam 2008; Blair 2012), though these studies are scarce. Employment benefits are definite and perceptible, however, wind royalties are not as distinct in terms of how much is actually paid to a landowner in rents, and where the royalties are actually being spatially distributed. Despite the extensive literature on the social and economic impacts of wind energy, no studies to date have considered royalty distribution to be a spatial problem. This could be attributed to the difficulties in "tracking" money. Therefore, this research "follows the money" to the land owner; however, no attempt is made to understand how landowners use their royalties. The present study addresses the gap in knowledge about spatial distribution of royalties to landowners and the effects of the alteration of contract terms on royalty amounts, and aims to investigate the socioeconomic impacts and wind energy potential within the study area.

This research has two areas of intellectual merit. First, Geographic Information Systems (GIS) modeling of the spatial distribution of royalties will help scholars understand the economic impacts of wind energy. It is still unknown how royalties generated from wind turbines are spatially distributed, how those distributions affect economic activity, whether some land use types are more desirable than others in siting decisions, and whether the alteration of relevant variables (wind turbines, contract term, and turbine output) significantly affects the distribution of royalties. Scholars have estimated the approximate amount in royalties paid to landowners (Slattery *et al.* 2011), the social perspectives of county residents (Brannstrom *et al.* 2011), and some have even made associations between economic returns and acceptance of wind farms, such as public support increasing when monetary benefits become apparent, or that residents support wind energy because of lease payments (Pasqualetti 2001; Sowers 2006). This research will fill the knowledge gap in how wind energy affects landowners economically and whether specific variables significantly affect royalty distribution.

Nolan and Taylor Counties encompass a land area of 474,744 hectares with some small cities and towns in the north, and the metropolitan area of Abilene in northeast Taylor County. The topography is mainly flat with some rolling hills and valleys. Including an abundant wind supply, many of these attributes are what make this rural area so attractive to wind developers. Land uses for rural areas in Nolan and Taylor are mainly ranch- and farmland, yielding cotton, wheat, sorghum, and hay production, as well as orchards. According to the US Department of Agriculture's Census, 188,243 hectares of Nolan County and 234,277 hectares of Taylor County are farmland (USDA 2012), which translates to 80% of Nolan County and 98% of Taylor County being farmland. The USDA census defines "farmland" as "any place from which $1,000 or more of agricultural products were produced and sold…during the census year" (USDA 2012), which indicates that farms and ranches are synonymous. There are 1,149 farms in Taylor County, and 478 farms in Nolan County, all producing some crop and/or livestock for sale. Wind developers are particularly attracted to farming and ranching land uses because wind energy can help boost the local economy and offset some farming costs (Sowers 2006). Abbott (2010) affirms that “farm production and wind power can coexist to increase the economic productivity of rural landscapes. Wind power can occur coincident with farming activities, such as ranging livestock or cultivating field crops. The steady and predictable revenue that turbines provide can close the gap on relatively volatile farm rents.”

This research begins with a literature review chapter, which encompasses the relevant observations from previous literature, how they correspond to the three dimensions of wind energy literature (the social, public policy, and socio-economic dimensions), and how they relate to the knowledge gap addressed in this thesis. The next chapter identifies the data sources and analytical methods used to determine the estimated spatial distribution of royalties for wind energy at the study site.

CHAPTER II

THE THREE DIMENSIONS OF WIND ENERGY

This chapter identifies prior wind energy research and relates relevant observations from those studies to each of the three dimensions of wind energy: Social, Socio-economic, and Public Policy.

II.1 The social dimension

II. 1. A. Acceptance/Opposition

One of the leading disputes over wind energy is the social acceptability of wind farms. Many researchers claim that one of the highest barriers to the implementation of wind energy is public acceptance (Bell *et al.* 2005; Sowers 2006; Devine-Wright 2007; Aitken 2009; Molina-Ruiz *et al.* 2011). Wind energy has been fervently protested in many communities because of noise, aesthetics, and avian mortality. Nevertheless, a number of studies have shown that public attitudes toward wind energy are very high (Krohn and Damborg 1999; Pasqualetti 2001; Rodman and Meentemeyer 2006; Brannstrom *et al.* 2011; Cowell *et al*. 2011;). However, the reasons behind positive public attitudes and social acceptability are variable and complex. Sowers (2006) asserts that residents allow and accept turbines because of their financial benefits. Conversely, Cowell *et al.* (2011) suggest that community benefits are the cause of acceptance rather than the effect. Swofford and Slattery (2010) claim that environmental benefits drive public support as opposed to climate change and use of fossil fuels. Cowell *et al.* (2011)

suggest an array of factors, ranging from “community benefits” to landscape value, have a bearing on people’s stance towards development. In the case of “community benefits,” residents affected by development of wind farms can be compensated for the inconvenience of having a network of turbines nearby. In addition to compensation, some residents may also be granted control over the terms of the development and be allowed active participation in the development process; however, this does not necessarily guarantee the residents’ acceptance of the network of turbines.

Public opinion of wind energy is one of the primary concerns of wind energy firms in the development of wind farms worldwide because the affected community has the potential to bar a project through political or judicial means. If a proposed wind farm meets considerable opposition during the planning phase, the project may never undergo construction. Likewise, if a proposed project is highly supported, it may potentially proceed through the various stages of development more quickly. Alternatively, active opposition may have no effect on the proposed development. On the other hand, as Bell *et al.* (2005, 2013) theorized, there may be what is termed a “democratic deficit”, wherein the majority of people are in favor of wind energy, but a particular development is opposed by a vocal minority who oppose wind power, and the outcome does not reflect the will of the majority. According to Bell *et al.* (2005), “the potential of opponents to block wind power developments is likely to be greater if they fit a particular educational and socio-economic profile that enables them to operate more effectively in the political arena”. Some communities may be more successful in their attempts to block or delay a development than others, as was the case with the Nantucket

Sound Cape Wind project, where it was established that the better resourced the opposition is economically, legally, and technically, the more likely to succeed (Bohn and Lant 2009; Firestone *et al.* 2009; Bell *et al.* 2013). Nevertheless, most people who support wind energy do not support it without hesitation (Wolsink 2000; Bell *et al.* 2005; Sowers 2006; Wolsink 2007; Bell *et al.* 2013; Mulvaney *et al.* 2013). Some believe wind energy is good in theory, but when implemented has its limits and faults; others believe that it can be detrimental to the landscape, wildlife, and humans. Public attitudes toward wind energy have also been found to vary throughout the stages of construction, from high acceptance before construction to lower acceptance during construction, and then high acceptance again after construction (Wolsink 1989; Gipe 1995; Krohn and Damborg 1999; Pasqualetti 2001; Devine-Wright 2005; van der Horst 2007; Wolsink 2007; Wüstenhagen *et al.* 2007; Warren and McFadyen 2010; Groth and Vogt 2014).

Another factor affecting acceptance or opposition to a wind farm is the level of education about turbines, wind energy and wind farms the public possesses (Krohn and Damborg 1999; Bell *et al.* 2005; Devine-Wright 2005; Aitken 2009; Sovacool and Ratan 2012). Improved public understanding about wind-power is beneficial, but it does not necessarily guarantee acceptance of the project. According to Bell *et al.* (2005), the more informed the affected residents, the more likely they are to accept a wind project and the availability, accessibility, and comprehensibility of the information are crucial to achieving this end. Conversely, Wolsink (2007) suggested that though improving public knowledge of wind energy is always beneficial, it will not likely change attitudes. Likewise, the level of education achieved by the public has been linked to acceptance or opposition to a wind development along with demographic data such as socioeconomic status, gender, and age (Thayer and Freeman 1987; van der Horst and Toke 2010; Bell *et al.*2013; Mulvaney *et al.* 2013). An early study conducted by Thayer and Freeman in 1987 showed that in general, positive attitudes about wind energy were held by females, older citizens, and those whose highest education level achieved was a high school diploma. On the other hand, Mulvaney *et al.* (2013) were unable to find any significant demographic factor or pattern triggering acceptance or opposition. Simply defined, Bell *et al.* (2013) contend that protests are more likely to succeed where the community has the best resources to do so (*i.e.* the community fits a socioeconomic and/or demographic profile that allows them to operate more efficiently in the political arena). However, possessing a certain educational background does not guarantee a successful protest; sometimes in the planning process, the community's protests are not considered legitimate because the public does not possess formal expertise in the field of wind energy. Aitken (2009) asserts that the public has its own set of credentials and expertise ("lay knowledge") about wind energy developments and dissenting opinions about a wind development should not be marginalized due to lack of formal or "expert" knowledge. Expert knowledge is deemed incontrovertible in decision-making, creating an atmosphere of mistrust between the public and the decision-makers and has potential to create more wind protestors.

According to most scholars, the biggest deterrent to implementation of wind energy is aesthetics (Krohn and Damborg 1999; Pasqualetti 2001; Devine-Wright 2005; Wolsink 2007; Bohn and Lant 2009; Swofford and Slattery 2010), which encompasses a broad range of visual aspects of a wind farm including but not limited to: the height of the turbines, the number of turbines in a wind farm, whether the turbine rotors are spinning, the color of turbines, and the geographic location of the wind farm. An unfortunate limitation of wind-generated electricity is that the turbines must be sited where the wind resource is the greatest. This usually means that turbines are placed in highly-visible areas, which may disrupt viewsheds. Many solutions have been proposed throughout the years to minimize the ostensible disfigurement of the landscape, including painting the turbines a neutral color, reducing the tower height and/or blade height, and assorted variations of turbine configurations (Pasqualetti 2004, Devine-Wright 2005; Wolsink 2007; Pasqualetti 2011). According to Wolsink (2007), clustering of turbines into farms is preferable to scattered individual turbines, and smaller farms are preferable to massive ones, but the most important factor in wind-power development is the landscape on which turbines will be placed. In selected case studies in the United Kingdom and Europe, smaller wind farms consisting of fewer than eight turbines were found more favorable by residents than scattered solitary turbines and large arrays, and fewer large turbines were preferable to numerous smaller turbines (Devine-Wright 2005). Some residents are even concerned that their property values will decrease as a result of wind farm development. A study conducted by Hoen *et al.* (2011) nevertheless determined that there is no evidence that the presence of wind turbines affects property values based on scenic area, and nuisance stigmata. As Abbott (2010) points out, aesthetics are subjective; some will find turbines to be attractive and others will find them blights on the landscape. Nevertheless, “as wind power increases its geographical footprint, multiple factors will inform how people respond to wind farms" (Brannstrom *et al*. 2011).

One such factor that may affect resident perceptions of wind farms is the sense of place identity or place attachment (Pasqualetti 2011). Place identity is the value, significance, and meaning of a location based on its inhabitants' sentiments toward it. Strong place identity and place attachment held by residents could be an indicator for possible resistance to the proposed wind farm (Devine-Wright and Howes 2010). On the other hand, residents have also expressed an increased perception of place identity as a result of wind farm construction. Some residents affected by wind farms believe that preservation of the landscape should be the top priority with emphasis on conserving the viewshed. The landscape may not necessarily have any intrinsic value as a tourist attraction, historical site, or scenic vista to be subject to conservation efforts by residents. The land holds value for residents because it is their home and they have formed an attachment to it, which will have some influence on whether or not a particular wind development is deemed acceptable. As Wolsink (2012) points out, "attachment to a particular location and the symbolic values of the site to both residents and non-residents play a significant role in shaping people's responses to any proposed changes to their surroundings." Since the geographic, as well as economic, social, and political, characteristics of each place are unique, public support will also vary from one place to the next. Another emergent belief is that people form a positive bond with the landscape over time and perceive that landscape as having greater value than others where a development may take place. "Landscape concerns are not simply based on aesthetic or visual appreciation of the landscape, but reflect the experience of living or spending time in a particular place" (Bell *et al.* 2013). Residents who have a strong place attachment may feel that wind turbines are a threat to their place identity or that their comfort in that place has been interrupted, stemming from a belief that the turbines will restructure how residents live.

II. 1. B. NIMBY/PIMBY

In the realm of wind energy and many other "noxious" land uses, the concept of opposition based on residents who prefer not to have turbines in the immediate vicinity is referred to as NIMBYism (Not In My Back Yard). When renewable energy first emerged, this seemed to be a popular and convenient way to explain opposition. Scholars have explored alternatives to the NIMBY mentality, a common justification for opposition to wind energy, which has hitherto been loosely defined and vastly oversimplified. NIMBY has been interpreted as acceptance until confronted with the prospect of wind farm development in the immediate vicinity after which it is opposed. Bell *et al*. (2005) assert that criticism of NIMBY is warranted because it does not adequately "reflect the complexity of human motives and their interaction with social and political institutions." If NIMBY is taken at face value, the opposition to wind farm development is purely for personal reasons and those in closer proximity to turbines should be expected to express the most opposition, which has not been the case. Krohn and Damborg (1999) simplified the results of their surveys in Europe to reflect that opposition arose from aesthetic, noise, or interference issues. While it may be true that these are just a few of the major contributors in justification of opposition, NIMBY is an inadequate explanation for this behavior. The location of a wind farm with respect to residents is an integral part of the study of wind energy, but is by no means the only factor that determines opposition. Swofford and Slattery (2010) find that overall, support for wind energy is high, although those few residents living within a 5 km radius of a farm express equally positive and negative attitudes about wind energy. So incongruous was the NIMBY "syndrome," that numerous scholars expressed their dissent on the subject (Wolsink 2000; Bell *et al.* 2005; Devine-Wright 2005; Aitken 2009; Bohn and Lant 2009; Swofford and Slattery 2010; Brannstrom *et al.* 2011; Bell *et al.* 2013), with the consensus being that NIMBYism does not reflect the complexity of human motives and perceptions. The NIMBY theory has been called oversimplified, outdated, unclear, inadequate, and even damaging. Additionally, many studies have found that NIMBYism is unsubstantiated, and that there seems to be no definite correlation between proximity to a wind farm and opposition (Krohn and Damborg 1999; Devine-Wright 2005; Warren *et al.* 2005; Wolsink 2007; Wüstenhagen *et al* 2007; Devine-Wright and Howes 2010; Swofford and Slattery 2010).

Alternatively, in some instances, development of wind farms is embraced, exhibiting a "Please In My Back Yard" (PIMBY) attitude, which more recent studies have revealed as an emergent belief (Pasqualetti 2004, Sowers 2006). In the case of Sowers' study, wind farms are accepted because they bring employment and prosperity and enhance the local identity. Some scholars indicate that there is a relationship between support for wind power and economic returns (Pasqualetti 2001; Sowers 2006), but that relationship has not been extensively explored. The theory is that people are more likely to accept wind farms in their back yards because they are profitable in some financial, socio-political, or environmental way. Although this attitude seems less detrimental to the spectrum of human emotions and motives, it is still deficient with respect to cataloguing the reasons for acceptance. While no statistical analysis was performed in the case of Sowers' (2006) research, a qualitative, survey-based approach was used to determine social perspectives of wind energy. The issue presented in Sowers' publication is that success of wind farms in one area of the Great Plains in Iowa is mostly attributed to residents' PIMBY attitudes. It is also intimated that financial benefits may contribute to positive attitudes. Critics of this attitude emphasize that PIMBYism does a disservice to people by assuming that their values can be bought. Bell *et al* (2005) stress the importance of distinguishing between NIMBYism and those whose principles are for sale at the right price. Indeed, there is a very fine line between compensation for supposed inconveniences and bribes for acceptance; but which is the best method for determining if someone's motives are born from greed and can any study truly capture those motives? A middle view is that people desire a return on their investments. Consequently, human motivations and perceptions will always be complex and difficult to study, even with the aid of statistical methods, and attributing them to one simplistic term or another (either NIMBY or PIMBY) is an overgeneralization and fails to adequately explicate reasoning for a decision.

II. 1. C. Socio-political

The success of wind development at the local scale is heavily dependent on socio-political factors such as the public's relationship to and with the wind developer, the relationship between a landowner with turbines and his neighbor without turbines, or the relationship between those opposed to wind farm development and those who are unopposed. Many wind projects have failed to reach the construction phase or have encountered opposition because of the nature of the decision-making infrastructure, the level of trust in the wind corporation or its representatives, or the extent of communication between the wind firm and the community about the project. Likewise, many projects have succeeded due to the same reasons. Some residents' opinions about wind energy in general or a wind project in particular can also be influenced by neighbors, friends, and/or family members. The socio-political aspects of a place are complex and challenging to categorize; nevertheless, many scholars have studied the effects of social politics on the development process of wind energy (Krohn and Damborg 1999; Bell *et al.* 2005; Devine-Wright 2005; Breukers and Wolsink 2007; Wolsink 2007; Wüstenhagen *et al.* 2007; Bohn and Lant 2009; Devine-Wright and Howes 2010; Fischlein *et al.* 2010; Swofford and Slattery 2010; Wolsink 2010; Cowell *et al.* 2011; Pasqualetti 2011; Wolsink 2012; Groth and Vogt 2014). The socio-political aspects in the literature are defined in this research as the governmental and societal dynamics between the community and the wind firm. The main issues that arise in the socio-political arena are: the degree of trust and/or communication between key actors, the decision-making infrastructure, and the level of perceived justice or fairness.

Communication between key actors is a broad issue, as it encompasses the communication between residents in the affected area, stakeholders and those who do not benefit directly from the success of wind energy, and the wind firm and residents.

Understandably, if communication is poor between the wind firm and residents, an environment of mistrust is created. Communication between residents can conceivably cause a development to fail if significant opposition is garnered; likewise, a development could achieve success if many residents support it. Neighbors, friends, and family members who support wind energy at the broad or specific scale have also been shown to influence those who do not support wind energy. However, if an individual has a true dislike for a wind energy development, little can be done to sway them. Nevertheless, a few scholars have noted that effective communication is one of the steps to increasing trust and acquiring support for a development (Krohn and Damborg 1999; Wolsink 2007; Swofford and Slattery 2010, Pasqualetti 2011). As Wüstenhagen (2007) stated, trust is dependent on perceived competence and intentions, which are in turn related to perceived similarity of objectives and thinking. Bell *et al*. (2005) suggest that "information will always be suspect in a climate of mistrust", but a possible solution is that information could be provided to residents from sources they can trust to help them make informed decisions about the development and allay their fears. Another proposed solution is to change the structure of the decision-making process to be more inclusive of residents with the aim of fairness and not causing any perceived injustice. Cowell *et al.* (2011) interpret justice as the equal distribution of goods and bads in the environment, but emphasize that in wind energy facility siting, justice is often knotted with sentiments of participation and recognition. Wolsink (2010) suggests that collaborative planning is the path to improved trust and acceptance, which are also closely associated with reciprocity, fairness, openness, respect, and perceived competence among the planners.

II. 1. D. Benefits

Social benefits increase the welfare of the affected community through the production of a good or service, which, in the case of Nolan and Taylor Counties, is the construction of and electricity generated from wind turbines. Such social benefits include control over the siting process in wind development planning, increased place identity, job creation and some job retention. Furthermore, the social benefits from these two counties extend to the state and national level in terms of renewable electricity production, as it benefits more than just Nolan and Taylor Counties.

Having some control over the siting process in the planning stage of wind development can be considered a two-part community benefit. Primarily, it gives the community the opportunity to modify, negotiate, and outright decline a proposal, effectively giving ownership of the project to the public. Second, it establishes a positive relationship between the community and the wind developer, which may help improve attitudes toward wind farms in general and the proposed wind farm specifically. Cowell *et al.* (2011) emphasize that the provision of administrative benefits is more favorable than pecuniary benefits in terms of reaching an acceptable outcome for all involved parties, as financial compensation may be negatively perceived. In cases where the vocal minority dominates the decision-making process, Bell *et al.* (2005) also suggest increasing public participation by allowing the unspoken majority to voice their opinions through participatory decision-making, though Breukers and Wolsink (2007) amend that participatory decision-making is unlikely to sway staunch wind protestors into supporters and may have more influence on conditional supporters. Furthermore, greater acceptance can be achieved by means of local ownership through cooperatives or other institutions (Wolsink and Breukers 2010; Brannstrom *et al.* 2011).

Another social benefit is increased place identity or place attachment, which was previously discussed in terms of negative public response. In contrast to the studies that declare opposition is an effect of place attachment, numerous residents affected by the presence of turbines have reported that turbines are beneficial to the community in some way and/or that their place attachment has strengthened (Thayer and Freeman 1987; Bell *et al.* 2005; Sowers 2006; Swofford and Slattery 2010; Warren and McFadyen 2010; Brannstrom *et al.* 2011; Jepson *et al.* 2012; Slattery *et al.* 2012; Sovacool and Ratan 2012). Among the sundry reasons some residents claim a stronger place attachment are that the turbines are a sign of progress toward the integration of renewable energy, they bring money to the region in the form of taxes and royalties, and they revitalize rural areas though tourism and population growth and/or retention. Towns that were once facing a severely waning population have begun to flourish after the addition of wind farms. According to Boccard (2009), towns with turbines are experiencing a population boom or influx as compared to previous years before turbines were present. Wind energy also allows the community to prosper by allowing its members to "buy shares in a community- or privately-owned wind energy development project so they have a financial stake in its success" (Bell *et al.* 2005), which may also afford the populace a sense of ownership and place identity.

Wind energy has moderate job creation potential, especially during the construction phase, and, upon completion, a few specialized industry jobs remain for maintenance and service. The majority of the workforce for wind turbine construction is subcontracted for the duration of construction (about one year), and only about 7% of those employees stay through the life of the plant, or about twenty years. This roughly translates to between eighty and one hundred jobs per 100 MW wind plant, with six to eight permanent positions for after-construction maintenance and operations (Slattery *et al.* 2011), or one permanent job for roughly every ten to twelve towers (New Amsterdam 2008). Furthermore, Brown *et al.* (2012) note that the average annual income for the county increases dramatically with each additional MW of wind power installed. According to the American Wind Energy Association (AWEA), "the wind industry supported 8,000-9,000 direct and indirect jobs in Texas in 2010 and supports approximately 75,000 direct and indirect jobs nationwide" indicating that "Texas is particularly strong in terms of its share of employment in the wind industry relative to the nation" (Blair 2012). As an added benefit of the enlarged workforce, local businesses often see increased activity and patronage, which in turn aids the local economy through rising wages, tax revenues, increased land values, decreased property taxes, and new construction.

II. 2. The socio-economic dimension

Distribution of economic benefits is perhaps one of the biggest points of contention amongst members of the affected community because those benefits seem to be distributed unequally. Wind energy has the potential to provide employment, income, and tax revenue to the community, and wind farm development may foster employment in the affected area for construction, manufacturing, and maintenance personnel. Subcontracted workers provide another possible source of income to the area because they spend money at local businesses. In terms of tax revenue, the local government may receive up to $12,000 per Megawatt (MW) in tax payments and landowners may receive up to $7,000 per MW in lease payments (Slattery *et al.* 2011). Hefty tax abatements and subsidy programs are the largest incentives to developing wind energy, but little is known about the distribution of these royalties to private landowners and whether they are spatially imbalanced. In fact, no studies have been conducted thus far that regard distribution of royalties as a spatial issue. Turbines are sited in rural areas with small populations, but in some cases, the areas affected by wind development do not reap the benefits. Furthermore, stakeholders tend to be more inclined to accept wind farms than those who do not have a stake in the success of the project, further widening the gap between those who benefit and those who do not.

Development of wind farms generally means more employment, sometimes for the local workforce, which leads to the generation of revenue and prosperity for the town, and the influx of wind employees may also lead to higher wages in the local economy. Local schools seem to benefit the most from wind energy revenues in the form of improvements to facilities and curriculum, scholarship opportunities, and educational electronic aids, which improve the quality of education (New Amsterdam 2008; Blair 2012; Slattery *et al.* 2012; Kahn 2013). Texas in particular has seen the growth of the wind industry through the creation of technical colleges and training programs designed to meet the industry's needs (Blair 2012). On the other hand, it may also bring about hardship for residents due in part to increasing property values and the lack of fiscal contribution from sub-contracted workforce (Brannstrom *et al.* 2011). In fact, “opponents of wind energy developments often highlight the unfairness of the distribution of benefits and burdens associated with developments” (Bell *et al.*2013). Many residents in affected areas have reported concerns about the rising cost of rentals and real estate due to wind developments (Brannstrom *et al.* 2011; Blair 2012; Ellis 2012).

While scholars have estimated the economic impacts of wind energy, very little is known about royalty disbursements or how sensitive royalties are to fluctuation of contract terms, specifically, turbine energy output, electricity price, and royalty rates. The dearth of literature on this topic is partially due to the proprietary nature of information concerning turbines’ wind capacity factors (CFs). CF is the ratio of actual energy production to the nameplate production maximum. Early estimates of CFs had an incredibly broad scope, spanning from 19% (Iniyan *et al.* 1998) to 60% (Cavallo 1995). Current global estimates of optimum CF are between 20% and 35%, with the upper value of 35% being rare (Boccard 2009). Uncertainties about CF affect whether turbine upgrades, wind resource fluctuation, and maintenance will significantly alter the distribution of royalties. For the purposes of this study, CF will be estimated within two categories (low and high). Three variables determine how royalties are allocated: CF, wholesale electricity price, and royalty rates (Brannstrom 2012). Wholesale electricity price is also variable and not fully known, but is still restricted information because landowners negotiate confidential contracts with wind-power firms and rural farmers negotiate with utilities. The wholesale electricity rate is estimated at approximately $35-

45 per Megawatt hour (MWh) (New Amsterdam 2008; Bolinger and Wiser 2009). According to stakeholders (who are primarily attorneys) in Nolan County, landowners receive a percentage royalty, normally 4% or a minimum guaranteed payment (New Amsterdam 2008). For the purposes of this study, a royalty rate of 4% is used to estimate the sensitivity of royalty disbursements.

II. 3. The public policy dimensions

Public policies play an important role in the entire process of wind farm development, from the Federal level to the community level, and from the infancy of planning to the completion of the project. At various levels of the government there are several policies in place to encourage the development of renewable energy and reduce carbon emissions, including Renewable Portfolio Standards, establishment of Competitive Renewable Energy Zones, and the Federal Production Tax Credit. It can be argued that wind development owes much of its success to the Federal Production Tax Credit (PTC), which is a ten-year inflation-adjusted per-kilowatt-hour income tax credit for electricity generated by a qualifying renewable energy source to encourage the development of renewables and foster economic growth (Bolinger and Wiser 2009). Under the PTC, eligible wind developers receive an income tax credit of 2.3¢ per kilowatt-hour (kWh), adjusted for inflation, for the first ten years of operation and reducing the cost of wind energy by roughly one-third (Blair 2012). First enacted in 1992, the Federal PTC has been renewed and revised several times, most recently in early 2013 with the American Taxpayer Relief Act of 2012. However, the Federal PTC expired at the end of December 2013, and any new turbines constructed after December

31, 2013 are not eligible to receive the credit. The PTC was extended seven times and allowed to expire five times, which caused fluctuations and instability in the wind energy market due to the uncertainty developers faced in the impending deadline to begin construction (Gipe 1998; Bird *et al.* 2005; Bolinger and Wiser 2009; Blair 2012). During years when the PTC approached expiration, wind developments experienced a surge in new construction to meet the deadline, and after the PTC had been renewed, new construction tapered off. The American Wind Energy Association (AWEA) has repeatedly called for extensions to the PTC, even to extend its contract to 10 years (AWEA 2012). After the last decade of immense growth in the wind energy sector, the last two years has presented a marked diminishment of progress after the expiration of the PTC, with only 1,098 MW installed between 2012 and 2013, and 217 MW installed between 2013 and 2014.

Less recognized at the federal level is the Renewable Energy Production Incentive, which is a cash production incentive afforded to those who are unable to take advantage of the Federal PTC. Unfortunately, funds are subject to Congressional appropriations and have an uncertain availability; as such, the effectiveness of the incentive is limited (Bird *et al.* 2005). Although some Federal regulations and incentives encourage the development of renewables, individual states are permitted to determine whether to implement them based on their available resources and electricity needs, as in the Public Utility Resources Policy Act (PURPA). PURPA was enacted in 1978 in response to an energy crisis, and was intended to reduce energy demand by promoting the development of renewables domestically. While it depreciated over time, PURPA played an important role in the advancement of renewable energies by exempting renewable developers from some regulatory laws. Market factors that may affect the expansion of wind power are the competitive pricing of alternatives such as natural gas, the state of the national economy, technological improvements, availability and cost of turbine components, and supply and demand fluctuation (Bird *et al.* 2005; Bolinger and Wiser 2009; Blair 2012). Higher costs may slow or cease the development of new wind projects.

At the state level, the main drivers of wind development are renewable portfolio mandates, feed-in tariffs, and other tax exemptions. A Renewable Portfolio Standard (RPS), also called a Renewable Energy Standard (RES), is a policy that requires electricity providers to supply a certain percentage of their electricity from renewable sources by a specific date (Bird *et al.* 2005), allowing it to be competitively priced with cheaper fossil-based fuels. RPS have been implemented in thirty-seven US States, either mandatorily (RPS) or voluntarily (Goals) as of 2013, but there is no program in place at the national level. The Texas RPS began in 1999 with Texas State Senate Bill 7, which mandated 2,000 Megawatts (MW) of renewable energy generation by 2009. Texas and Iowa were the first states to institute renewable energy requirements, beginning the impetus for increased energy capacity in the United States, and allowing the U.S. to become a global competitor in the renewable energy market (Blair 2012). The mandate for RPS for the upcoming years is 5,880 MW by 2015 and a goal of 10,000 MW by 2025 for all qualifying renewable energy sources. Feed-in tariffs (FIT), on the other hand, are designed to stimulate investment in renewable energy through long-term contracts with renewable energy providers based on the cost of energy generation. Renewable electricity providers are paid a cost-based price for renewable electricity supplied to the grid, promoting the development of diverse technologies. FIT have only been employed in a handful of U.S. States including California, Florida, and New York, though few states utilize FIT for wind-generated electricity. Several policies and market factors can be used to promote wind energy, but the most effective is state RPS.

Texas specifically owes much of its success in wind development to the factors listed above in addition to a simple permitting system, high social acceptance, an abundant wind resource, and the Texas Public Utility Commission's (PUC) Competitive Renewable Energy Zones (CREZ). There are no climate-change or Greenhouse Gas (GHG) mandates in Texas. The Electricity Reliability Council of Texas (ERCOT) was authorized to create CREZ in 2005 with State Senate Bill 20 and the initiative of the Texas PUC. CREZ are sites where the best wind energy potential exists and from which transmission lines are constructed to deliver renewable energy to consumers throughout Texas. The PUC allotted nearly $7 billion to the construction of transmission lines by seven transmission and distribution utilities. Five CREZ were established in 2008: Panhandle A, Panhandle B, Central West, Central, and McCamey (PUCT 2012). The project was completed at the end of 2013 and transmits 18,500 MW of wind power from windy west Texas and the panhandle to highly-populated metropolitan areas of the state (PUCT 2014).

CHAPTER III

DATA AND METHODS

This chapter details the data sources utilized for this study and the descriptive and analytical methods used to determine the estimated spatial distribution of wind-power royalties potentially generated by wind power in Nolan and Taylor Counties.

III. 1. Data

The study area is comprised of Nolan and Taylor Counties located in west-central Texas (Figure 1), which are home to the Roscoe Wind Farm and the Horse Hollow Wind Energy Center, two of the largest wind farms in the world. These two counties are part of a larger expanse of wind farms that stretch across a five-county area including Fisher, Scurry, and Mitchell Counties. There are 2,262 wind turbines in this five-county region, with an installed capacity of more than 3 Gigawatts (GW). Nolan and Taylor Counties alone have 1,746 tur bines, with an installed capacity of 2.8 GW. Nolan County accommodates 1,372 turbines from fifteen wind farms with an installed capacity of more than 2 GW. Taylor County holds 374 turbines from six wind farms and has an installed capacity of 625 Megawatts (MW). Nolan and Taylor Counties combined have a land area of 474,744 hectares, most of which is rural land used for cattle grazing, hunting leases, and cotton, and are home to more than 145,000 people. Located in northeast Taylor County is the major metropolitan area of Abilene, where about 80% of

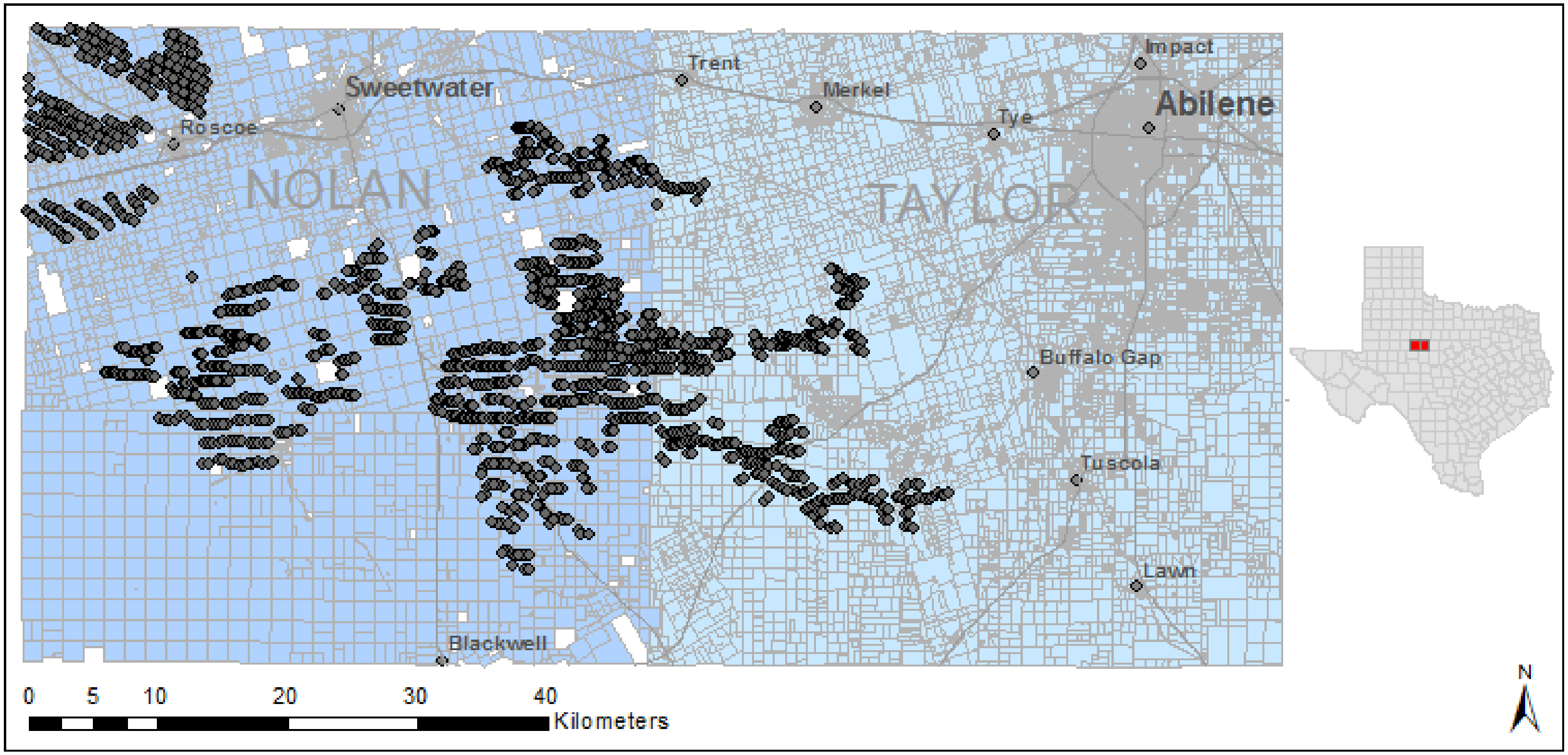


Figure 1. Nolan and Taylor Counties in west Texas with parcel delineation and turbine points. Number parcels= 75,595. Number turbines=1,745.

the county's population resides; the nearest wind farm is approximately 20 miles from the heart of Abilene. Sweetwater, the study region's next largest city (population=10,762), regularly hosts wind-energy and related events and trade shows. Its economic and political elites have labeled the city as a center of wind energy in North America. Wind turbines are approximately seven miles from the center of Sweetwater. Roscoe, a much smaller town (population=1,322) is surrounded by wind farms, which are mainly located on land devoted to growing cotton, which is irrigated only infrequently because of slightly saline groundwater. Wind farms first developed in the western portion of Taylor County, with the 150 MW Trent Mesa wind farm in 2001, which has a contract with College Station Utilities as part of the Wind Watts program. Wind-farm construction expanded onto mesas south of Sweetwater. During 2009-2010, most new wind turbines were being located on farmland near Roscoe.

Data for this research were gathered from the Nolan and Taylor County Appraisal Districts (CAD), the Federal Aviation Administration (FAA), and the Public Utility Commission (PUC). Data from CAD and FAA were obtained in 2011 from the NextEra Wind Energy Project based at Texas Christian University. The CAD records for the 2010 tax year contain landowner information such as name, address, land area, taxable value, and other legal information. These records are used in conjunction with parcel polygons to spatially visualize land ownership. Additionally, wind turbine coordinates from the FAA in the form of points are used in union with PUC records for the spatial locations of turbines, the name of the farm to which turbines belong, the number of turbines in each farm, and each tower's nameplate (installed) capacity, which normally is the turbine's maximum output. All spatial data for this study are utilized and illustrated through ArcGIS 10.2.

III. 2. Methods

The first step toward determining how wind royalties are spatially distributed is to determine the amount each wind farm generates in royalties based on the PUC data, which contains the nameplate capacity (maximum output) of turbines. Only a handful of scholars have approximated the amount in royalties generated by wind energy, which is generally estimated around $5,000 per turbine per year. The deficiency in wind energy literature about wind royalties is partly due to the confidential nature of the contracts between landowners and wind developers. However, as the study by New Amsterdam (2008) indicates, estimating royalties is actually quite simple. Additionally, Brannstrom *et al.* (2011) interviewed key actors in this study's community who provided insight into current estimates of royalty rates. The three main factors affecting the total royalties received by landowners are wind capacity factor (CF), royalty rate, and wholesale electricity price. Several factors influence the CF of a turbine, including intermittency of the power source (*i.e.* the wind), engineering, wind characteristics, and economic and grid curtailment. For example, a 1 MW turbine that has an abundant wind resource, but is inefficient, poorly maintained, and has a below average transmission capacity may have a CF far lower than an efficient 1 MW turbine with excellent maintenance, steady wind, and excellent transmission capacity. The daily CF is likely to vary from one day to the next due to wind intermittency, so CF calculations have been derived from multiple years' worth of data (Boccard 2009). Furthermore, since there is currently no way to store electricity generated from wind energy, if there is a surplus of energy, some turbines may be placed in neutral position until electricity prices rise enough to overcome operating expenses.

In principle, hourly CF for wind turbines in Texas could be calculated from data maintained by the Electric Reliability Council of Texas (ERCOT), the grid operator. However, CF, as previously indicated, is a function of wind conditions, mechanical engineering in the gearbox, software engineering of controls, maintenance, economic conditions, and transmission capacity, all of which make CF fluctuate on timescales ranging from minutes to months. Therefore, actual output of electricity in megawatts (MW) per turbine may vary, on a single day, from zero to 100%. However, ERCOT datasets on CF are highly complex and computationally challenging to analyze; moreover, analyses of actual CF using ERCOT data have not appeared in the peer-reviewed literature. Most estimates in the published literature indicate that it is reasonable to assume a CF between 25% and 35%. Making this assumption, rather than analyzing ERCOT data does not undermine these estimates of the spatial distribution of royalties, using only the mean estimated royalty per parcel.

In this study the royalty rate of 4% was estimated from previous research that included semi-structured interviews with key actors knowledgeable about this process (Brannstrom *et al.*2011). Royalty rates, indicated on private contracts between landowners and wind farm developers are confidential and variable, but the 4% rate is considered reasonable for the two-county study region. Some landowners received less than 4% and others negotiated higher rates; the estimated royalty rate does not account for potential rents obtained through roads, maintenance facilities, or substations sited on private land.

The third estimated variable is the wholesale electricity price, which is also highly variable, as Baldick (2012) has reported. Moreover, the actual price that an individual wind farm obtains is dependent on several factors, such as presence of long- or short-term contracts, whether the operator seeks the spot (instant) market, and whether the operator has entered the market for the Renewable Electricity Credits (RECs). ERCOT datasets indicate wholesale prices in real time; however, these data are highly challenging to analyze and they may not present the actual prices that wind-farm operators use to calculate royalties they pay to landowners. Therefore, wholesale electricity price is estimated between \$35 and \$45/MWh, congruent with published analyses (Baldick 2012).

In summary, the three variables that determine royalty payments to landowners are located in confidential contracts impossible to obtain or housed in highly complex datasets; by contrast, the datasets that indicate the location of wind turbines, their nameplate capacity, and landowners, are relative transparent and far less difficult to manipulate in a spatial context. Therefore, this study seeks precision and accuracy in terms of the location of wind turbines and land parcels, while opting to use reasonable estimates for CF, royalty rate, and electricity price. For example, if a single turbine has a nameplate capacity of 1.5 MW, the formula to determine its royalty would appear as outlined in Table 1 below.

	Low	**High**
Capacity Factor (CF)	1.50 MW * 0.25 = 0.375	1.50 MW * 0.35 = 0.525
Hours/year	0.375 * 8,760 = 3,285	0.525 * 8,760 = 4,599
Low revenue ($/MWh)	3,285 * 35 = 114,975	4599 * 35 = 160,965
High revenue ($/MWh)	3,285 * 45 = 147,825	4599 * 45 = 206,955
Royalty rate low revenue	114,975 * 0.04 = $**4,598.56**	160965 * 0.04 = $**6,438.60**
Royalty rate high revenue	147,825 * 0.04 = $**5,913**	206955 * 0.04 = $**8,278.20**

Table 1. Example royalty calculation for a 1.5 Megawatt (MW) turbine.

The low royalty for a 1.5 MW turbine is $4,599, the high royalty is $8,278, and the average royalty is $6,439. Royalties are distributed on a turbine-per-year basis, so one 1 MW turbine would generate an average of $6,439 per year for a landowner. Nameplate capacities of turbines for the study region range from 1 MW to 2.3 MW and vary by wind farm. PUC records for some wind farms indicate a discrepancy between the number of turbines in the model and those confirmed by the PUC. However, as many of the turbines attributed to an incorrect wind farm have the same nameplate capacities, this is largely disregarded in this study. A complete summary table of the royalty calculations for the study area can be found in Appendix A.

Attribution of the royalty estimates per turbine to landowners is completed in several steps in GIS. First, the raw tax appraisal data (75,595 parcel polygons), FAA data (1,746 turbine points), and PUC data (16 unique wind farms) are integrated across the two-county study region (Figure 1). The blank or "missing" parcels in Nolan County in Figure 1 are owned by the State of Texas and therefore have no ownership information associated with them. As such, the 44 turbines on these "missing" parcels have been removed from the maps, but information regarding energy output and royalties have been retained for analysis. Then, urban parcels were eliminated using the geographic boundaries of cities or towns because turbines are not located in urban areas. This procedure yielded 17,526 parcels, approximately 76% fewer than the initial total (Figure 2).

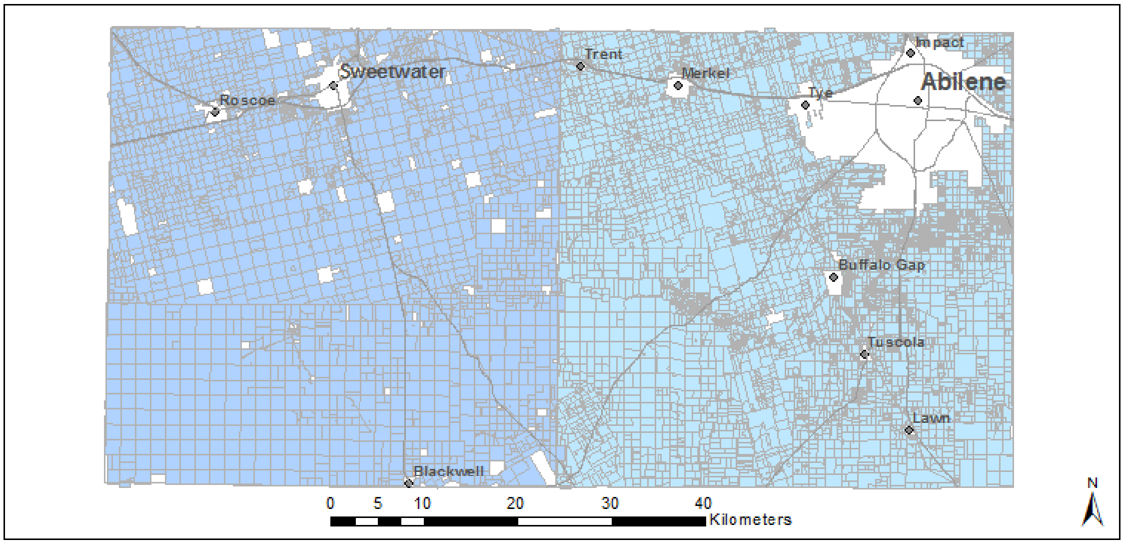


Figure 2. Nolan and Taylor Counties with urban areas removed. Number of parcels=17,526.

Next, the remaining 1,702 turbine points were joined to the parcels. This procedure yielded a count of the number of turbines per parcel. Associated wind information such as CF and wind farm name were then included in the parcel attribute table. Land parcels were then dissolved by landowner tax address to consolidate landowners who own several contiguous and non-contiguous parcels of land (Figure 3), thus reducing the number of parcels further to 8,369, approximately 89% fewer than the initial total. Summary statistics for the land area of this dataset are presented in Table 2. This step also has the added advantage of effectively illustrating rural parcel ownership. This procedure relies upon tax address as the ultimate unique characteristic of land. If

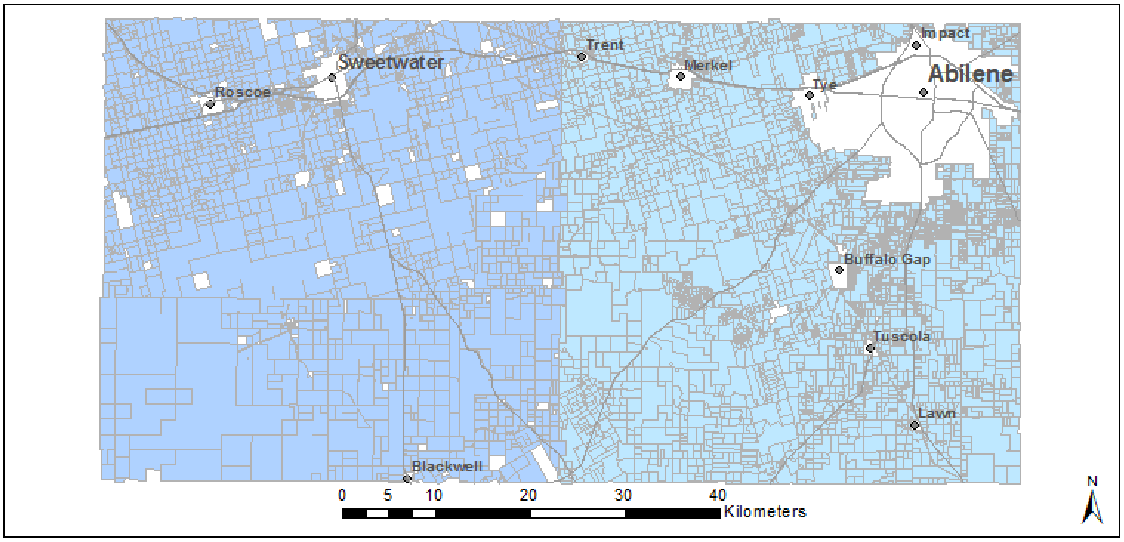


Figure 3. Nolan and Taylor Counties with urban areas removed and dissolved by landowner address. Number parcels=8,369.

	Area (Hectares)
Mean	54.10
Median	2.39
Mode	0.42
STDEV	254.78

Table 2. Summary statistics for all non-urban landowners dissolved by tax address.

tax addresses of two distinct parcels, in terms of property tax, are identical, then we assume they are controlled by the same landowner and parcels are aggregated through the dissolve procedure. For the purposes of this study, it does not matter whether landowners are individuals, LLCs or trusts—the address used to receive property tax statements from the county tax appraisal office is what is of interest. This may have resulted in under-estimated concentration of land ownership in the event that one landowner or landholding entity used different tax addresses for different parcels. Next, the landowners without turbines were removed, leaving only 241 landowners with turbines (parcels=578), and 99.3% fewer parcels than the initial total (Figure 4). Therefore, 0.7% of all land parcels in the two-county study region are the location of installed wind power and ~3% of all unique rural tax addresses (rural landowners after parcel aggregation) are the location of wind turbines.

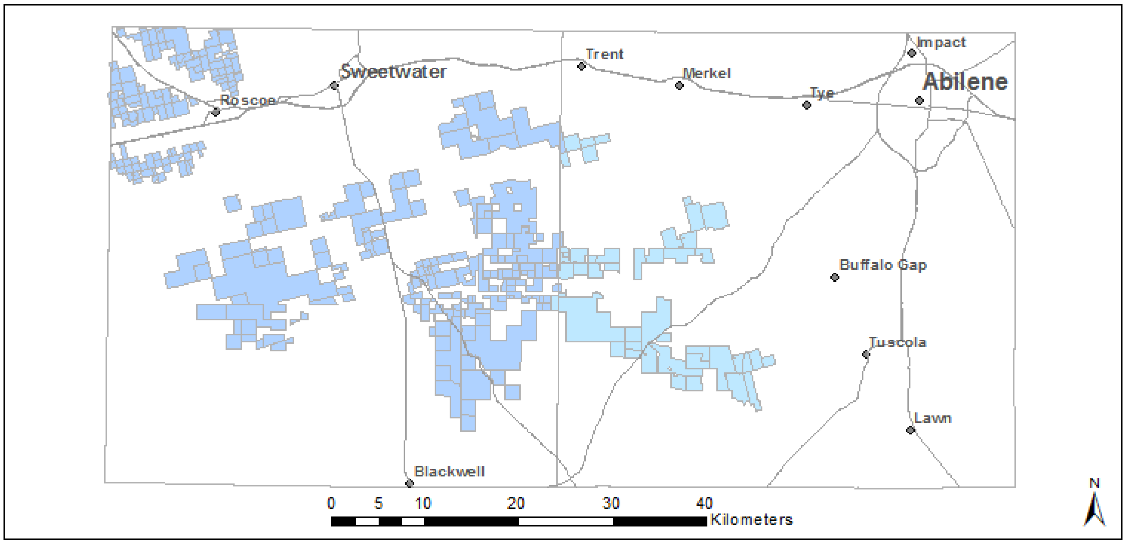
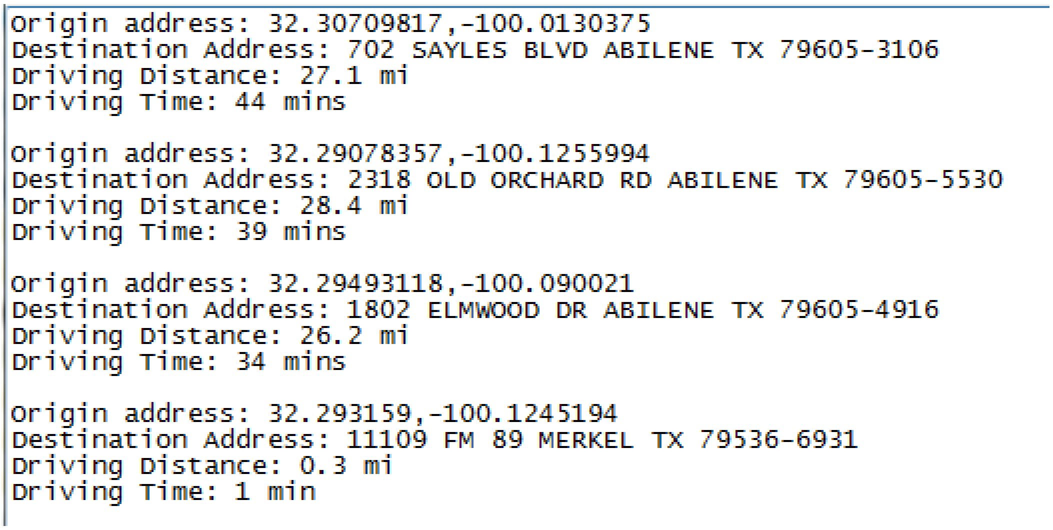


Figure 4. Nolan and Taylor Counties with urban areas removed, dissolved by landowner address, and landowners with turbines only. Number parcels=578. Number landowners=241.

The next procedure was to determine whether landowners live on their parcels based on comparison between *situs* address (the latitudinal and longitudinal location of the parcel) and tax address. In this research, the *situs* is the latitude and longitude of the centroid of the parcel, and in cases where landowners own non-contiguous parcels, the *situs* is the center point between the centroids of the non-contiguous parcels. It is clear, after a cursory glance, which landowners are immediately categorized as non-residents when the tax address is in another state, however, other landowners are more difficult to classify. This step is important because it is unknown whether royalties accrue to landowners who reside near their parcels. However, if landowners do not actually reside in the area, then it is unlikely that royalties are circulating in the local economy. To determine residency, the latitude and longitude coordinates of the centroid of the parcel are needed along with the tax address. This data, when entered in to a Google Maps directions form, will yield turn-by-turn directions via public transport, vehicle, bicycle, or pedestrian as well as the travel time and distance from one place to another. However, there are 241 landowners with turbines, which makes the process of determining landowner status challenging. For this reason, a simple code was written in C# to query Google Maps for only driving distance and time between two points without turn-by-turn instructions for all landowners. The output of the code is illustrated in Figure 5, and this information is entered into landowner attributes to facilitate separation of residents from non-residents via a simple relationship.

Landowners were separated into two groups: residents and non-residents. Residents live within twenty miles of their *situs* addresses, so for the purpose of this research, landowners live on or near their parcels and therefore, their turbines and all associated information is attributed to the parcel. This threshold is based on the assumption that the landowner must travel from one's *situs* address to retrieve mail from the tax address (where tax statements are mailed), and that twenty miles is too far to travel one way to do so. The 241 landowners with turbines become 129 resident



```
Origin address: 32.30709817,-100.0130375
Destination Address: 702 SAYLES BLVD ABILENE TX 79605-3106
Driving Distance: 27.1 mi
Driving Time: 44 mins

Origin address: 32.29078357,-100.1255994
Destination Address: 2318 OLD ORCHARD RD ABILENE TX 79605-5530
Driving Distance: 28.4 mi
Driving Time: 39 mins

Origin address: 32.29493118,-100.090021
Destination Address: 1802 ELMWOOD DR ABILENE TX 79605-4916
Driving Distance: 26.2 mi
Driving Time: 34 mins

Origin address: 32.293159,-100.1245194
Destination Address: 11109 FM 89 MERKEL TX 79536-6931
Driving Distance: 0.3 mi
Driving Time: 1 min
```

Figure 5. Output of code which feeds in the coordinate of the centroid of the parcel and the tax address and gives an output of the driving distance and time between the two points.

landowners (approximately 54% of total landowners with turbines) and 112 non-residents (Figure 6). Non-residents live more than twenty miles or forty-five minutes from their parcels, so turbines and associated information for these landowners must be attributed somewhere other than their parcels. Given that landowner tax addresses contain a street address at the most specific level and a zip code at the broadest level, the only way to visualize non-residents is at the zip code level. However, Zip Code Tabulated Areas (or ZCTAs) are not widely-recognizable boundaries, unlike county boundaries. Therefore, the county name needs to be established for each non-resident landowner, which is accomplished by performing a simple Google search query of the county for each unique Zip Code. Using the combination of Zip Codes, county names, and American National Standards Institute (ANSI) state codes (*i.e.* Texas' state code is 48, Oklahoma's state code is 40, *etc.*), data for each non-resident landowner's turbine count and royalty is retained in the attribute table for counties. Several landowners reside in the same counties as their fellow non-residents, especially in the larger cities in Texas, which distributes the 112 non-residents across 53 counties nationwide (Figure 7). Counties with multiple non-resident contributors have a cumulative count of turbines and royalties.

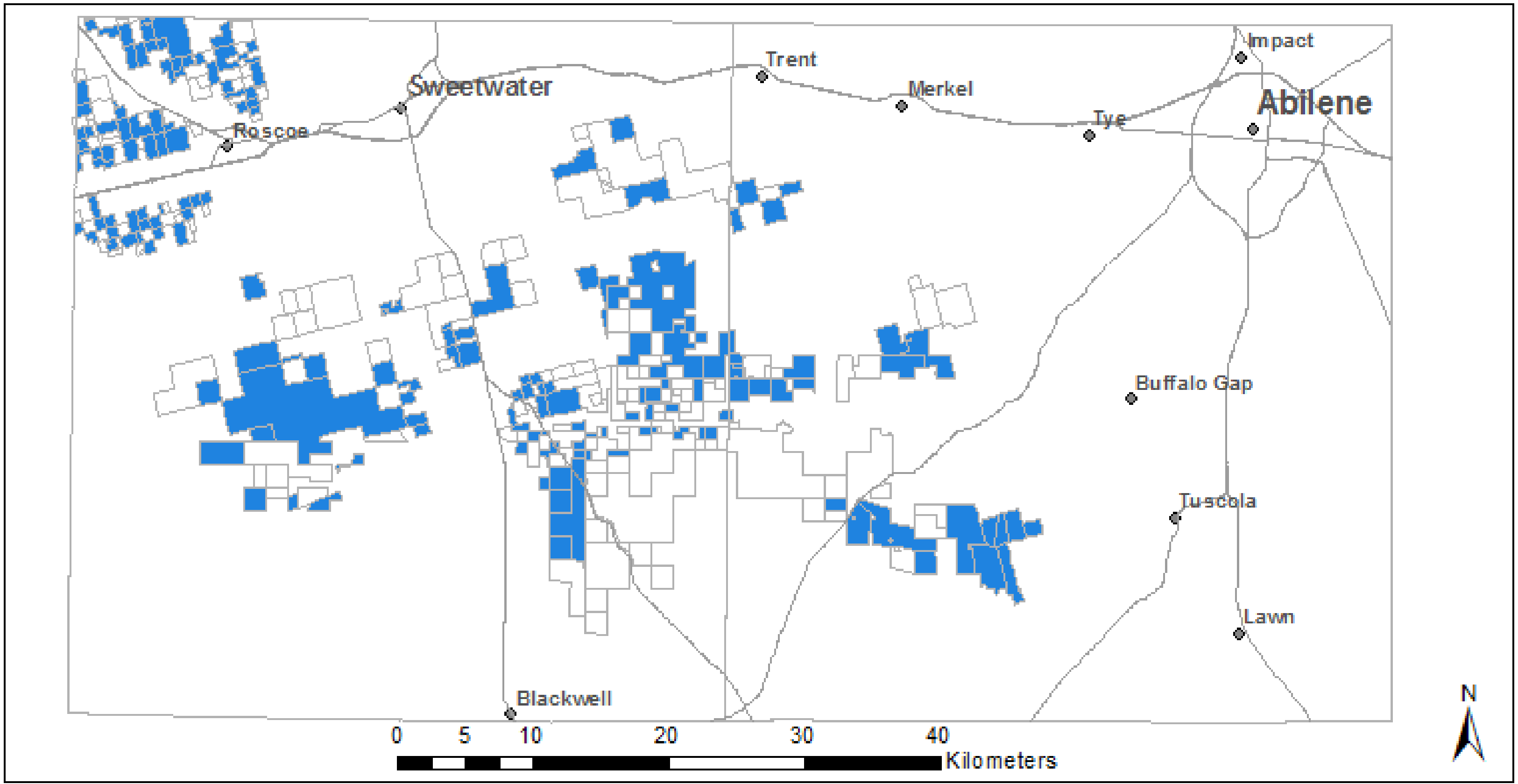


Figure 6. Parcels of landowners with turbines who live less than or equal to 20 miles driving distance or 45 minutes driving time from tax address (residents displayed in blue). Number landowners=129.

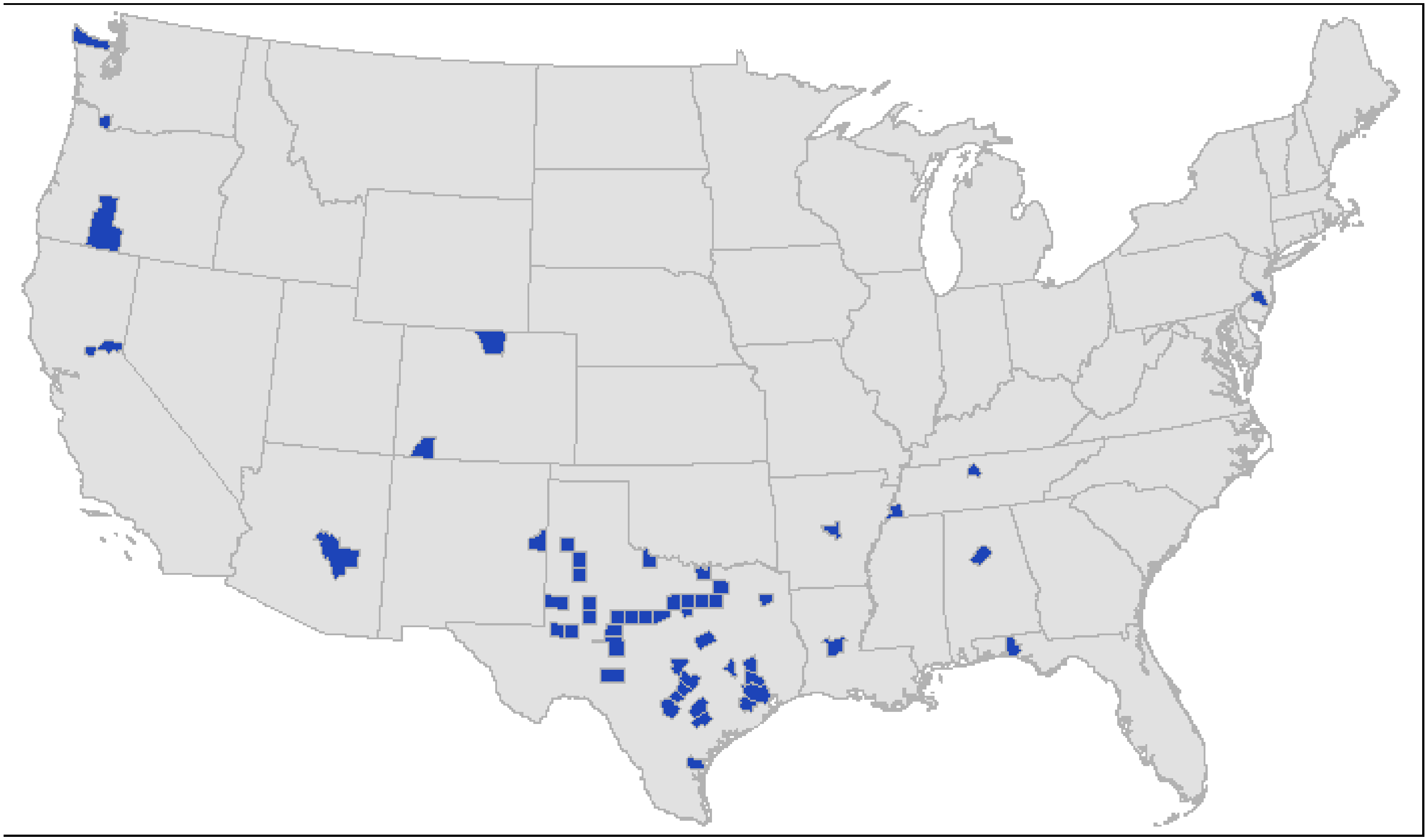


Figure 7. Counties of landowners with turbines who live more than 20 miles or 45 minutes from the tax address (non-residents). There are 112 non-resident landowners in 53 counties nationwide.

CHAPTER IV

RESULTS

This chapter describes the main findings of this thesis regarding characteristics of landowners with turbines, the spatial distribution of turbines, and the spatial distribution of estimated wind-power royalties.

IV. 1. Spatial distribution of turbines

The spatial distribution of turbines in the two-county area is skewed heavily toward Nolan County and follows no discernible pattern other than avoidance of urbanized areas and transportation routes; however, this observation is a testable claim beyond the scope of this research. As previously discussed, these wind farms are situated in areas where the wind resource is likely the greatest, and where transmission lines are accessible. In brief, Nolan and Taylor Counties contain 1,701 turbines owned by 241 landowners on 66,117 hectares. Most turbines are located in central and east Nolan County and in the northwest section of Nolan County near the town of Roscoe (illustrated in Figures 1 and 4), with a small portion of turbines in Taylor County. Of the 75,595 total parcels, 578 have turbines, which equates to 0.7% of the total number of parcels. Out of 8,408 rural landowners (aggregated by tax address), 241 have turbines on their land, which amounts to ~3% of the total rural landowners. Nolan County hosts 1,372 turbines from sixteen wind farms, and there are 373 turbines from six wind farms in Taylor County, representing about 22% of the total number of turbines for both counties. The 297 turbines located in the area northwest and southwest of Roscoe in Nolan County are within three wind farms, and make up about 17% of total turbines. These turbines are on smaller parcels of less than 600 hectares per single parcel, and there are no more than ten turbines on a single parcel. The larger parcels located in the center of the two counties are mainly ranchland and generally contain more turbines than those on farmland. There are eleven landowners whose tax records specify that their land is used as a working ranch (as part of a Corporation or Partnership of some type). These eleven landowners hold 281 of the total turbines (about 16%), and are situated on approximately 10,600 hectares combined, spread across the middle of the two counties. Meanwhile, there are only two landowners whose tax records specify their land is used as a working farm, both of which are located near Roscoe as previously indicated. Only eleven turbines are located on these smaller parcels with a total land size of 269 hectares. Of all parcels with turbines, 15% have only one turbine, and 21% have ten or more turbines. Furthermore, there are forty-four turbines in Nolan County from seven wind farms that are owned by the State of Texas; about 2.5% of the total number of turbines.

To better understand the allocation of turbines amongst landowners, all landowners with turbines were divided into quintiles of approximately 48 landowners per quintile. Table 3 illustrates each quintile with selected statistics, and Figure 8 is a box and whisker plot of turbine quintiles derived from Table 2. The bottom of the lower box (“Bottom” in Table 3) rests on the first quartile (“Q1” in Table 3). “2Q Box” refers to the second quartile, or the difference between the median and the first quartile, and “3Q Box” refers to the third quartile, or the difference between the third quartile (“Q3”) and the median. “Whisker –” denotes the difference between Q1 and the minimum, and “Whisker +” denotes the difference between the maximum and Q3. The majority of turbines (60%) are in the top quintile, meaning that approximately one-fifth of landowners have 60% of the total turbines on their property. The maximum number of turbines on a single landowner’s property is 104, with an overall mean of 7, a median of 4, and a mode of 2 turbines per landowner. Generally, landowners with large parcels are expected to have more turbines than landowners with smaller parcels because of turbine spacing requirements. Many times this is the case, though there are a few exceptions, as illustrated in Figure 9.

		Turbine and Royalty Quintiles				
		Q1	**Q2**	**Q3**	**Q4**	**Q5**
Turbines	**Count**	48	48	48	48	49
	Mean	21.25	6.83	3.60	2.44	1.29
	STDEV	17.92	1.65	0.5	0.5	0.46
	Min	10	5	3	2	1
	Q1	12	5	3	2	1
	Median	14	6	4	2	1
	Q3	20	8	4	3	2
	Max	104	10	5	3	2
	Bottom	12	5	3	2	1
	2Q Box	2	1	1	0	0
	3Q Box	6	2	0	1	1
	Whisker-	2	0	0	0	0
	Whisker+	84	2	1	0	0
	Total	1,020	328	173	117	63
	Percent	60.0%	19.3%	10.2%	6.9%	3.7%
Royalties	**Mean**	146,189	44,356	26,032	15,998	7,656
	STDEV	111,288	10,932	4,134	3,340	2,067
	Min	70,829	30,904	19,746	9,873	4,292
	Q1	83,707	37,556	21,460	12,876	6,439
	Median	100,444	39,492	27,473	17,168	8,584
	Q3	142,942	51,512	29,619	19,317	9,873
	Max	591,474	69,534	30,904	19,746	9,873
	Bottom	83,707	37,556	21,460	12,876	6,439
	2Q Box	16,737	1,936	6,013	4,292	2,145
	3Q Box	42,498	12,020	2,146	2,149	1,289
	Whisker-	12,878	6,652	1,714	3,003	2,147
	Whisker+	448,532	18,022	1,285	429	-
	Total	7,017,091	2,129,078	1,249,539	767,913	375,148
	Percent	60.8%	18.5%	10.8%	6.7%	3.3%

Table 3. Turbine and royalty quintiles with totals and percentages.

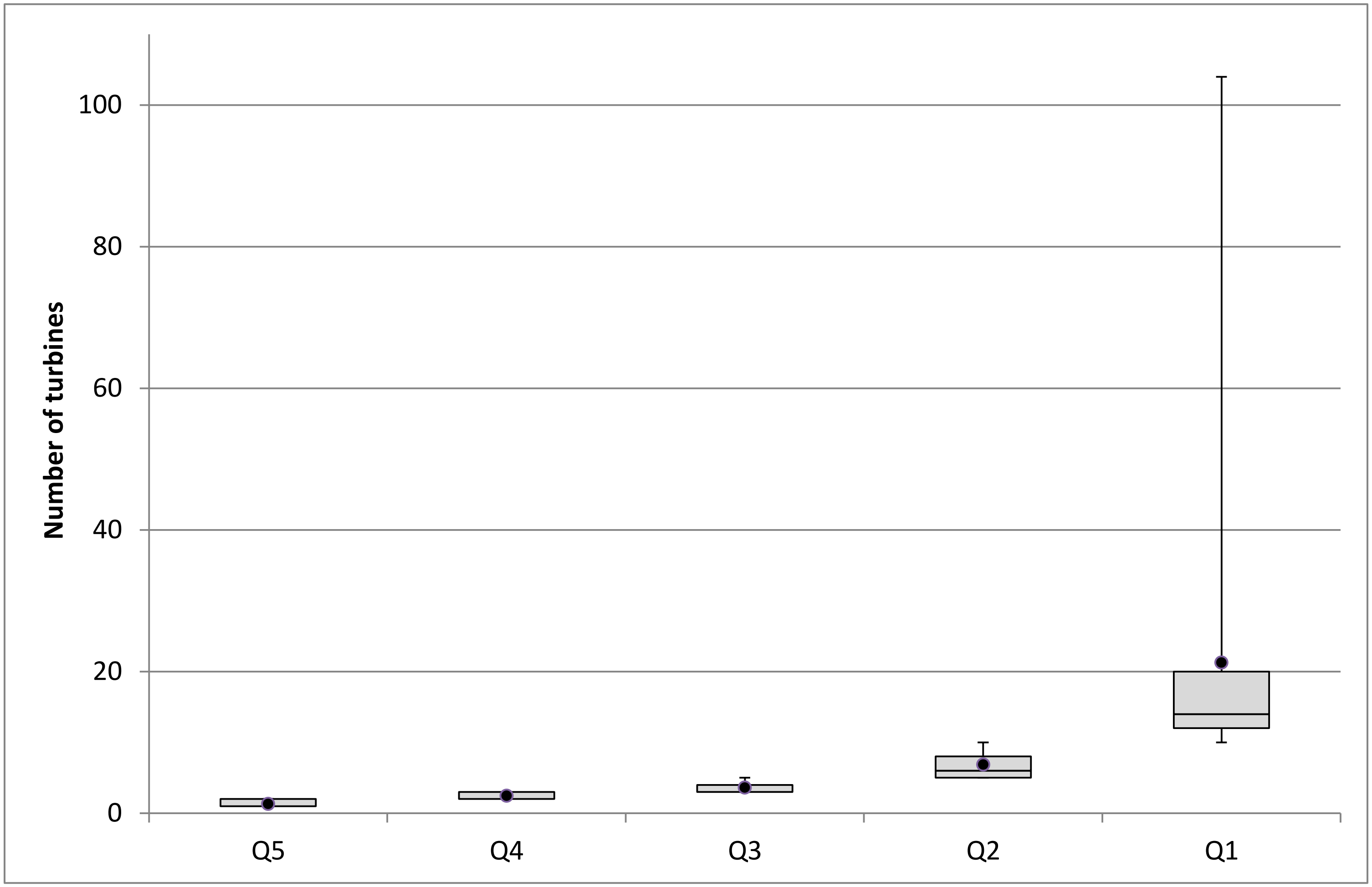


Figure 8. Distribution of turbines by landowner quintiles

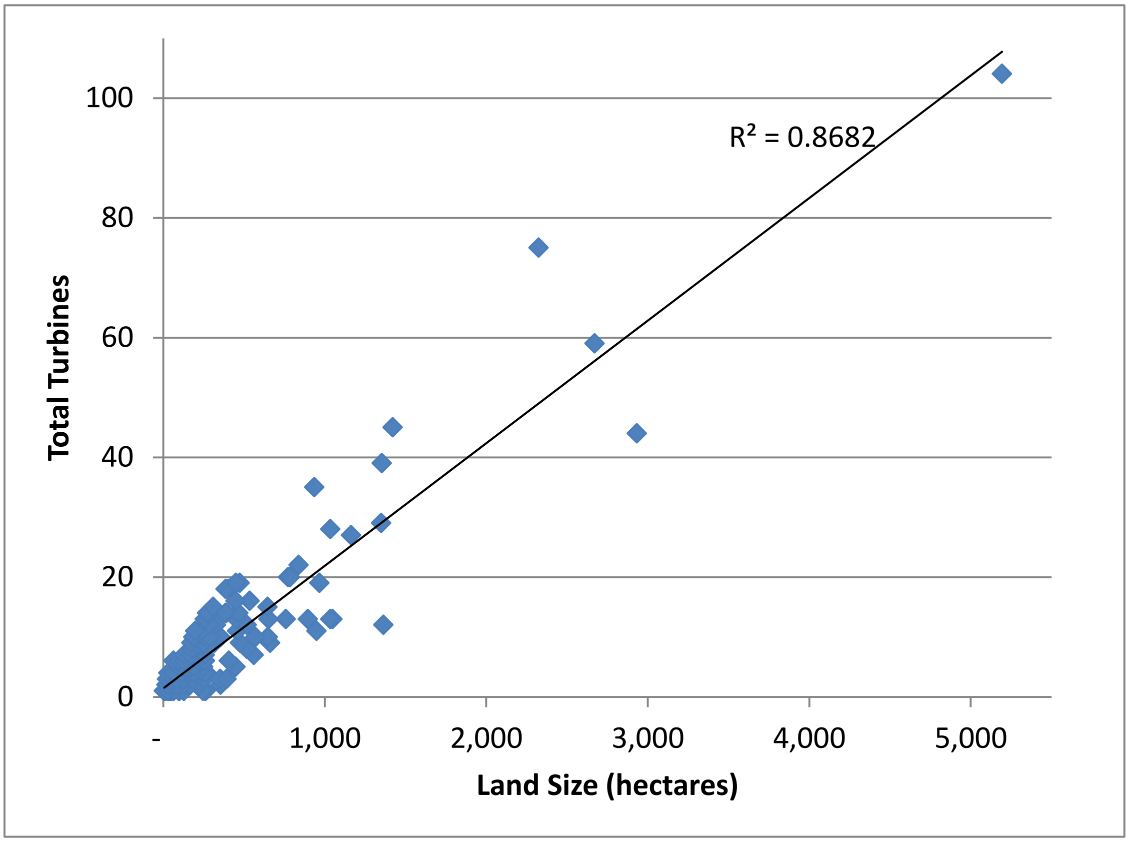


Figure 9. Total turbines by land size in hectares. The r^2 value indicates the strong relationship between parcel size and number of turbines.

IV. 2. Spatial distribution of royalties

The total estimated amount in royalties paid to all landowners with turbines is \$11,538,769 per year. If all royalties were distributed equally amongst the 241 landowners with turbines, this would amount to \$47,879 per landowner. If royalties were distributed equally amongst all rural landowners in the two counties, each rural landowner would receive approximately \$1,372 per year. Yet, the spatial distribution of royalties is imbalanced (Figure 10). Some rural landowners did not have desirable land for wind turbines and others refused contracts offered by wind-farm developers, but the precise reason is not possible to determine with available data. As expected, landowners who own smaller parcels tend to receive less in royalties than landowners with larger parcels because larger parcels can support more turbines. Wind turbines require adequate spacing and they must be well-suited according to knowledge of wind characteristics, electricity substations, maintenance roads, and transmission lines. However, a larger parcel does not always equate larger royalties, as shown in Figure11. For instance, the parcel that contains the fifth most turbines (n=44) is larger than the parcel that contains the second most turbines (n=74) by about 600 hectares and the latter landowner receives approximately \$186,000 more in royalties per year on average than the former. Some landowners also have several different wind farms represented on their property which generate distinctly different amounts in royalty payments, which may be another cause for the discrepancy in payments from one landowner to the next. Also expected is that landowners with more turbines are likely to receive more royalties. However, because of the disparity between royalty payments in different wind farms caused by varying

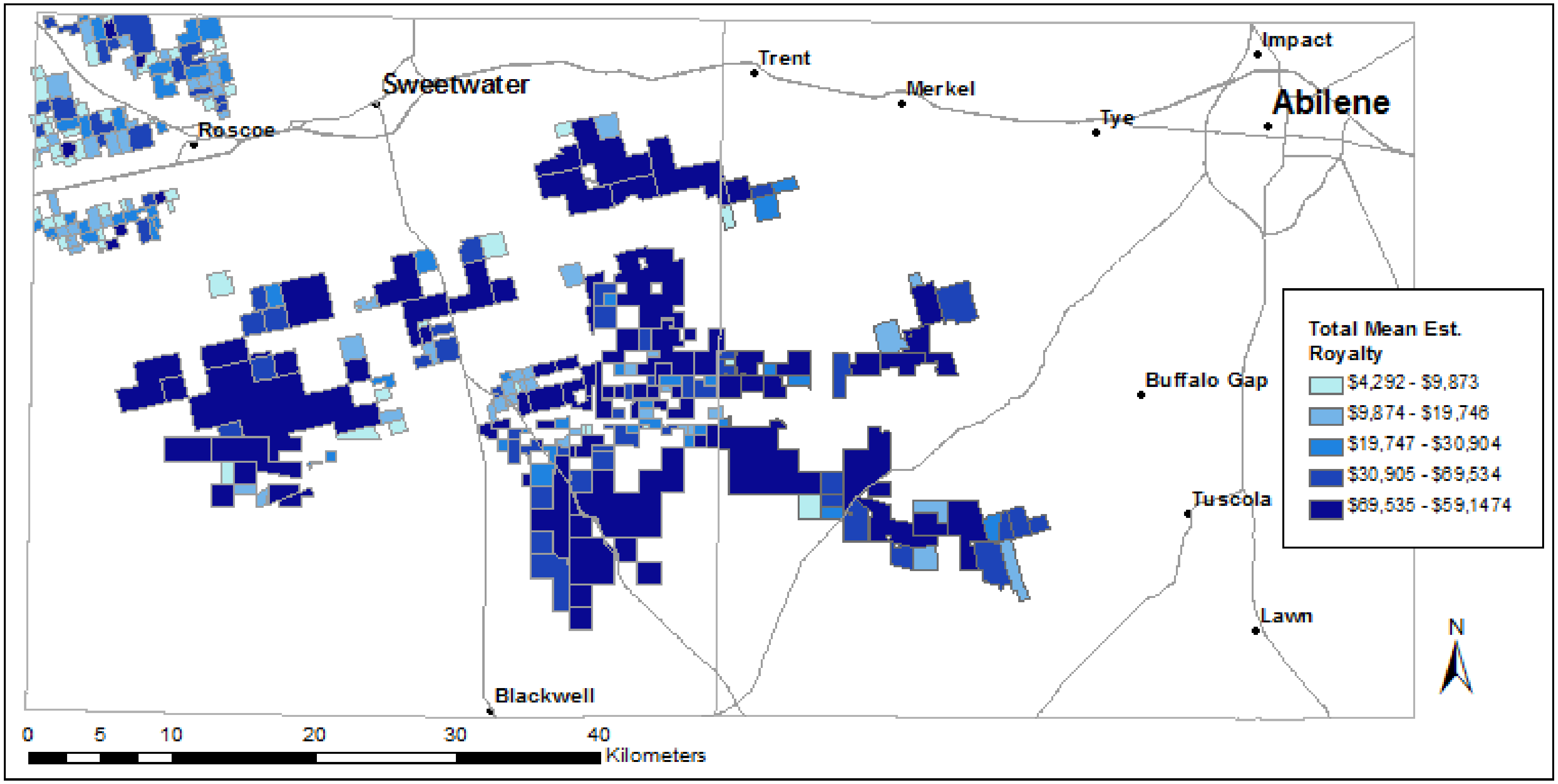


Figure 10. The spatial distribution of royalties to all landowners with turbines. The key is binned by landowner quintiles.

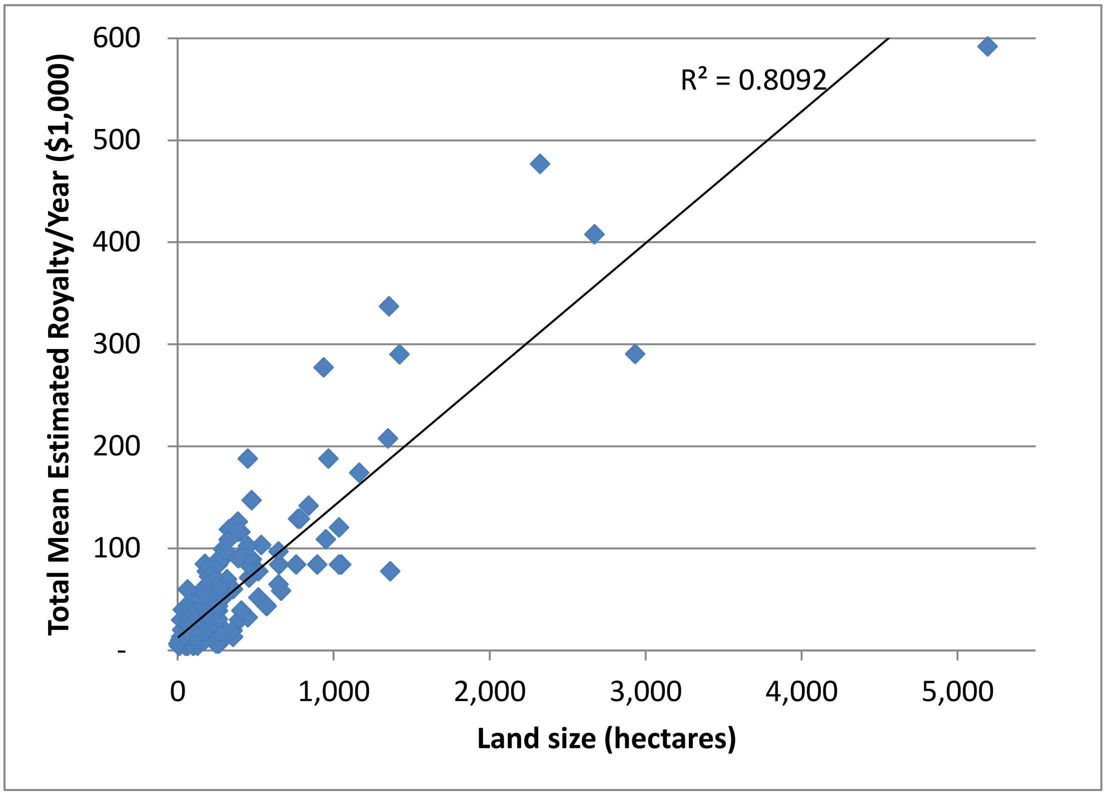


Figure 11. Total mean estimated royalty by land size in hectares. The r^2 value indicates that there is a strong relationship between land size and royalties.

nameplate capacities, some landowners with fewer turbines receive more in royalties than those with more turbines. In one particular instance, one landowner has twelve turbines, receiving $51,504 average per year in royalties, while another landowner with eight turbines receives $61,808 average per year. Average royalty payments range between $4,292 and $9,873 and the overall average for all farms is $7,404 per turbine per year. The aggregate mean is $47,879, with a median of $25,756, and a mode of $29,619 per landowner per year. The minimum amount a single landowner is paid on average per year in royalties is $4,292, and the maximum is $591,500.

To better understand how royalties are distributed amongst landowners with turbines, all landowners with turbines were divided into quintiles of approximately forty-eight landowners per quintile. Table 3 illustrates each quintile with statistics, and Figure 12 is a box-and-whisker illustration of royalties as described in Table 3. Since the correlation between number of turbines and royalties is so strong, Figure 12 closely resembles Figure 8 in shape. It is clear from Table 3 that the majority of total royalties (about 61%) are in the top quintile. That is, the forty-eight landowners with the most turbines receive about 61% of the total royalties per year, while the fifth quintile, the 20% of landowners with the fewest turbines comprised of forty-nine landowners, receives approximately 3% of the total royalties. Almost 80% of royalties are distributed to 40% of turbine-possessing landowners. The forty-four turbines owned by the State of Texas have a royalty range between $4,292 and $9,873 average per turbine, and an accumulated sum of $267,421 per year; just over 2% of the total royalties for the two counties. When this sum is added to the total mean estimated royalties paid to all landowners, the average sum of all royalties for Nolan and Taylor Counties is $11,806,190 per year. There are thirteen landowners whose land is used either as farm or ranchland. The eleven landowners whose tax records indicate their land is used as a working ranch hold $1,998,229 of royalties, which is about 17% of the total royalties, and the two landowners with working farms hold $47,212, which is less than half a percentage of the total royalties (~0.41%). The royalty per parcel also appears lower in the parcels surrounding Roscoe compared to the parcels on mesas south of Sweetwater. Since the parcels surrounding Roscoe are smaller than many of the parcels south of

Sweetwater, it is expected that fewer turbines would fit on the land and therefore, fewer royalties would accrue there. A t-test was performed to compare the total mean estimated royalty for both areas at the 95% confidence level. The test revealed that mean royalties for the two areas are significantly different (Table 4). This difference may be explained by unsuitability of the land near Roscoe to host several turbines, or the fragmentation of the land into smaller parcels. The low p-values for both the equal variance and unequal variance two-tail t-test indicate that there is evidence in contradiction of the null hypothesis that there is no difference between the mean royalties for the Roscoe area and the area south of Sweetwater.

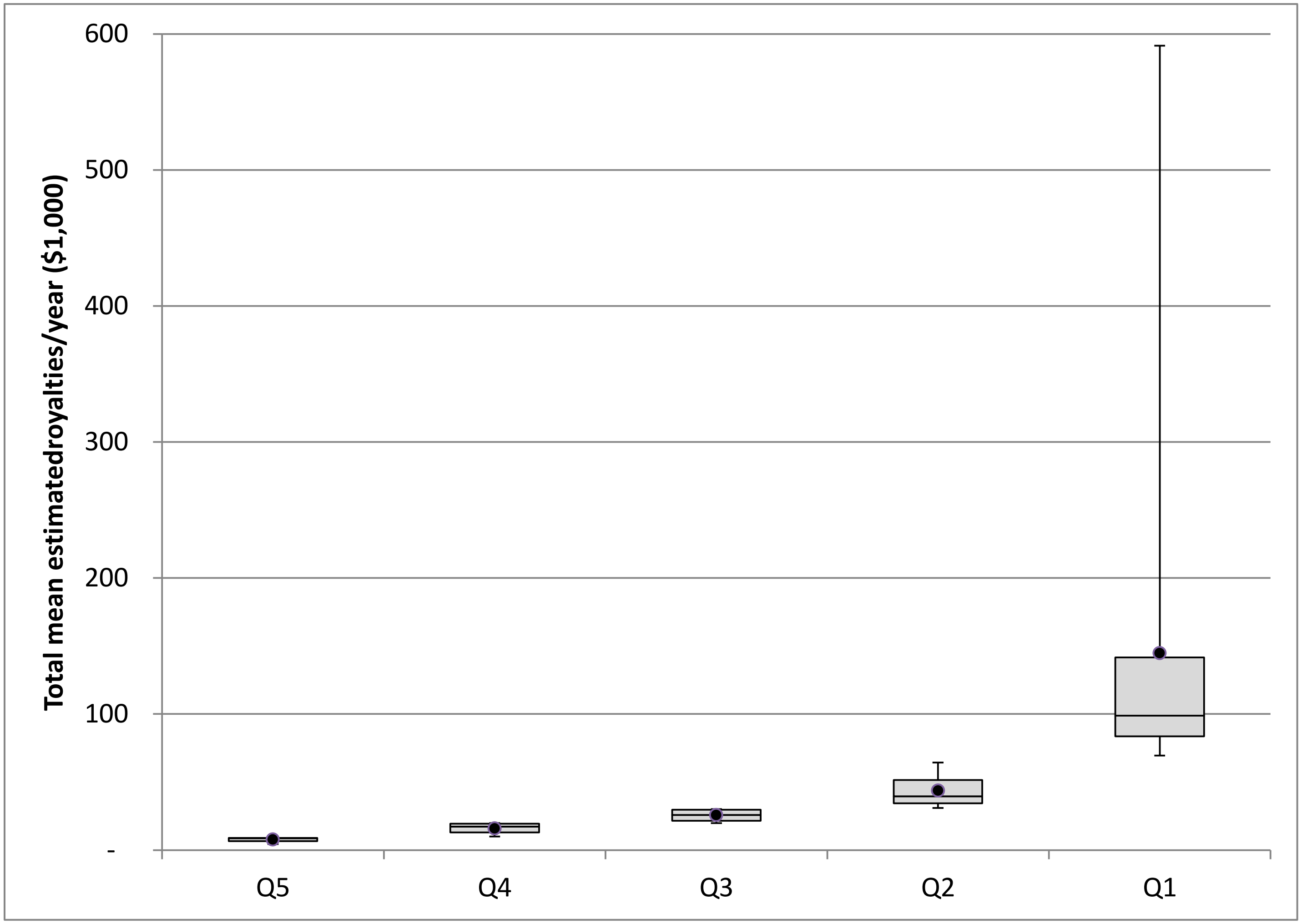


Figure 12. Distribution of total mean estimated royalties per year by landowners quintiles.

T Test: Two Independent Samples									
SUMMARY			Hyp Mean Diff	0					
Groups	*Count*	*Mean*	*Variance*	*Cohen d*					
TMER_Roscoe	85	19,310	251457420.8						
TMER_Other	156	63,307	6947410908						
Pooled			4594021398	0.649128806					
T TEST: Equal Variances				Alpha	0.05				
	std err	*t-stat*	*df*	*p-value*	*t-crit*	*lower*	*upper*	*sig*	*effect r*
One Tail	9137.623634	4.814975955	239	1.30662E-06	1.651254165			yes	0.297365811
Two Tail	9137.623634	4.814975955	239	2.61324E-06	1.969939406	-61998.00296	-25996.87321	yes	0.297365811
T TEST: Unequal Variances				Alpha	0.05				
	std err	*t-stat*	*df*	*p-value*	*t-crit*	*lower*	*upper*	*sig*	*effect r*
One Tail	6891.517097	6.384289187	174.8527392	7.49698E-10	1.653607437			yes	0.434786649
Two Tail	6891.517097	6.384289187	174.8527392	1.4994E-09	1.973612462	-57598.62211	-30396.25406	yes	0.434786649

Table 4. T-test and selected statistics comparing total mean estimated royalty (TMER) of the area around Roscoe and all other areas. The p-value indicates that there is a significant difference between TMER for the two areas.

IV. 3. Resident/non-resident comparisons

Out of the 241 total landowners with turbines, 129 have a local tax address and are considered residents, according to the definition used in the previous chapter (drive time>=45 minutes, or drive distance>=20 miles) and of the total 1,701 turbines, 914 (about 54%) are located on parcels where landowners are residents. Total royalties paid to resident landowners are $6,115,102 on average per year; 53% of the total royalties for all landowners. The maximum royalty paid to a single resident landowner is $591,474 per year, and the average royalty payment for residents is $47,404 per year. Average land size per residential landowner is 258 hectares, with a minimum of 8, a maximum of 5,194, and a median of 128 hectares. The land area held by residents is 33,312 hectares, which is about 50% of the total land area for all landowners with turbines. This land area has value itself in addition to the value of the wind turbines, but appraised land value is indeterminable once parcels have been dissolved partly because of the unknown process of estimating land value. Figure 13 indicates the spatial distribution of royalties for resident landowners, which appears to follow no specific pattern in terms of land size, number of turbines, spatial distribution of residents, or distribution of royalties.

The remaining 787 turbines are located on parcels where landowners have a non-local tax address, meaning they drive more than twenty miles (~32 km) or forty-five minutes to reach their tax address and therefore live outside the area. Most of the results depicted in Figure 5 cannot definitively answer the question of whether landowners are truly residents or non-residents, but they do provide insight into where landowners might reside permanently. The forty-five minute/twenty mile threshold may seem arbitrary,

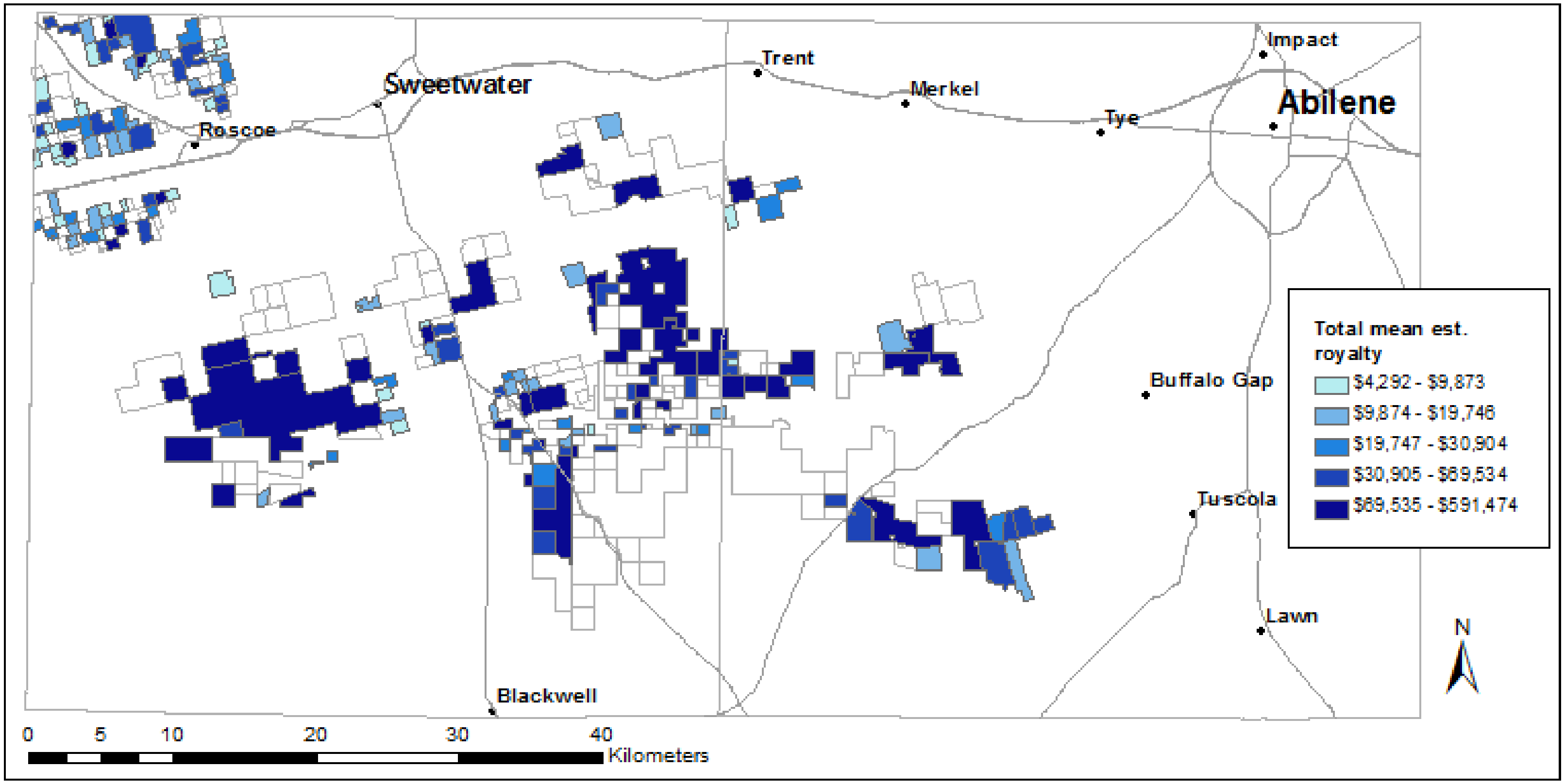


Figure 13. The spatial distribution of royalties for resident landowners of Nolan and Taylor Counties illustrated in gradients of blue. Non-resident landowners with turbines are outlined in light gray. The key is binned by landowner quintiles.

however, it was chosen based upon travel time to retrieve mail from the tax address mailbox, as forty-five minutes is an unreasonable amount of time to drive one way to retrieve mail. Figure 14 illustrates the driving distance for each landowner from their *situs* to their tax address. Several landowners are considered non-residents though they reside in Nolan or Taylor County as a result of the *situs*-to-tax-address calculation. Only eighteen landowners in Nolan and Taylor Counties are classified as non-residents despite their situs addresses also being in Nolan or Taylor, which equates to 7% of the total landowners with turbines, and 16% of non-residents. Amongst these landowners, $971,848 is accrued in royalty payments, which is ~8% of the total estimated royalty distribution, and ~18% of the total estimated non-resident royalty distribution. A total of $7,086,950 accrues to all residents with tax addresses in Nolan and Taylor Counties (~61% of total royalties). Less than half of the landowners with turbines have non-local tax addresses, as previously indicated in Figures 6 and 7. Figure 15 is a representation of each landowner’s spatial relationship to their tax address in terms of whether they reside in Nolan and Taylor Counties, inside Texas, or outside Texas. The total mean estimated royalty for the 112 non-resident landowners is $5,423,667 annually, which is about 47% of the total royalties per year. Non-residents receive an estimated average of $48,426 per landowner per year, and the maximum royalty to one landowner is $407,373 per year. While the difference between the non-resident and resident average royalty per landowner per year is only slightly more than the average royalty for one turbine, the majority of royalties accrue to landowners with local tax addresses. The land area of the non-resident parcels is 32,805 hectares with a minimum of 5, a maximum of 2,933 and a median of 130 hectares.

The spatial distribution of royalties for non-resident landowners is localized within Texas and follows no perceptible spatial pattern outside of Texas (Figure 16). Fifteen of the 112 non-resident landowners reside outside of Texas as recorded in Table 5, comprising about 13% of the non-resident population and about 6% of the total landowners with turbines. Non-residents in states other than Texas accrue $798,857 per year in royalties, which amounts to ~15% of the total non-resident royalties, and ~7% of the total royalties. Within the non-resident group, 97 landowners reside within Texas, where $4,624,810 (~85%) of non-resident royalties and 40% of the total royalties are distributed. Figure 17 illustrates the spatial distribution of royalties for non-residential landowners only in Texas. Most royalties (~61%) are allocated to addresses in Nolan and Taylor Counties, despite being the two counties where the turbines are sited, and 11% of total royalties is generally distributed in major metropolitan areas in Texas rather than in smaller cities or towns. For example, Dallas, Fort Worth, and Austin are three of the cities with the highest royalties. This suggests that landowners with the most turbines are living in larger metropolitan areas than in smaller towns, or that more landowners live in large cities, as many counties have a cumulative count for landowners receiving royalties.

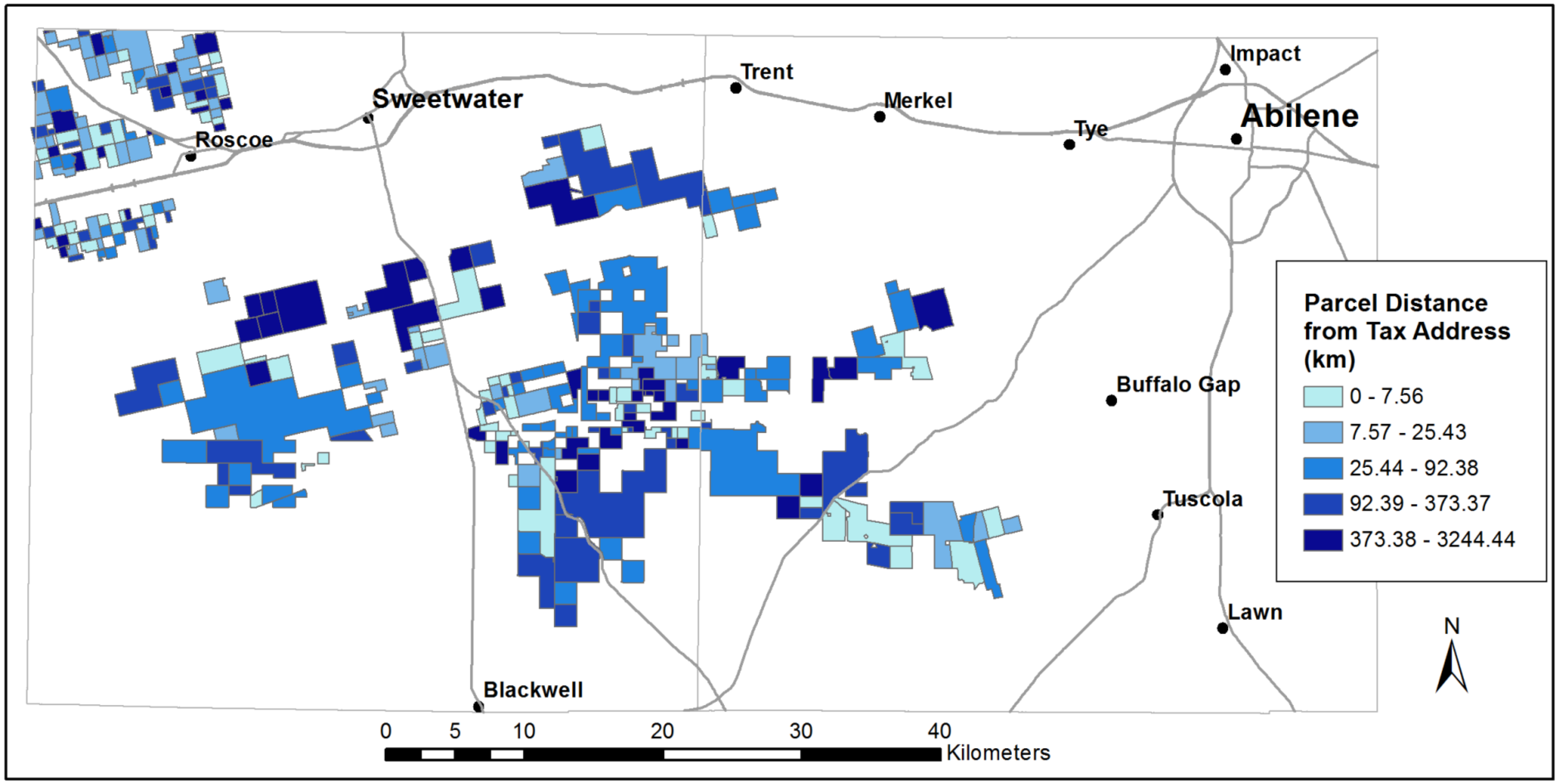


Figure 14. Drive distance (in km) from *situs* address to tax address for all landowners in Nolan and Taylor Counties.

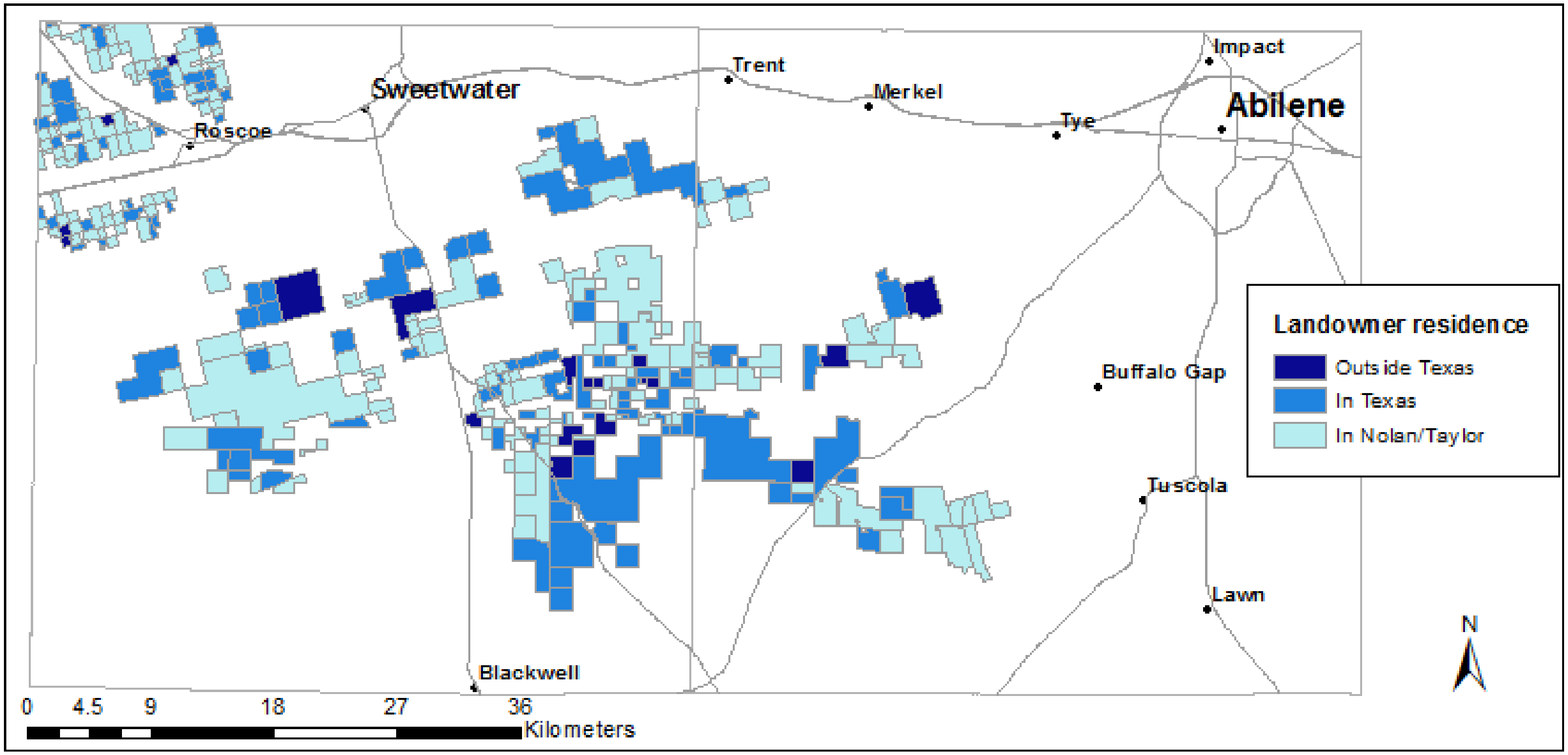


Figure 15. Landowner residence status for each landowner in Nolan and Taylor Counties.

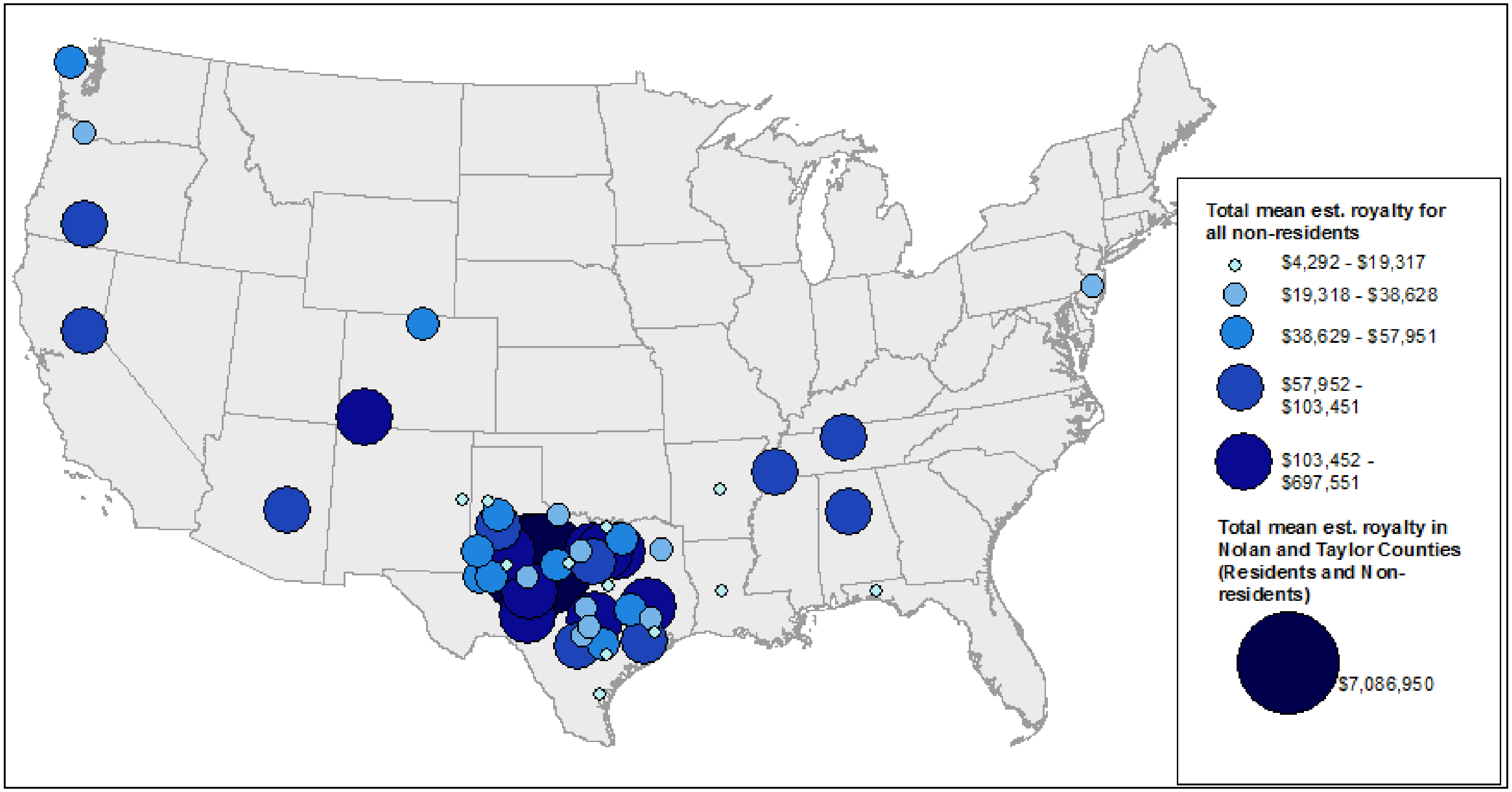


Figure 16. The spatial distribution of royalties for non-residents by county with Nolan and Taylor County total royalty for comparison.

State	County	Turbines	Royalty
LA	Rapides Parish	1	9,873
AR	Pulaski	2	8,584
WA	Clark	2	19,746
NM	Curry	2	8,584
FL	Walton	2	12,878
WA	Clallam	4	39,492
NJ	Burlington	5	32,195
CO	Larimer	8	51,512
OR	Klamath	9	84,563
TN	Davidson	10	64,390
CA	Placer	11	70,829
TN	Shelby	13	83,707
CO	La Plata	14	125,773
AL	Jefferson	14	90,146
AZ	Gila	15	96,585
		112	798,857

Table 5. Non-resident landowners not residing in Texas

A t-test was performed to compare the mean royalties for residents and non-residents at the 95% confidence level. The test determined that mean royalties for the two groups are not significantly different (Table 6). The p-value of 0.91 for both the equal variance and unequal variance two-tail t-test indicates that there is no evidence in contradiction of the null hypothesis that there is no difference between the mean royalties for residents and non-residents.

IV. 4. Landowner type and land tenure

Another consideration in determining royalty distribution is type of land ownership or tenure. In this study, any landowner not listed as an individual or an individual with a spouse in tax records is regarded as a non- traditional owner type or

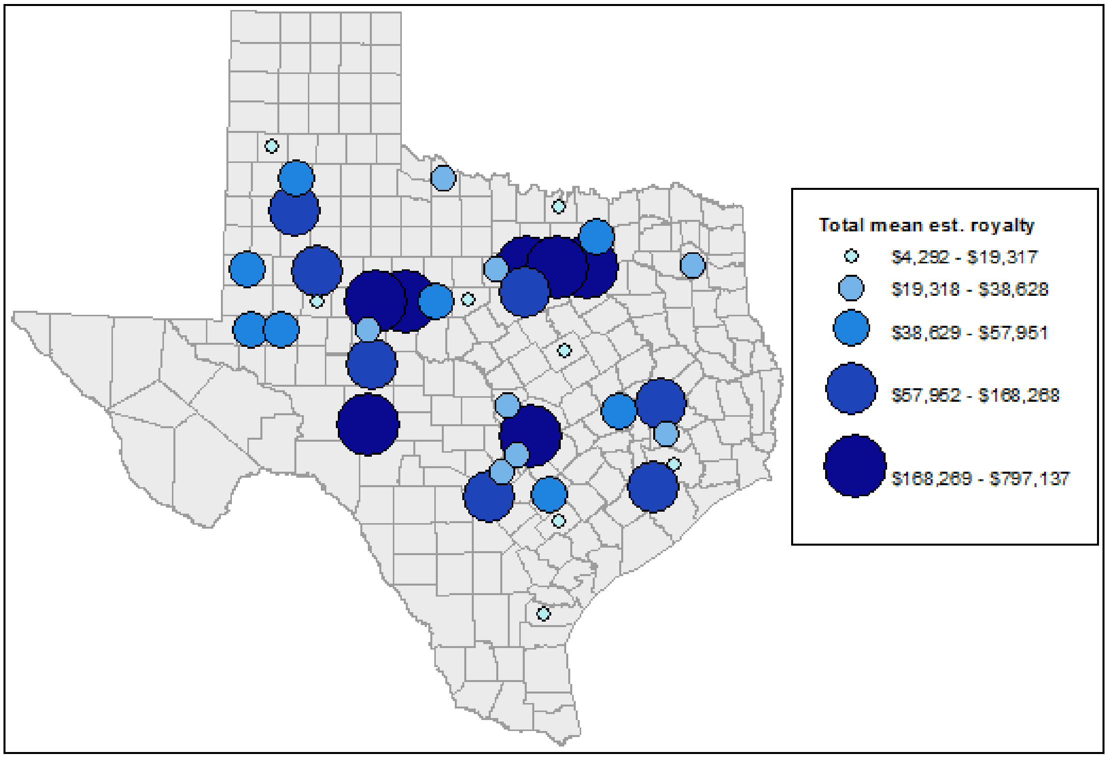


Figure 17. The spatial distribution of royalties for non-residents only in Texas

a landowner with some land tenure in place. Tenure is the legal regime in which land is owned, controlled, used, and transferred. Numerous parcels in Nolan and Taylor Counties are not owned by an individual or set of individuals, but are listed as life estates, trusts, Limited Liability Partnerships (LLPs), Limited Partnerships (LPs), or are companies or working ranches. Nearly one-third (n=78, or 32%) of all landowners with turbines fall into one of the above categories, and approximately 45% of total royalties per year are attributed to such landowners (Table 7). Within this group, forty-six landowners are non-residents, with $3,100,545 paid in average yearly royalties (~ 27%

of the total royalties, and ~57% of non-resident royalties), and thirty-two landowners are residents with $2,056,565 paid in average yearly royalties (~18% of the total royalties, and ~34% of resident royalties). 738 turbines are located on land where some type of tenure is in effect, 433 of which are on property where the landowner is considered a non-resident. Nine of the fifteen non-resident landowners not residing in Texas have some type of tenure in effect, accounting for seventy-six turbines and $541,301 per year in royalties.

The most-represented land tenure types are Trusts (twenty-three landowners), and those who have specified their ownership as "*Et al*" (eighteen landowners). The least-represented land tenure types are listed as "Family" (one landowner), and "Company" (two landowners). Despite Trusts being the most represented land tenure type for residents and non-residents, the tenure type with the most turbines and royalties are LTDs or Limited companies with 181 turbines and $1,229,394 in annual royalties (11% of total royalties). The probable reasons for placing land ownership in this type of regime are to protect the land or landowners, transfer the land to beneficiaries, or for tax purposes.

IV. 5. Sensitivity of royalties to fluctuation of contract terms

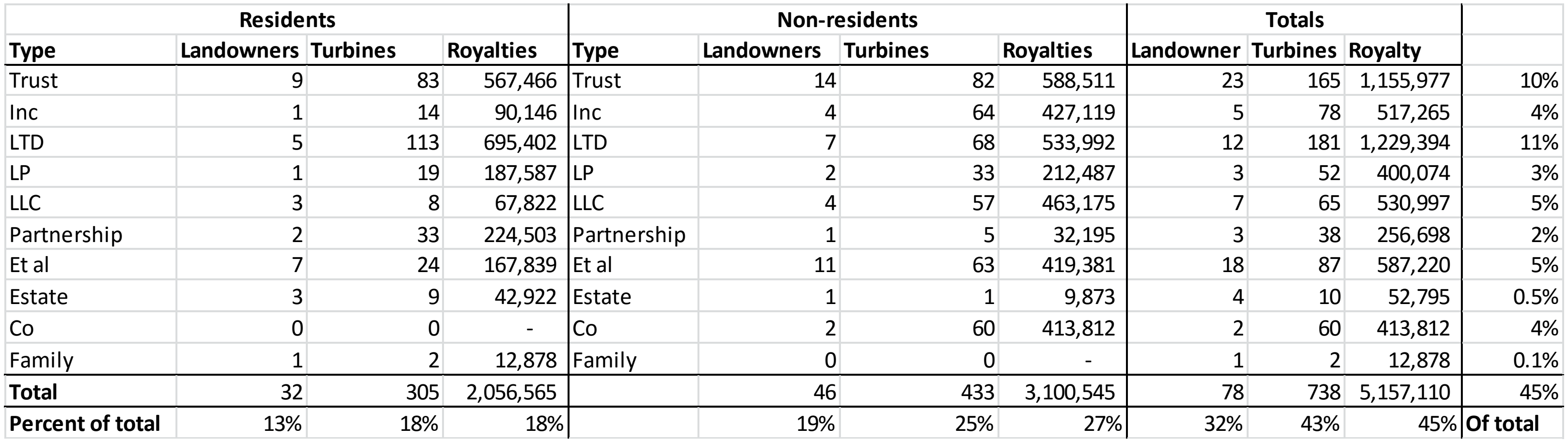
As previously discussed, some scholars and observers claim that the royalty payments are $5,000 per turbine per year, while other sources claim that royalties range between $5,000 and $10,000 per turbine per year. The total estimated average royalty for this study site is $7,404 per turbine per year, with a minimum average royalty of $4,292 and a maximum average royalty of $9,873 per turbine per year. Our estimates fit within

T Test: Two Independent Samples									
SUMMARY			Hyp Mean Diff	0					
Groups	*Count*	*Mean*	*Variance*	*Cohen d*					
Residents	129	47,404	5638150684						
Non-residents	112	48,426	4351197784						
Pooled			5040444525	0.014391029					
T TEST: Equal Variances				Alpha	0.05				
	std err	*t-stat*	*df*	*p-value*	*t-crit*	*lower*	*upper*	*sig*	*effect r*
One Tail	9169.361066	0.111426165	239	0.455685966	1.651254			no	0.007207
Two Tail	9169.361066	0.111426165	239	0.911371932	1.969939	-19084.8	17041.38	no	0.007207
T TEST: Unequal Variances				Alpha	0.05				
	std err	*t-stat*	*df*	*p-value*	*t-crit*	*lower*	*upper*	*sig*	*effect r*
One Tail	9086.064861	0.112447661	238.9636515	0.455281434	1.651254			no	0.007274
Two Tail	9086.064861	0.112447661	238.9636515	0.910562869	1.969939	-18920.7	16877.29	no	0.007274

Table 6. T-test and selected statistics comparing residents and non-residents. The p-value of 0.91 indicates that there is not a significant difference between the mean royalties for resident and non-resident landowners.

earlier estimates. However, royalties fluctuate with the market and contract terms negotiated between wind firm and landowner. Alteration of any of the three key components of royalties (CF, royalty rate, and wholesale energy price) will cause the average royalty price to fluctuate. This study assumes a CF between 25% and 35%, a royalty rate of 4%, and the wholesale energy price to be between $35 and $45 per MWh, with all components reflecting current market estimates. However, if the circumstances of wind energy production shift, and market conditions were to depress or turbine efficiency was suppressed, the average royalty would shift in a similar direction.

For instance, if the CF was between 20% and 30% instead, and royalty rate and wholesale energy price were to remain the same, the average royalty for the study site would reduce to $6,196 per turbine per year, with a minimum average royalty of $3,592, and a maximum average royalty of $8,261. Instead of $11.5 million, total estimated royalties in the two-county study region would be $9.6 million. Since CF is a measure of how much electricity the wind turbine actually produces, it becomes extremely important for researchers to calculate and establish an accurate CF in situations where the economic benefits of wind energy are estimated. One landowner with 104 turbines who would usually receive $591,474 in royalties would receive $494,962 under this new regime, a 16% reduction overall. In another instance, if the CF and royalty rate were to remain constant and the wholesale price of energy was suppressed to between $30 and$40 per MWh, the average royalty for the study site would decrease to $6,498 per turbine per year, with a minimum average royalty of $3,767 and a maximum average royalty of $8,664. The total estimated royalty for the study area would be $10.1 million.



Residents				Non-residents				Totals			
Type	**Landowners**	**Turbines**	**Royalties**	**Type**	**Landowners**	**Turbines**	**Royalties**	**Landowner**	**Turbines**	**Royalty**	
Trust	9	83	567,466	Trust	14	82	588,511	23	165	1,155,977	10%
Inc	1	14	90,146	Inc	4	64	427,119	5	78	517,265	4%
LTD	5	113	695,402	LTD	7	68	533,992	12	181	1,229,394	11%
LP	1	19	187,587	LP	2	33	212,487	3	52	400,074	3%
LLC	3	8	67,822	LLC	4	57	463,175	7	65	530,997	5%
Partnership	2	33	224,503	Partnership	1	5	32,195	3	38	256,698	2%
Et al	7	24	167,839	Et al	11	63	419,381	18	87	587,220	5%
Estate	3	9	42,922	Estate	1	1	9,873	4	10	52,795	0.5%
Co	0	0	-	Co	2	60	413,812	2	60	413,812	4%
Family	1	2	12,878	Family	0	0	-	1	2	12,878	0.1%
Total	32	305	2,056,565		46	433	3,100,545	78	738	5,157,110	45%
Percent of total	13%	18%	18%		19%	25%	27%	32%	43%	45%	**Of total**

Table 7. Land tenure breakdown of residents and non –resident turbines and royalties with percentages.

The same landowner with 104 turbines would then receive $519,090, a 12% reduction overall. Lastly, if the royalty rate was reduced from 4% to 3.9%, and CF and wholesale price of energy were constant, the average royalty for the study site would fall to $7,219 per turbine per year, a 2% reduction. Clearly, CF fluctuation has the highest potential to considerably alter estimates of royalty disbursements. On the other hand, CF will probably not fluctuate in a way that could affect long-term estimates. If early estimates of CF were to be followed (anywhere from 19% to 60%) and other components remained constant, the average royalty for the study site would be $10,170. While this figure falls in line with the upper limit of royalty estimates, a CF of 60% is highly unlikely. Moreover, a larger range for CF will result in royalty values greatly skewed toward the high end of estimates.

Contracts negotiated between landowners and wind firms are generally long-term, lasting twenty years or more, which is striking when considering long-term financial benefits under the current market conditions (*i.e.* disregarding inflation). If all landowners in the study area negotiated a twenty-year contract, the total estimated royalty for the study area would be $230,775,380 during the lifetime of the contract. This means that the average landowner (turbines=7, royalty=$47,879) could potentially receive $957,580 over the period of twenty years under current market conditions. Of course, market conditions will fluctuate throughout the period of the contract, and while the royalty rate will likely remain unchanged, inflation may cause the wholesale electricity price to fluctuate, and weather conditions and maintenance may alter the efficiency of the turbines from month to month and year to year.

CHAPTER V

DISCUSSION

This chapter discusses the implications of the findings in the previous chapter and suggestions for future studies on this topic.

The main objectives of this research were to: determine the spatial distribution of turbines and royalties, explore the effects of alteration of the contract terms upon royalty disbursements, and investigate the socioeconomic impacts of wind energy in the study area. Upon inspection of Figure 1 it is immediately apparent that there is a considerable disparity between the landowners with turbines and those without in Nolan and Taylor Counties; only 241 landowners have turbines on their property, leaving 8,128 non-urban landowners without. There may be numerous reasons for this disparity, and among them could be: the parcel may be too close to an urban center, the parcel may not be large enough to support a turbine or network of turbines, the wind resource is perhaps insufficient for siting a turbine, there may already be enough turbines in the area, the landowner declined having a turbine on property, or siting more turbines in the area might not be cost efficient (*i.e.* there is already an abundance of energy output, transmission lines may be too costly, or turbines may be too expensive). Wind turbines seem to be emphatically welcomed in this particular area (New Amsterdam 2008; Brannstrom *et al.* 2011, Jepson *et al.* 2012, Slattery *et al.* 2012), so the matter of fervent local protest as a possible reason for the absence of turbines on some properties is largely dismissed from consideration. More information is needed to draw conclusions about why turbines are on some parcels and not on others. Despite the difficulty in determining the reasoning behind the current configuration of turbines, the fact remains that only about 3% of non-urban landowners are receiving millions of dollars in royalties per year. With no cohesive spatial pattern for siting, since Texas has no regulations governing wind siting (Bohn and Lant 2009), landowners with turbines almost appear to have been chosen at random. Turbines are grouped into farms on the land and connected to the electricity grid, so they exhibit some spatial pattern and grouping, but testing has not been performed to determine whether turbine siting is truly randomized. This theme has not yet been studied in wind energy literature.

Additionally, the spatial distribution of royalties amongst the 3% of rural landowners is heavily skewed toward the top quintile (see Figure 12 and Table 3); 60% of royalties are distributed to 20% of rural landowners. This means that 0.7% of rural landowners in Nolan and Taylor Counties are receiving 60% of royalties, and just over 1% of rural landowners are receiving nearly 80% of all royalties from wind energy. In quantifiable terms, this equates to 0.7% receiving \$7,017,091 annually, and 1.1% receiving \$9,146,169 annually. For the bottom quintile, 0.6% of all rural landowners receive 3.2% of royalties, or \$375,148 annually. This skewed distribution of royalties is highly correlated to parcel size ($r^2=0.81$); generally, the larger the parcel (or group of parcels), the more turbines, and therefore more royalties. The imbalance in the distribution of royalties may lead to negative opinions amongst residents or landowners who receive no direct financial benefits from the presence of wind energy. Ironically, as several scholars have pointed out, support for wind turbines is very often linked to monetary benefits (Pasqualetti 2001; Sowers 2006; Jepson *et al.* 2012; Slattery *et al.* 2012; Mulvaney *et al.* 2013; Groth and Vogt 2014).

Evaluation of all rural CAD landowner records for the study area also fails to provide a definitive answer about the attractiveness of siting on farmland or ranchland. There are forty-one parcels identified as farms or ranches in the tax records in Nolan and Taylor Counties, thirteen of which have turbines. However, there are numerous other parcels in Nolan and Taylor Counties that are used for farming or ranching but are not indicated as such on tax records. Moreover, distinguishing between landowners who claim their land as a working farm or ranch on tax records and landowners who have land used for farming or ranching but is not delineated as such on tax records would be extremely difficult. Most of the rural land in the study area is used for farming and/or ranching, so there may be no correlation between land use and turbine siting. Generally, the land in northwest Nolan County near Roscoe is used as farmland, and the land in the southeast is mainly used as ranchland. The parcels in the northeast are smaller, only having room for one or two turbines per parcel and therefore landowners receive small royalty payments, whereas parcels in the southwest are larger and have room for several more turbines per parcel and therefore landowners receive larger royalty payments. However, without definitive information about the land use of each parcel, it would be impossible to draw a reasonable conclusion about the distribution of royalties to farmers and/or ranchers, or whether any preference is given to one or the other in turbine siting. It has been stated that land uses such as farming or ranching are ideal for wind turbines because they utilize minimal space on the land, close the gap with otherwise volatile rent payments, and increase crop yield (Pasqualetti 2001; Sowers 2006; New Amsterdam 2008; Abbott 2010). However, there have been no quantitative studies to date that have investigated whether ranchland or farmland is preferential in siting decisions. Worth noting, on the other hand, in Brannstrom *et al.* (2011) and Jepson *et al.* (2012), is the statement by a respondent that "the difference between ranchers and farmers with wind turbines on their property is about two or three decimal places. Some ranchers have turbines producing over 100 megawatts on their property, whereas most farmers have turbines producing three megawatts." This theme could benefit from further inquiry in future studies.

Another concern in this study is that there is a "leakage" of royalties out of the two-county area for non-resident landowners, which has not previously been studied. Although just over half (54%) of landowners with turbines are residents of Nolan or Taylor County, only 53% of royalties are distributed to landowners with local addresses. The non-resident landowners are broken down into two groups: those landowners who reside in Texas and those who reside outside of Texas. The non-resident landowners residing outside of Texas collect 7% of total royalties and 15% of non-resident royalties, whereas non-residents residing in Texas collect 40% of total royalties and 85% of non-resident royalties. It is important to note that though some non-resident landowners still live inside Nolan or Taylor Counties, they are labeled as non-residents because they live outside the driving distance or time range established in the previous chapters. The thresholds set for this study do not provide a conclusive answer about whether landowners are residents or not, but they do provide a reasonable estimate about landowner location based on tax addresses. If royalties for residents of Nolan and Taylor Counties are added to royalties for non-residents with tax addresses in Nolan and Taylor, \$7,086,950 or ~61% of total royalties is shown to stay in the two-county area. Clearly, while the "leakage" of royalties out of the study area seems drastic, the community is still able to reap most benefits from the establishment of wind farms nearby.

Alteration of the terms of the contract between landowners and wind firms is one of the keystones of this research since the royalty estimation formula utilized here is an approximation of actual royalties distributed. Other researchers have estimated royalties to be anywhere between \$2,000 and \$10,000 per turbine per year (Pasqualetti 2004; Sowers 2006; Pasqualetti 2011, Blair 2012; Ellis 2012) because variables like CF or wholesale energy price were approximated too high or low, or inflation was not accounted for. Owing to the confidential nature of the contracts, the royalty calculations can only be estimated. New Amsterdam (2008) provides reasonable estimates for CF, revenue, and royalty rate, which have been adjusted for inflation in this research. When these three variables fluctuate independently, they have various effects on the overall average estimated royalty: altering CF has the most impact on the overall average, followed by revenue, then royalty rate when CF is varied by 5%, revenue is varied by \$5/MWh, and royalty rate is varied by 0.1%. This indicates that annual total mean estimated royalties for Nolan and Taylor Counties fluctuate by 16% using current estimates, and by extension, long-term estimates will vary proportionately. Moreover, long-term ramifications of royalty disbursements have essentially been ignored in the literature. Many landowners signed 20-year contracts, and as a result, the average landowner receiving $47,879 annually in royalties would receive $957,580 during the lifetime of the contract without adjustments for inflation. Some landowners may have negotiated for a higher rate than others when contracts were signed, consequently, some landowners may receive more royalties than others despite having signed a contract at the same time for turbines from the same wind farm.

Social perspectives and social acceptance are pivotal parts of wind energy research. Most studies conducted about wind power in the last three decades have focused on its social facets, up to and including how benefits have affected acceptance levels, yet, few studies have been conducted discussing the link between social acceptance and royalties. Several authors mention in passing that “benefits” (Pasqualetti 2001; Cowell *et al.* 2011; Slattery *et al.* 2012; Groth and Vogt 2014), “financial compensation” (Mulvaney *et al.* 2013), or “incentives” (Sovacool and Ratan 2012) are associated with acceptance, but most importantly, Jepson *et al.* (2012) indicate that there is a connection between support for wind energy and “economic benefits” in this study area. Numerous researchers have examined how public opinion could be influenced by disbursement of benefits, but research is scarce on how disbursement of benefits influences public opinion. Despite some protest, acceptance levels for wind power are generally high, but why do so many landowners support wind power if so few are receiving direct financial benefits? Many studies ignore how royalties matter when discussing social acceptance or opinions regarding wind power, disregarding the reasoning behind high levels of acceptance. It is possible that respondents classified as “wind welcomers” in both Brannstrom *et al.* (2011) and Jepson *et al.* (2012) most likely “love the wind” because they receive royalties or know someone who does. One’s viewpoint of wind power (or any renewable energy source) likely depends on economic factors, therefore more research should be conducted to investigate the idea of royalties as the impetus for social acceptance.

This research has its limitations in that it does not seek to determine how royalties are spent, but merely the approximate volume and destination of royalties. Future studies may advance this topic by determining how landowners use their royalties and whether royalties influence landowner decision-making or spending. For instance, are landowners using royalties for farm operations, investing in other businesses, reserves in the form of a trust fund, or paying down debt? Do royalties influence debt reduction, land-use decision-making, or urban businesses? Are community businesses prospering because more revenue is available in the local economy? Are landowners without turbines also reaping benefits?

CHAPTER VI

CONCLUSION

This chapter discusses the implications of the findings in the previous chapters, considers broader issues, and provides suggestions for future studies on this topic.

Wind energy royalties are distributed to a small percentage of the population in Nolan and Taylor Counties, and a small fraction of that population receives the majority of royalties. Two-fifths of the landowners with turbines do not reside in the county where turbines are sited, and nearly half of royalties are distributed to non-residents, but there is no statistical difference between mean resident and non-resident royalties. Furthermore, there is no discernible pattern in which turbines are arranged on the landscape other than avoidance of urban areas and major transportation routes. Ranchers appear to be favored over farmers for royalties, however, ranchland is usually larger than farmland and can support more turbines, though more data is required to determine conclusively whether one sub-region is preferred over another. The variable established as the principal determinant of mean estimated royalties in this study was capacity factor, followed by revenue, and then royalty rate. Nevertheless, not all contracts are created equally, and some landowners may receive more royalties than others since individual landowners negotiate contract terms with wind firms. For this reason, royalty estimates in this study are necessarily approximations. Above all, this research has highlighted the disparity between rural landowners with turbines and those without in addition to the disparity between the wealthiest two-fifths of rural landowners with turbines and all other rural landowners.

The existing literature regarding royalties for wind energy does not take into account that royalties may be one of the main reasons for social acceptance. Alternatively, most literature has deliberated over factors that may increase social acceptance, including cooperative decision-making, incentive programs, or financial benefits, mostly in reference to the approach to cessation of protests for the early stages of wind development. Further investigation of the socioeconomic dynamics of the area should be completed to discover the motivation behind landowner acceptance of and support for wind energy despite few landowners actually receiving royalties. Fairness in benefit distribution is appears not to be a concern amongst the majority of residents in Nolan and Taylor Counties. Why do residents without turbines (more than 90%) still welcome the wind? Royalties may have more far-reaching benefits than the obvious, immediate benefits received by landowners with turbines. Are residents without turbines reaping benefits other than royalties? Many scholars have already studied the employment impacts, tax impacts, and real estate impacts of wind energy and determined that the effects are widespread. There may be some factor not yet studied that also benefits all landowners. What other factors can help explain why wind power is so popular in this region? Extended, comprehensive studies could provide the answers to these questions through the use of personal interviews and extensive investigation of tax records along with the examination of other sources of wealth in the area (*e.g.* oil or natural gas).

The findings herein add some transparency to the existing literature on royalties and contract terms, identifying variables, clarifying estimates, and facilitating the understanding of individual benefits. The new element introduced is the spatial element of royalty distributions, which has not previously been examined in the literature. More can be expounded on and understood from this new facet of wind energy research which is in its infancy.

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APPENDIX A

	Units	Power Capacity		Capacity Factor		MWh/yr [8760 hrs/yr]		Total Revenue [$35/MWh]		Total Revenue [$45/MWh]	
	#	MW	MW/unit	25%	35%	CF = 25	CF = 35	CF = 25	CF = 35	CF = 25	CF = 35
Buffalo Gap	67	120.6	1.80	30.15	42.21	264,114	369,760	9,243,990	12,941,586	11,885,130	16,639,182
Buffalo Gap 3	74	170.2	2.30	42.55	59.57	372,738	521,833	13,045,830	18,264,162	16,773,210	23,482,494
Buffalo Gap II	155	232.5	1.50	58.125	81.375	509,175	712,845	17,821,125	24,949,575	22,912,875	32,078,025
Callahan Divide Wind Energy Center	76	114.0	1.50	28.5	39.9	249,660	349,524	8,738,100	12,233,340	11,234,700	15,728,580
Champion (Roscoe II)	54	124.2	2.30	31.05	43.47	271,998	380,797	9,519,930	13,327,902	12,239,910	17,135,874
Horse Hollow II	129	296.7	2.30	74.175	103.845	649,773	909,682	22,742,055	31,838,877	29,239,785	40,935,699
Horse Hollow Wind Energy Center	292	438.0	1.50	109.5	153.3	959,220	1,342,908	33,572,700	47,001,780	43,164,900	60,430,860
Inadale (Roscoe IV)	148	148.0	1.00	37	51.8	324,120	453,768	11,344,200	15,881,880	14,585,400	20,419,560
Roscoe	100	100.0	1.00	25	35	219,000	306,600	7,665,000	10,731,000	9,855,000	13,797,000
South Trent Mesa	43	98.9	2.30	24.725	34.615	216,591	303,227	7,580,685	10,612,959	9,746,595	13,645,233
Sweetwater	176	264.0	1.50	66	92.4	578,160	809,424	20,235,600	28,329,840	26,017,200	36,424,080
Sweetwater #4a	136	136.0	1.00	34	47.6	297,840	416,976	10,424,400	14,594,160	13,402,800	18,763,920
Sweetwater #4b	46	105.8	2.30	26.45	37.03	231,702	324,383	8,109,570	11,353,398	10,426,590	14,597,226
Sweetwater 5	35	80.5	2.30	20.125	28.175	176,295	246,813	6,170,325	8,638,455	7,933,275	11,106,585
Trent Mesa Wind Farm	101	151.5	1.50	37.875	53.025	331,785	464,499	11,612,475	16,257,465	14,930,325	20,902,455
Turkey Track	113	169.5	1.50	42.375	59.325	371,205	519,687	12,992,175	18,189,045	16,704,225	23,385,915
	1,745	2750.4		687.6	962.64	6,023,376	9,695,612	210,818,160	295,145,424	271,051,920	379,472,688

Appendix figure A.1. First half of royalty calculation chart for turbines in Nolan and Taylor Counties.

Low: Total Revenue [$35/MWh]				High: Total Revenue [$45/MWh]							
Gross Royalty [4%]		Royalty/unit		Gross Royalty [4%]		Royalty/unit					
CF = 25	CF = 35	CF = 25	CF = 35	CF = 25	CF = 35	CF = 25	CF = 35	Low	High	Avg	
369,760	517,663	5,519	7,726	475,405	665,567	7,096	9,934	5,519	9,934	7,726	Buffalo Gap
521,833	730,566	7,052	9,873	670,928	939,300	9,067	12,693	7,052	12,693	9,873	Buffalo Gap 3
712,845	997,983	4,599	6,439	916,515	1,283,121	5,913	8,278	4,599	8,278	6,439	Buffalo Gap II
349,524	489,334	4,599	6,439	449,388	629,143	5,913	8,278	4,599	8,278	6,439	Callahan Divide Wind Energy Center
380,797	533,116	7,052	9,873	489,596	685,435	9,067	12,693	7,052	12,693	9,873	Champion (Roscoe II)
909,682	1,273,555	7,052	9,873	1,169,591	1,637,428	9,067	12,693	7,052	12,693	9,873	Horse Hollow II
1,342,908	1,880,071	4,599	6,439	1,726,596	2,417,234	5,913	8,278	4,599	8,278	6,439	Horse Hollow Wind Energy Center
453,768	635,275	3,066	4,292	583,416	816,782	3,942	5,519	3,066	5,519	4,292	Inadale (Roscoe IV)
306,600	429,240	3,066	4,292	394,200	551,880	3,942	5,519	3,066	5,519	4,292	Roscoe
303,227	424,518	7,052	9,873	389,864	545,809	9,067	12,693	7,052	12,693	9,873	South Trent Mesa
809,424	1,133,194	4,599	6,439	1,040,688	1,456,963	5,913	8,278	4,599	8,278	6,439	Sweetwater
416,976	583,766	3,066	4,292	536,112	750,557	3,942	5,519	3,066	5,519	4,292	Sweetwater #4a
324,383	454,136	7,052	9,873	417,064	583,889	9,067	12,693	7,052	12,693	9,873	Sweetwater #4b
246,813	345,538	7,052	9,873	317,331	444,263	9,067	12,693	7,052	12,693	9,873	Sweetwater 5
464,499	650,299	4,599	6,439	597,213	836,098	5,913	8,278	4,599	8,278	6,439	Trent Mesa Wind Farm
519,687	727,562	4,599	6,439	668,169	935,437	5,913	8,278	4,599	8,278	6,439	Turkey Track
8,432,726	11,805,817	5,289	7,404	10,842,077	15,178,908	6,800	9,520	3,066	12,693	Avg	
		1,557	2,180			2,002	2,803	1,557	2,803	Stdev	
										7,404	

Appendix figure A.2. Second half of royalty calculation chart for turbines in Nolan and Taylor Counties.