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Forest Feedstock Supply Chains and Market Potential for Wood Pellet Facilities in the Ozark and Appalachia Regions

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FOREST FEEDSTOCK SUPPLY CHAINS AND MARKET POTENTIAL FOR WOOD PELLET FACILITIES IN THE OZARK AND APPALACHIA REGIONS OF THE UNITED STATES

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In Partial Fulfillment

Of the Requirements for the Degree

Master of Science, Agriculture

By

James R. Criger

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ABSTRACT

The pellet wood industry in the United States has grown exponentially in recent years, due mostly to the expanding export market to Europe. At this time, the European market for pellet wood is highly subsidized as part of the Renewable Energy Directive (RED) in an effort to mitigate fossil fuel consumption for power production. Although there are other popular renewable resources such as wind, water, and solar, the burning of biomass is among the most utilized sources of renewable energy today. This study examines the existing pellet wood industry in the United States, particularly within the Ozarks and Appalachia Regions, so as to identify locational characteristics of existing pellet wood facilities. Taking this study a step further, this data was then used to identify localities within the study area that could reasonably be predicted to facilitate an expansion of the pellet wood industry in the future. This industry expansion would have the potential to create many regional jobs within the industry, and bring outside money to struggling rural economies.

KEYWORDS: pellet wood, biomass, bioenergy, Appalachia, Ozarks

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They say it takes a village to raise a child, and though I'm an older student, it has certainly taken a village to get this student through college!

I dedicate this thesis to my entire family, whose support has been integral to my success.

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INTRODUCTION

The pellet wood industry in the United States has grown exponentially in recent years, due mostly to the expanding export market to Europe. At this time the European export market of pellet wood is highly subsidized by the 28 countries of the European Union (EU28) as part of their Renewable Energy Directive (RED) in an effort to mitigate fossil fuel consumption for power production (Bowd, 2018). Although wind and solar are popular and clean renewable sources of energy, their production output is environmentally sensitive and highly variable. For this reason, wind and solar will likely always need to be augmented by more consistent and predictable forms of renewable energy such as hydro and the burning of biomass/biofuels ("Biomass Compared to Fossil Fuels, Solar, and Wind," 2019).

This study examines the existing pellet wood industry in the United States, particularly within the Appalachia and Ozarks Regions. These regions were chosen for the similarities in forest type, average rainfall, growth rates, etc. Additionally, biomass supply is high in these regions given the ubiquitous mixed hardwood forest dominance. Using classical location theory, we were able to identify locational characteristics of existing pellet wood facilities.

The study areas consisted of county-level observational units, grouped by sub-region. These observational units were identified by their unique FIPS code for purposes of data collection and analysis. Variables examined include relative distance to standing biomass sources, as well as mill residues. Biomass supply availability was further examined by national, state, and private ownership classes. Additionally, relative distance to logistic variables such as rail and major waterways were also taken into consideration. Lastly, socio-economic factors such as population density and mean housing price (as a proxy for economic conditions) were considered based on previous research (Aguilar, Goerndt, Song and Shifley, 2012).

A Logit model was used to examine the commonality of observational units that had been identified as having an indicated presence of pellet facilities. This model forecasted a predictive value of the probability for each observational unit.

Given the premium currently being paid for wood pellets by virtue of the highly subsidized European markets, this study attempts to satisfy the anticipated need for information regarding potential expansion sites for the wood pellet industry in the United States. An excellent visualization of an overview of the pellet industry and its associated considerations in North America can be seen in Figure 1. The expansion of the pellet wood industry could have the potential to create many regional jobs, and bring outside money to struggling rural economies.

LITERATURE REVIEW

Wood Pellets / Biofuels

Wood pellets are the most commonly used biofuels made from compressed biomass. Fuel pellets can be made from various waste products, but wood pellets are typically made from mill residues or timber by compressing sawdust into pellet form. Additionally, wood pellets are made from the wastes of other industries such as pallet making, furniture making, and construction. Pellets are a well-known product, very popular and easily traded (Spinelli, Pari and Magagnotti, 2018). The two types of pellets most commonly traded are for residential heating, and for large-scale district heating or power producing co-firing installations (Goh et al., 2012).

The subject of whether or not the burning of biofuels is in fact clean energy, carbon neutral, etc., continues to be debated amongst leading scientists. Porso, Hammar, Nilsson and Hansson (2018) indicated that choice and origin of raw material and efficient use of the biomass are important factors when assessing the climate impact of wood pellet systems, and that precious land use and its initial carbon stock are crucial factors, as they determine whether the system is going to be a net carbon sink or emitter. The general view has been that carbon emitted into the atmosphere from biological materials is carbon neutral—part of a closed loop whereby plant regrowth simply recaptures the carbon emissions associated with the energy produced (Sedjo, 2013).

According to Holubcik, Jandacka and Durcansky (2016), utilization of biomass for energy purposes is becoming more current and supported by almost the entire world. The development of the wood pellet industry is largely influenced by market characteristics and public policies (Goh et al., 2012). On April 23, 2018, Environmental Protection Agency (EPA) issued a policy statement making clear that in future regulatory actions, biogenic CO_2 emissions from the use of biomass from managed forests will be treated as carbon neutral when used for energy production at stationary sources, provided the use of forest biomass does not cause conversion of forests to non-forest use (Wheeler, Perdue and Perry, 2018). In the European Union (EU), biomass fuels have been declared carbon neutral, and are thus considered to count toward fulfilling the commitments of the Paris Agreement (Schlesinger, 2018).

Industry Demand

Wood pellets are the fuel with the fastest growing market in the last ten years. Such market growth mostly results from the price increase of fossil fuels (especially light oil and heating oil), and from policy measures in the field of climate change mitigation and environmental protection (Glavonjic, Krajnc and Hubert, 2015). The transatlantic trade of wood pellet trade is an example of a mutually beneficial system that has the potential to provide environmental, as well as socioeconomic benefits in both the United States and Europe (Parish, Herzberger, Phifer and Dale, 2018). In the northern hemisphere, legislation that promotes substitution of fossil fuels with renewables includes the EU Renewable Energy Directive (RED), the US Energy Policy Act of 2005 and US Energy Independent and Security Act of 2007 (Bowd et al., 2018).

Many countries are reliant upon the importation of wood pellets due to the limited availability of domestic feedstocks. On a more detailed level, an increased demand for wood pellets within the EU is foreseen to, apart from increased EU production, result in substantially increased imports from outside the region. The main sources of wood pellet supply are projected to be Russia, Canada, and in particular, the United States (Jonsson and Rinaldi, 2017). Several

EU countries currently import wood pellets from the United States. Currently, approximately 98% of United States wood pellet exports are shipped across the Atlantic to Europe (Dale et al., 2017). The imported wood pellets are co-fired in power plants with the aim of reducing overall greenhouse emissions from electricity production and meeting EU renewable energy targets (Hanssen, Duden, Junginger, Dale and Van Der Hilst, 2017).

The international trade of wood pellets is triggered by demand-side policies (Jonker, Junginger and Faaij, 2014). In 2010, more than 80% of pellets produced in the United States were used domestically. Today, North America is predominately an exporter, but there is also a strong domestic market in the United States (Goh et al., 2012). Production of pellets has garnered much attention as U.S. exports have grown from negligible amounts in the early 2000s to 4.6 million metric tonnes (MMT) in 2015 (Dale et al., 2017). In recent years, approximately 7 million metric tons of wood pellets per year have been shipped from the United States to the EU (Schlesinger 2018).

European demand for renewable energy resources has led to rapidly increasing transatlantic exports of wood pellets from the southeastern United States since 2009 (Parish et al., 2018). The European Union is the main user of wood pellets, responsible for approximately 80% of global pellet consumption in 2015 (Duden et al., 2017). This is due largely to the EU Renewable Energy Directive (RED), an agreement in which the 28 member states have agreed to an increased use of renewable energy production from the 2011 target of 10%, to 20% by the year 2020 (Bowd et al., 2018).

A global perspective of the pellet wood industry has also revealed other studies of interest. Krievina and Melece (2016) stated that although wood pellets might not be the immediate substitute for fossil fuels in Latvia, in the light of the increased movement towards low-carbon economy, wood pellets allow replacing a great deal of currently used natural gas in the transformation sector. Latvia is the single largest producer of wood pellets in the EU, leaving behind such important suppliers as Germany and Austria, allowing it to be the leading exporting country in the EU. Considerably more developed production of wood pellets against the level of the consumption is also to be observed in Portugal and Croatia. In Portugal, all major national companies focus on exporting pellets because the domestic market cannot absorb the entire production. The main countries to which Portugal exports its output are the countries of northern Europe, with main emphasis on England, Denmark and Sweden. The needs of the internal market are exclusively ensured by domestic production, so that imports are almost non-existent (Nunes, Matias and Catalao, 2016).

Finland has the greatest forest cover of western European countries and thus considerable raw material potential for wood pellet market development (Poskurina et al., 2016).
Although the scale of the Finnish forest industry means good availability of raw material for wood pellet production, wood pellets play a relatively minor role in Finnish bioenergy. However, reaching the 100% renewals by 2050 requires the development of all possible options for biofuels, including wood pellets (Proskurina, Alakangas, Heinimo, Mikkila and Vakkilainen, 2017). Karner, DiBauer, Enigl, Strasser and Schmid (2017) thoroughly examined the pellet industry in Austria, and likewise found that demand for wood pellets increased in all scenarios. In China, even though the substitutability of wood pellets over coal is questionable because of the existing small production capacities and limited feedstock resources of pellet production, the Chinese government has been making great efforts to lessen coal reliance so as to improve air quality and reduce greenhouse gas emissions (Wang, Chang, Zhang, Pang and Hao, 2017).

However, according to Goh (2012) East Asia is predicted to become the second largest consumer after the EU in the near future. If Goh is correct in this prediction, future study may be directed toward Alaska as a future source of biomass and wood pellet production for export to East Asian markets.

Theoretical Framework

This study of location and predicted location of pellet wood facilities is largely based on industrial Classical Location Theory. Access to markets and raw materials is discussed in industrial location studies as important locational factors (Anderson and Johnston, 1992). Weber (1929) identified the four factors most responsible for driving industrial location as: fixed capital costs, costs of materials/fuel/power, labor costs, and transportation costs. In a case study by Singh, Cubbage, Gonzalez and Abt (2016), feedstock delivery price is identified as the most important cost component in producing wood pellets. This was followed by labor, energy, consumables, depreciation, and taxes, respectively. Singh's results suggest that the US, Canada, and Chile may be best suited to receive investments in wood pellet mills given their abundant wood resources and attractive investment climates.

Methods

USDA Forest Service Forest Inventory Assessment (FIA) data has been used extensively for a wide range of similar studies. For regional-level analysis of forest biomass and other attributes, the most authoritative and readily available forest inventory data comes from the U.S. Department of Agriculture Forest Service's Forest Inventory and Analysis (FIA) program (Goerndt, Wilson and Aguilar, 2019). Buchholz, Gunn and Saah (2017) used FIA forest inventories and harvests data, as well as data from regional pellet industries similarly in his study of greenhouse gas emissions of local wood pellet heat from northeastern US forests.

For this study, the study area of the Ozarks region was defined by Keys et al. (1995), and the Appalachia region defined by the Appalachian Regional Committee. A study by Aguilar et al., (2012) determined that county-level was the smallest practical observational unit in which many of the specific factors such as land value, transportation, and resource availability of biomass could be estimated. Additionally, Aguilar et al. (2012) noted that information is often aggregated at this level to keep some level of anonymity in the data, in particular to agricultural and timber production.

The types of woody biomass available, potential suppliers (e.g., manufacturers, private forest owners, public forests, etc.) and locations are all important considerations (Boukherroub, LeBel and Lemieux, 2017). Cost estimation determinants range from raw material procurement cost, raw material transportation cost, investments, production and storage cost, to wood pellet delivery cost (Boukherroub et al., 2017).

Hypothesis

Henderson, Joshi, Parajuli and Hubbard (2017) showed that the wood pellet industry can bring a wide range of benefits to local economies. Bioenergy markets can assist landowners and society to achieve desired economic, social, and environmental outcomes by supplementing incomes to private landholders and thereby enabling management required to improve forest conditions and protect ecosystem services (Dale et al., 2017).

Given the vast woodstock resources of the Ozarks, and the increasing demand for pellet wood, it is hypothesized that there are units (counties) within the study areas that are capable of successfully supporting new pellet wood facilities. This study attempts to identify these localities. Although much work has been done to examine the pellet wood industry globally (Singh et al. 2016), we were unable to find any work that examined specific regions within the United States as prospective loci for pellet wood facilities.

METHODS

Study Area

This study focused on the U.S. Appalachia Region as defined by the Appalachian Regional Commission, and the U.S. Ozarks Region of Missouri and Arkansas as defined by Keys et al. (1995), henceforth referred to as the Ozarks Region. These two regions were selected for their similarities ecologically, as both regions are dominated by oak/hickory forest type and experience similar weather and rainfall patterns. Additionally, these regions share many similarities economically and culturally as well. The Appalachia Region is comprised of 422 counties within the states of Alabama, Georgia, Kentucky, Maryland, Mississippi, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, and West Virginia. The Appalachia Region was further divided into five sub-regions for this study. Figure 2 provides an outline of study area, delineated by individual states, and showing hardwood and mixed-forest coverage.

The Ozarks Region as defined by this study is comprised of 88 counties within the states of Arkansas and Missouri and was not further subdivided. It should be mentioned that there are 7 counties within the state of Oklahoma that are generally included within the defined area of the Ozarks region that were omitted from this study due to lack of sufficient forest inventory data. Each county within the study area was considered an observational unit as was done by Aguilar et al., (2012), as the county-level is the smallest practical observational unit in which many of the specific factors could be estimated and identified. Due to confidentiality concerns, specific USDA Forest Service Inventory and Analysis (FIA) plot location information is not available to the general public. This, in combination with the issue of high sampling variance for sub-county areas, makes county-level boundaries the best choice for defining observational units. For purposes of data collection and processing, each of these observational units was identified by its unique Federal Information Processing Standards (FIPS) code which uniquely identifies counties within the United States.

Presence of Pellet Facilities

The first and most important data collected for this study was the identified presence of pellet facilities. This data came from Biomass Magazine's website (August, 2018) and as can be seen in Figure 3, provided locational data for operational facilities, facilities under construction, and proposed facilities. Additional data for these facilities, such as size of facility and primary feedstock, came from this source, but ultimately was not used in this study.

Potential Feedstock Data

Biomass data pertaining to mill residues was collected from the U.S. Forest Service's Timber Products Output (TPO) database for each observational unit. Volume of all residues data from the most current reporting year was utilized. Fuel by-products and unused by-products were looked at individually, as well as the total of all by-products.

Standing biomass data collected from the U.S. Forest Service's Evalidator database was also used. Above ground biomass of live trees (at least 1-inch dbh) within timberland sorted by ownership class was examined for federal, state, and private ownership, and total of other ownership classes, as well as the total of all ownership classes combined.

Other Data / Factors

Logistical and infrastructure data collected included the presence of commercially important waterways, railways, and interstate highways located within each observational unit. This data was collected by extrapolation from ArcGIS maps. Waterways were only selected if commercially important. Also of note, all major waterways used in this study feed either directly to the east coast, or to the Mississippi River which flows into the Gulf of Mexico. In either case, shipping hubs to Europe are present.

Other data collected and used within this study includes population density per square mile of land area, and mean housing price. Population density was assumed to be of importance as too great a density would inevitably be the antithesis of uninterrupted tracts of forest land, and too low a density could potentially lead to problems in keeping pellet facilities staffed. Mean housing price was used as a proxy indicator of the variability of economic conditions amongst sub-regions.

Econometric Analysis

After determining what data would be used in our statistical model, pellet facility locations, as well as logistical and infrastructure data were then converted to a binary form so as to simply express the presence or absence of the variable within each given observational unit.

Specific variables to be used were identified through literature, as well as personal observation. Econometric models for count data were then developed in order to quantify the effect of selected variables so as to then be correlated with the known occurrence of wood pellet facilities at the county level. A summary of these variables can be seen in Table 1.

Logistic Regression Models. Occurrence of wood pellet production is contingent first on the physical presence of a wood pellet facility (and intrinsic factors), and second on external and location factors encouraging or limiting pellet facility occurrence or pellet manufacture such as supply infrastructure or the physical availability of biomass materials. Therefore, the probability of wood pellet production (*y)* at the *i*th location is conditional on the expected probability of a wood pellet facility sited within the *i*th location (E[c_i]) given a vector of variables affecting wood pellet production (*c*) and ancillary factors influencing wood pellet production captured in information matrix *X*. Hence, the probability of placement of a wood pellet facility for county *i* can be expressed as follows:

$$(1)\ \text{Prob}(y_i=1|X, L) = (e^{X\beta + \gamma E[ci|L]})\ (1 + e^{X\beta + \gamma E[ci\ |L]})^{-1},$$

where γ is a parameter for the expected probability of the presence of a wood pellet facility at the *i*th location.

Zero Inflated Poisson (ZIP) models. Zero Inflated Poisson (ZIP) models were considered as an alternative to using a binary indicator of presence/absence of wood pellet facilities due to the high number of observational units with a value of zero (absence of facilities). Aguilar and Garrett (2009) used similar methods to assess location and clustering of industries using count econometric models. The issue of under-dispersion (overabundance of "zero" observations) in the response is prevalent in this data, given the inherit rarity of wood pellet facilities throughout the region; therefore, it was deemed appropriate that an alternative count data econometric model be assessed to determine its effectiveness in alleviating the aforementioned under dispersion issue. The ZIP model was selected because of the discrete nature of the dependent proxy (count data), and the known presence of under-dispersion (excessive zero counts) (Cheung and Rensvold, 2002; Aguilar and Garrett, 2009). In the context of this study, the standard Poisson regression model takes the following form:

$$P(y_i \mid x_i) = \exp[-\mu(x_i)]\mu(x_i)^y / y!$$

where y is the count of wood pellet production facilities per county and x_i is a vector of auxiliary variables. In the presence of an excessive number of zero counts, the Poisson model assumes that

$$P(y_i \mid x_i) = \begin{cases} \pi_i + (1-\pi_i)exp(-\pi_i) & for\ y_i = 0 \\ (1-\pi_i)\dfrac{exp[-\mu(x_i)]\mu(x_i)^y}{y_i} & for \geq 1 \end{cases}$$

where π is the probability of y_i μ but still with a value of $y = 0$ (Cheung, 2002). Essentially, π_i can be modeled as $f(z_i\lambda)$.

The most common function for this $f(.)$ is a logit function, which was used in this study and is generally referred to as the initial “logit step”. This denotes the fact that the Poisson analysis for ZIP regression is preceded by a logistic regression analysis in which π_i is modeled using a logit link function. Consequently, the initial logit step typically utilizes explanatory variables that are also used as covariates in the Poisson analysis.

Model Validation

Models were assessed and compared on the basis of relative percentage of correctly predicted observations (presence/absence). For model validation purposes, an arbitrary 0.5 value was used in our study, as was done by Aguilar et al. (2012). If the predicted value of probability for a county was ≥ 0.5 it was given a value of one and if the predicted value was < 0.5 it was given a value of zero. Accuracy was then tested by comparing these values with the indicators of known presence of existing facilities with the expectation that observational units with pellet facilities present would most likely render a high prediction of probability from our model.

Presentation of Model Results

Results extracted from the model were presented as a forecasted percentage of probability, so that the likelihood of each observational unit successfully accommodating a pellet facility was “rated” with a decimal between zero and one (percentage of probability). Results in such a form were determined to be difficult to visualize and ultimately not revealing of the relativistic nature of the results. Therefore, predictions for each observational unit were ranked against the others so as to establish relative probability.

RESULTS

Model Summary

A summary of statistics and coefficient estimates for our full logit model evaluating pellet facility presence within a county can be seen in Table 2. The regression yielded a log-likelihood ration test with p-value < 0.001 providing strong evidence for the significance of the model's explanatory power. Given the high quantity of predictions within the Northeast sub-region, we took this research a step further and with some slight adjustments re-ran our model specific to that sub-region. This was logical, given the lack of significance for the sub-regional indicator variables in the full model, combined with fairly dense presence of existing facilities in the Northeastern sub-region in particular. Model results from this closer look at the Northeast sub-region can also be seen in Table 2.

As is common with model selection methodology, our models were adjusted several times before settling on a final model. Depending on the structure of the model at the time, variables that frequently showed at least marginal significance included residues (fuel, unused, and total), and commercial waterways. One variable showed strong significance in every version of the model, and that variable was above ground biomass on privately owned forestland. Interestingly, the presence of waterways was only significant (marginally) in the reduced model that focused on the Northeast sub-region. In the absence of significant sub-regional indicators in the full model, it is likely that the significance of waterways was a sub-regional effect, as will be discussed in the next section.

Model Predictions

As with Aguilar et al. (2012), initial validation of model predictions was rudimentary and relied upon comparison of presence or absence of existing pellet facilities with the model-predicted probabilities by county. Using this strategy, the full logit model predictions were assigned a value of "1" if the predicted probability was ≥ 0.5 and "0" otherwise, as was explained in the methods. Though the estimated model strength was about 93% of correct predictions based on this strategy, such an evaluation has limited application in this study. A more important assessment is the spatial distribution of counties with "relatively" high predicted probability of pellet facility placement compared to other counties in the same sub-region and throughout the study area. Therefore, predictions made from our Logit model for this study are best interpreted using maps, so as to better visualize the areas of high potential that our model has identified as probable places for pellet industry expansion. In Figure 4 we see the results given by using the arbitrary ≥ 0.5 value of probability. As can be seen in Figure 4, these results are quite limited, both in quantity and application.

The maps in Figures 5 and 6 give us a visualization of the results when viewed relatively on a percentile basis. In Figure 5 we see only the results of the 90^{th} percentile, and an obvious area of high potential is easily identified. The map in Figure 6 displays the results of the 90^{th}, 80^{th}, and 70^{th} percentiles, each separately shaded for easier visual interpretation. Again, these results emphasize the original area of high potential seen in the northern extremity of our study area, but additionally three smaller areas of interest begin to be seen in this image. These new areas of interest that begin to be seen at the 80^{th} and 70^{th} percentiles include parts of West Virginia, Alabama, and the Ozarks.

DISCUSSION

Limitations of Research

The broad scope of this study required many assumptions to be made in regards to the analyses for woody biomass supply, as well as delivered costs/logistics. Perhaps the greatest of these assumptions is that harvest rates, annual growth, and removals will remain constant in the foreseeable future. Although an important consideration, it was beyond the scope of this study to consider potential variation of these factors in the future. A sensitivity analysis could be helpful in predicting the impact that future changes could have on the results of this study.

Another limitation, is that cost assumption were average values for the entire region, as opposed to fluid values which change geographically. Cost of feedstocks can vary by state and sub-region, and are subject to influence by market conditions, particularly supply and demand. Unfortunately, making accurate estimations of cost variation at the state or sub-region level is quite difficult as many states do not have developed markets for biomass from which to obtain reliable estimates.

Lastly, as all of the data utilized in this study was derived from empirical data, the results are intended to serve as a baseline for analysis of the potential for production of wood pellets. Further limitations include incomplete biomass data in certain regions, and the sub-regional grouping used by the USFS in an effort to protect the privacy of independent sawmills.

Econometric Model

The most significant variable was shown to be above-ground biomass on privately owned forest land (Table 2). The significance of these variable points to supply as being of utmost importance when evaluating potential pellet facility locations. This differs from a similar study of cofiring by Aguilar et al. (2012) where logistic (transportation) factors were shown to be of great importance. It's also important to note that marginal significance on residues, as seen with cofiring, highlights importance of byproducts as opposed to direct forest feedstocks.

Interestingly, when examining the econometric model showed presence of major waterways as a significant negative effect. This is likely due to the variable for major waterways serving as a proxy for subregional variation in occurance of wood pellet facilities.

Potential Placement of Pellet Facilities

Although the strength of model fit and summary statistics of individual coefficients is useful for assessing overall model performance, it is somewhat uninformative as to the ability of the model to identify counties with particularly high probability of current or future placement of wood pellet facilities. Predicted probabilities from the logit model were assessed to determine which counties in the study area have a high potential for pellet facility placement. Figure 4 highlights the counties that have a predicted probability of ≥ 0.5 for pellet facility placement, and makes evident spatial similarities between the areas of high predicted value. Notably, each of the five counties with predicted probability ≥ 0.5 currently contain at least one wood pellet facility. Additionally, the sub-region in which these counties reside contains a large number of additional counties with current existing or proposed pellet facilities. This particular result is not surprising, as these sections of New York, Pennsylvania and West Virginia are key areas of the Central Hardwoods Region for high forestland resource availability coupled with a fairly high density of wood mills and other timber processing facilities.

Recall that the logit model coefficients with the highest statistical significance pertained to biomass feedstock supply, particularly from private forestland standing biomass and wood mill by-products (in the case of the reduced model). While it is beneficial for the spatial assessment of the results to confirm our hypothesis regarding the importance of external factors of feedstock supply, these results are fairly restrictive for determining which other counties in the study area have relatively high future potential for pellet facility placement compared to others. By examining the results relatively, we were able to visualize the results in a way that has a greater potential for practical application, and provide information not known to us prior to the onset of this study. The results given in Figures 5 and 6 show the counties that we can expect to support growth of the pellet industry in the future, many of which are not known to have existing pellet facilities at this time.

An important observation to be made by this study is the importance of proximity to ample amounts of privately owned forest land. It is apparent that supply is the major factor affecting pellet facility potential, and that privately held forest lands are of great importance in this regard. This is expected as the vast majority of forest land holdings throughout the study area are under private ownership. It should also be noted that as expected, the areas of high potential identified in our results are mostly in areas of relatively low population. This is no surprise as the presence of human population is often the antithesis of the presence of uninterrupted forest land. The high-potential area identified within the Missouri Ozarks is located in the states least populated areas, and amongst the state's highest concentrations of both private and publicly held forest lands.

In addition to direct feedstock supply, the high importance placed by the econometric model on private forestland available biomass also denotes a lack of current utilization for potential feedstocks from public forestland. While forest feedstocks in the study region can be procured from both public and private land, this study has indicated that there is currently very little emphasis on utilizing National Forestland to a greater potential for providing key linkages in regional or localized feedstock supply chains for pellet facilities. One likely reason for this disparity is regional convention with regard to existing contracts for harvesting and transporting small-diameter wood and logging residues from large-scale private lands during timber harvesting.

Harvest and utilization of wood from National Forestlands (as well as other public lands) that is not classified as traditional roundwood has been limited in the past. In addition to such considerations, the creation of new long-term management programs for National Forestland, such as the Collaborative Forest Restoration Project (CFLRP) "Missouri Pine-Oak Woodland Restoration" creates a fairly unique opportunity to actually support active forest management with use of forest biomass feedstocks. Combining acquisition of consistent feedstock supplies within localized areas with traditionally non-timber management objectives is a key factor to long-term utilization of National Forestland and other public forestland for wood pellet feedstocks. As these new programs are implemented, the current areas where pellet facility placement potential is high may expand, and relative potential may dramatically increase in areas that have previously had very little potential.

Another point of discussion is the importance of residues as opposed to direct forest feedstocks. Certainly the availability of localized biomass if of the highest importance, but a deeper look reveals that it is residues that are significant in this study. We can only assume that the reason for this has something to do with a lack of technological and mechanical developments that would make acquisition of direct feedstocks financially feasible. At this time, residues, having already been transported from the forest and processed to some degree, represent the most practical and economical feedstock for pellet production.

Applications

The goal of this study was to identify localities with the potential for accommodating new pellet facilities. Though this study could be used by pellet facility proprietors, it is hopeful that it would also be used by local governments and municipalities in efforts to secure monetary assistance, tax credits, and possibly even legislation favorable to bringing this industry to their communities.

Additionally, the study highlights the importance and monetary value of biomass utilization. Modern forestry practices in the central hardwoods region often encourage mid-rotational thinnings at approximately 10 year intervals. Each of these thinnings produce large amounts downed of biomass that typically is left to rot. Not only is this wasteful management of an otherwise valuable product, but is also counter-productive to the most recent wildland fire management practices. Given the vast amounts of forest fires observed in recent years, forest managers have begun preventative management by burning sections of forests after thinnings in order to eliminate the resulting ground fuels in a controlled manner, as opposed to waiting for these fuels to feed an uncontrolled wildfire. If the downed biofuels from mid-rotational thinnings could be utilized by the pellet industry it would not only be a valuable and expansive source of feedstocks, but it would also greatly reduce the resulting ground fuels on managed forest lands.

CONCLUSION

The pellet wood industry has grown exponentially in recent years, due mostly to the expanding export market to Europe. Although there are other popular renewable resources such as wind, water, and solar, the burning of biomass appears to be an important source of renewable energy in the years to come.

This study examined the existing pellet wood industry in the United States, particularly within the Appalachia and Ozarks Regions, so as to identify locational characteristics of existing pellet wood facilities. Econometric models utilizing regression analysis were developed for this study and utilizing biomass data, logistical data, and other data of perceived importance, we were then able to identify localities within these regions that could reasonably be predicted to facilitate an expansion of the pellet wood industry.

Results were presented relatively, grouped by percentile, and then presented in contiguous maps found in Figures 4 and 5. Figure 5 clearly indicates a major area of high predicted values within the Northeast sub-region. Three other areas of high predicted values can also be seen in parts of West Virginia, Alabama, and the Ozarks. Within the Ozarks, Texas County Missouri demonstrated the highest relative probability. This came as no surprise as Texas County is not only the largest county in the state, but it is also at the heart of Missouri's existing timber industries. Future expansion of the pellet wood industry into these areas could potentially create many regional jobs within the industry, and bring outside money to these struggling rural economies.

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Table 1: Model Variables

Variable	Description	Units	Source
ENF	National Forest land	Dry Short Tons	USDA/USFS Evalidator database
EPL	Privately owned forest land	Dry Short Tons	USDA/USFS Evalidator database
Res_tot	Total mill residues	1000 m^3	USDA/USFS Timber Products Output database
Res_fuel	Fuel residues	1000 m^3	USDA/USFS Timber Products Output database
Res_unused	Unused mill residues	1000 m^3	USDA/USFS Timber Products Output database
Roads	Presence of major roadways	Binary	U.S. Census Bureau 2000
Rails	Presence of commercial railways	Binary	U.S. Census Bureau 2000
Waterways	Presence of commercial waterways	Binary	U.S. Census Bureau 2000

Table 2: Logit Model Output

	Full Model			Adjusted Model for Northeast Sub-region		
	Estimate	**Std Error**	***p-value***	**Estimate**	**Std Error**	***p-value***
National Forest land	6.44E-08	6.31E-08	0.3081	1.67E-07	1.58E-07	0.2889
Privately owned land	1.29E-07	3.13E-08	<0.0001	1.42E-07	5.94E-08	0.0169
Roads	0.6334	0.5103	0.2145	-0.0932	1.1118	0.9332
Rails	0.3305	0.4519	0.4645	0.0602	0.7762	0.9382
Waterways	-0.7967	0.4562	0.0807	-1.1495	0.9867	0.2440
Residues, total	0.00578	0.00401	0.1498	0.0246	0.0116	0.0335
Residues, fuel	-0.00055	0.000398	0.1697	-	-	-
Residues, unused	-0.001	0.00391	0.7989	-	-	-

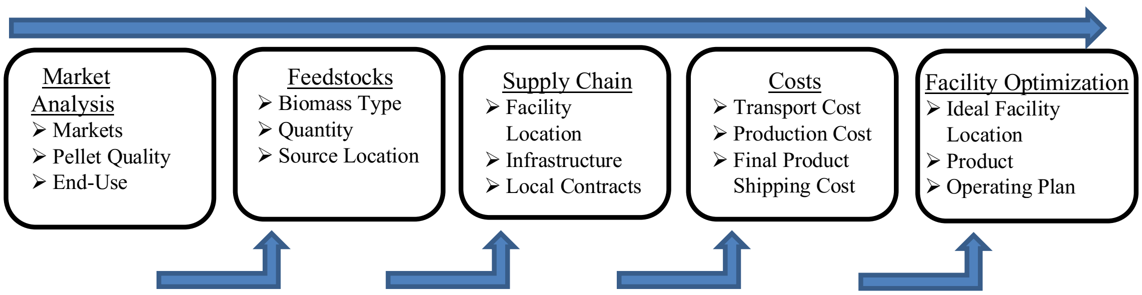

Figure 1: Marketing plan for regional and localized wood pellet industry

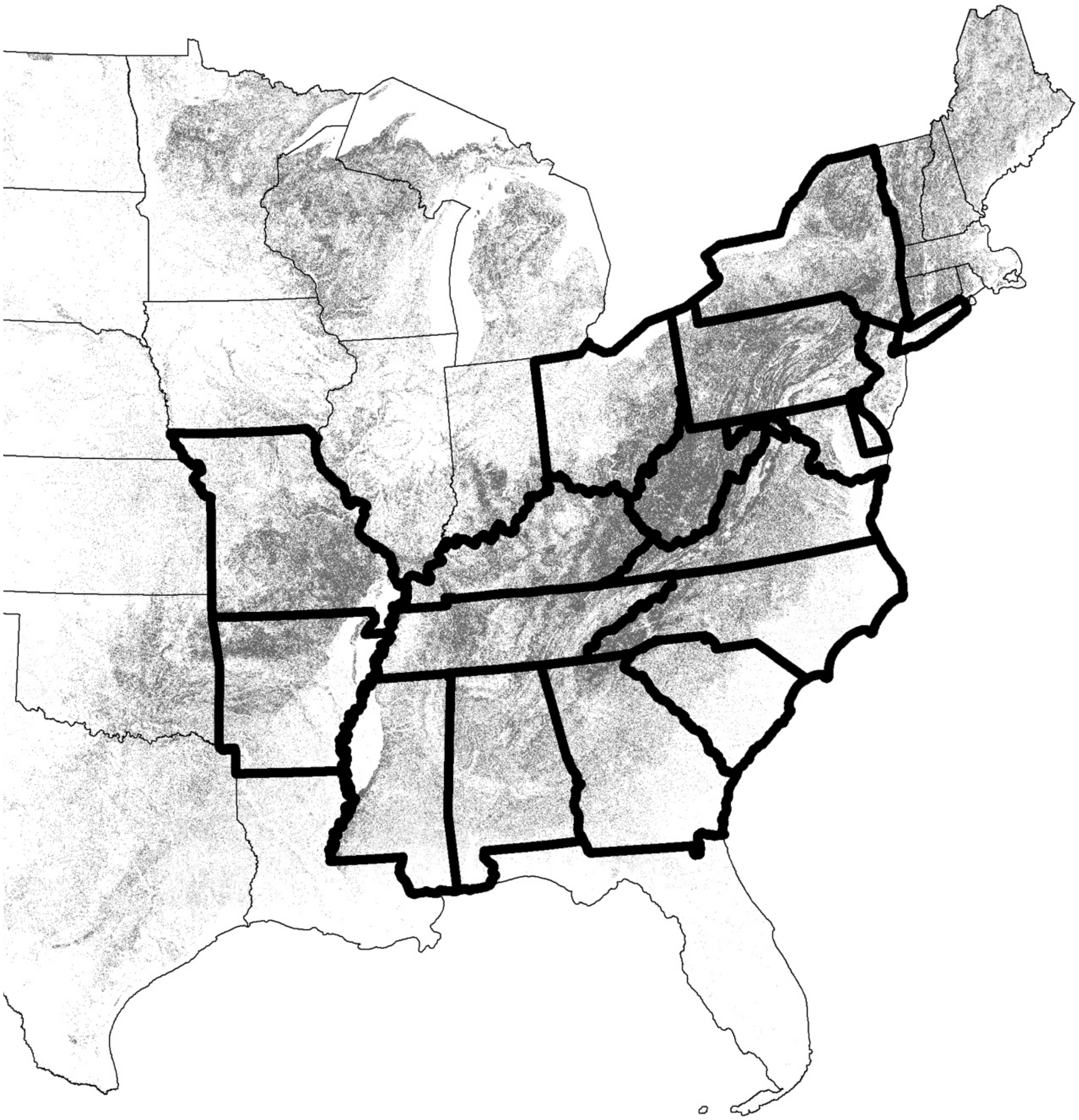

Figure 2: Study area with coverage of hardwood and mixed forest types

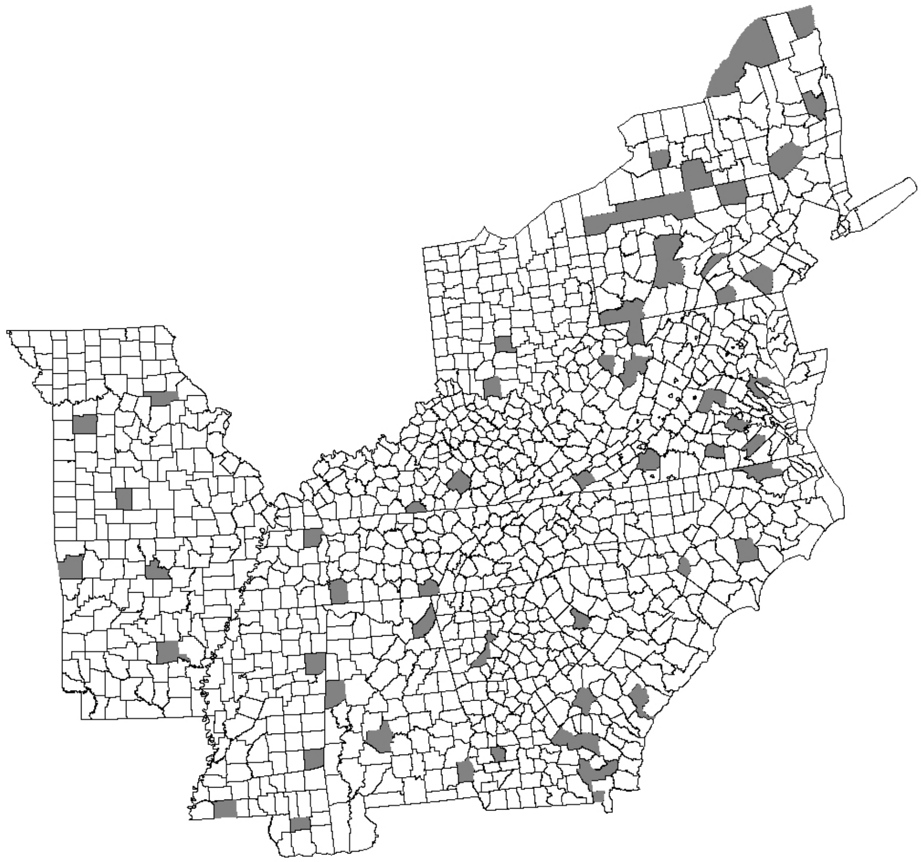

Figure 3: Known pellet facility presence

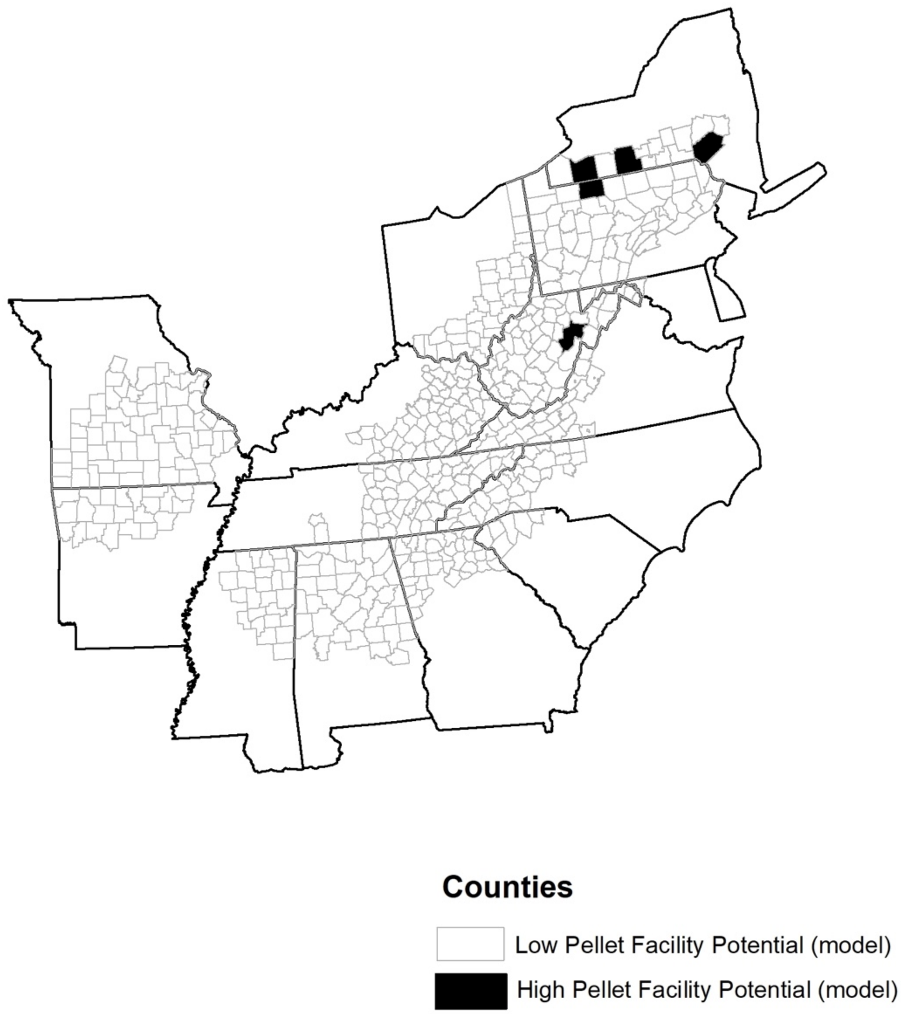

Figure 4: Results (≥ 0.5 predicted value)

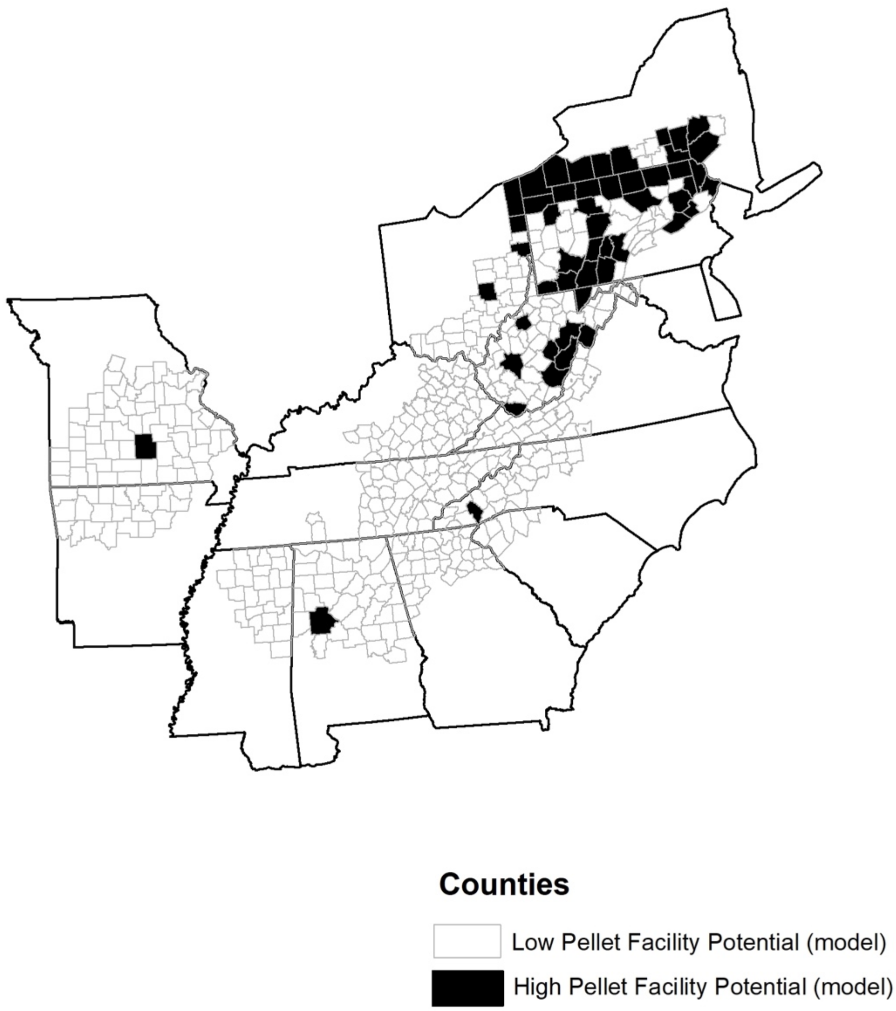

Figure 5: Results (90th percentile)

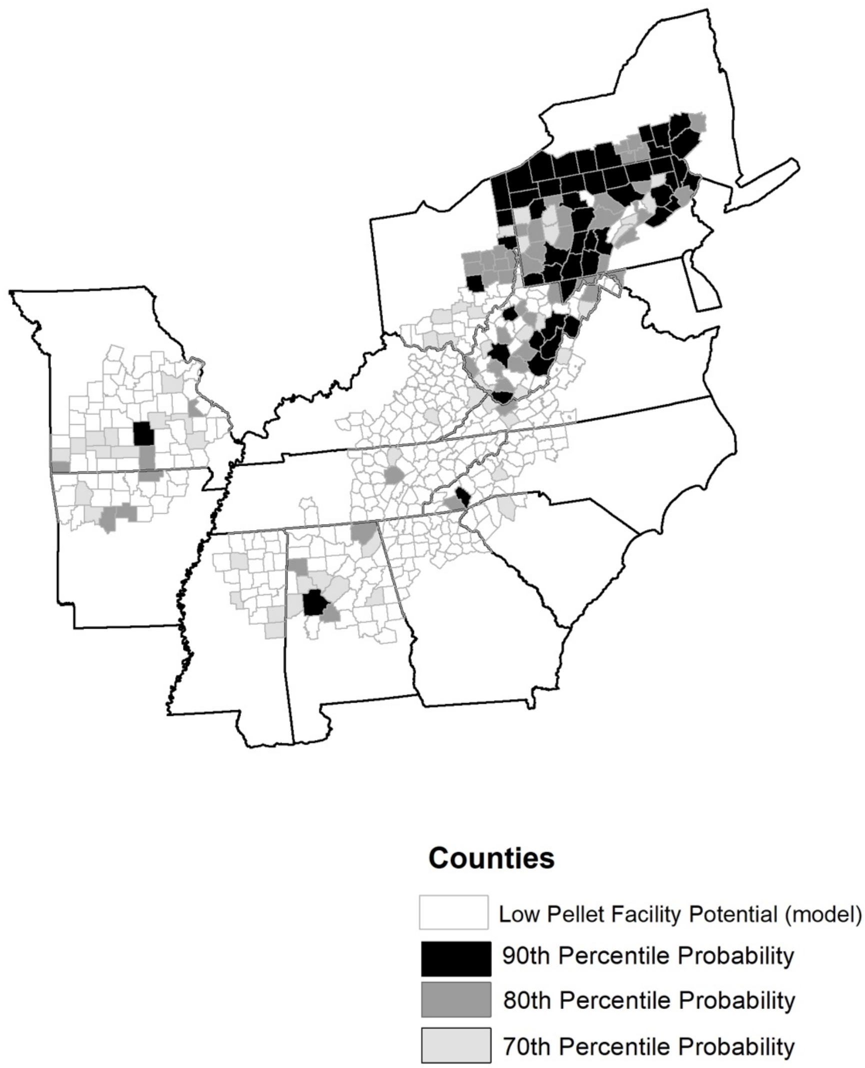

Figure 6: Results (90th, 80th, 70th percentiles)