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The Development of Nebraska's Advanced Biofuels Plant Decision Support System

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By the Rainwater Basin Joint Venture

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INTRODUCTION

Second generation biofuel production is increasingly being promoted and explored by researchers and government organizations (Tilman et al. 2009; Mitchell et al. 2012; Uden 2012). Yet, few commercial-scale advanced biofuel production facilities have been established, partly due to the lack of infrastructure required to manufacture ethanol from alternative crop types, such as sorghum (*Sorghum bicolor*) or switchgrass (*Panicum virgatum*). As pressure for advanced biofuel production increases, ethanol companies such as Abengoa Bioenergy are preparing to implement exploratory production on a large scale. In 2013, a proposal was established to convert one or both of Abengoa Bioenergy's traditional corn feedstock ethanol manufacturing facilities in Ravenna and York, Nebraska to sorghum-based advanced biofuel production facilities. Advanced biofuel production in the region may help reduce land-use stressors on the environment, water supplies, and wildlife populations, particularly if grassland-dominant crop types are also used in the manufacturing process.

In order to supply each facility with enough materials for production, state and federal agencies are highly motivated to work with Abengoa to develop opportunities to offer incentives to landowners to convert fields currently in row crop production to alternative crop types such as sorghum or switchgrass. Converting row crop fields to grassland stands has the potential to provide added environmental and ecological benefits in the region, but various complex environmental and ecological relationships must be first considered. In addition, there may be opportunities for Abengoa to utilize other sources of biomass, such as eastern red cedar (*Juniperus virginiana*) or other woody species. Harvesting woody cover in areas where it has limited valued to the environment, particularly in areas where woody species such as eastern red cedar are considered highly invasive, may provide additional benefits to wildlife if these areas are converted back to grassland. These multiple objectives established by stakeholders can be effectively addressed and maximized by using a Decision Support System (DSS) to help make informed decisions on where to offer alternative crop incentives within the ethanol facilities' service areas.

A DSS is a computer-based information system that is used by decision makers to compile important information from personal knowledge, data, and models to identify solutions to problems and make informed decisions. Here we describe the construction and implementation of a Geographic Information System (GIS) -based DSS intended to help prioritize focal regions for establishing landowner incentives while maximizing the likelihood of achieving multiple stakeholder objectives.

METHODS

Service Area

The establishment of grasslands in key regions within the ethanol facilities' service areas can provide additional ecosystem services and benefits to wildlife (Ribaudo 1989; Dunn et al. 1993; Delisle & Savidge 1997); yet transporting crops to ethanol facilities is costly and must also be addressed. In order to reduce transportation costs to the manufacturer, we limited the extent of our DSS models to 75 miles surrounding each facility. We created a Proximity Factor in our DSS using three distance buffers around each ethanol plant (e.g., 0-25 miles, 25-50 miles, and 50-75miles) in a Geographic Information System (GIS; Figure 1). We assigned values to each distance buffer: land units contained in the closest distance band had a value of 100; any unit within the mid-distance buffer was assigned a value of 66; and the furthest land units were assigned a value of 33. These values were used in conjunction with weights assigned to the Proximity Factor in the DSS, establishing priority to properties that are closer to the ethanol manufacturing facilities.

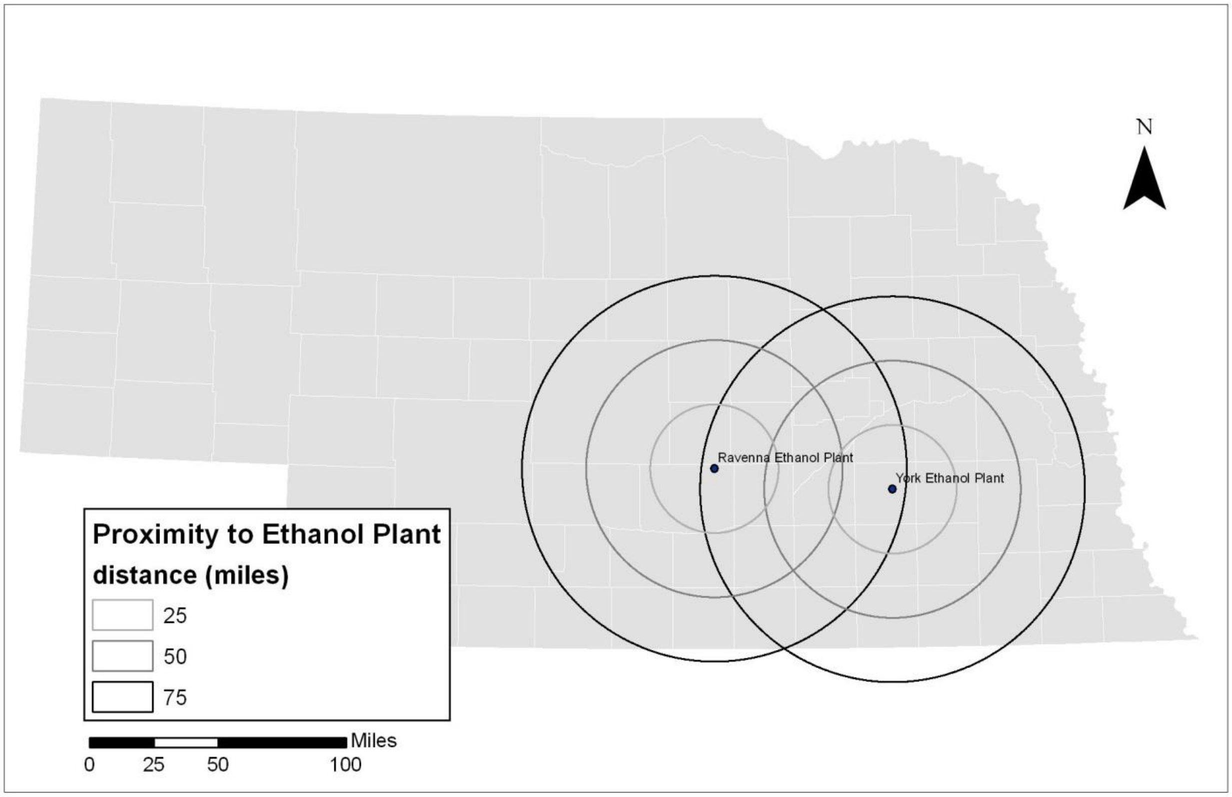

Figure 1. Distance buffers of 25, 50, and 75 miles surrounding ethanol manufacturing facilities in Ravenna and York, Nebraska were established to prioritize grassland-dominant crop incentives to landowners who own land closer to the ethanol plants.

Species Distribution and Scenario Planning

The composition and configuration of landscape characteristics plays an important role in the distribution and abundance of wildlife (Helzer & Jelinski 1999; Fletcher & Koford 2002) and can potentially affect management success (Jorgensen 2012; Jorgensen et al. *In Review*). Failing to account for constraining factors in the landscape prior to implementing habitat management activities can have negative impacts on wildlife and can lead to undesirable management outcomes. Alternatively, careful consideration and planning can increase the chances of reaching conservation benchmarks and even exceeding expectations in species response. In order to help maximize the benefits of grassland crops to wildlife in a principally agricultural landscape – particularly for key socially and economically important game species such as the Ring-necked Pheasant (*Phasianus colchicus*) and Greater Prairie-Chicken (*Tympanuchus cupido*), we utilized spatially explicit models using GIS to determine areas likely to have the greatest benefit to these species, given the surrounding landscape.

We used species distribution models developed for Ring-necked Pheasant (Jorgensen 2012) and Greater Prairie-Chicken (Rainwater Basin Joint Venture 2012; Figure 2) in Nebraska to identify regions and land units predicted to have the highest likelihood of population increase once grassland-dominant cropping practices are implemented throughout the service area. Species distribution models are GIS-based spatially explicit models that are useful in predicting the likelihood of a species occurring, based on that species' relationships to landscape, topographic, and climate variables. These models allow extrapolation of relatively limited field samples from finite study areas to the entire potential range of a species. In addition, species distribution models can be used to predict changes in species distributions resulting from climate change, identify how species respond to changes in habitat connectivity, forecast biological invasions, detect biological hotspots, discover new species' ranges, and predict species responses to changes in land use.

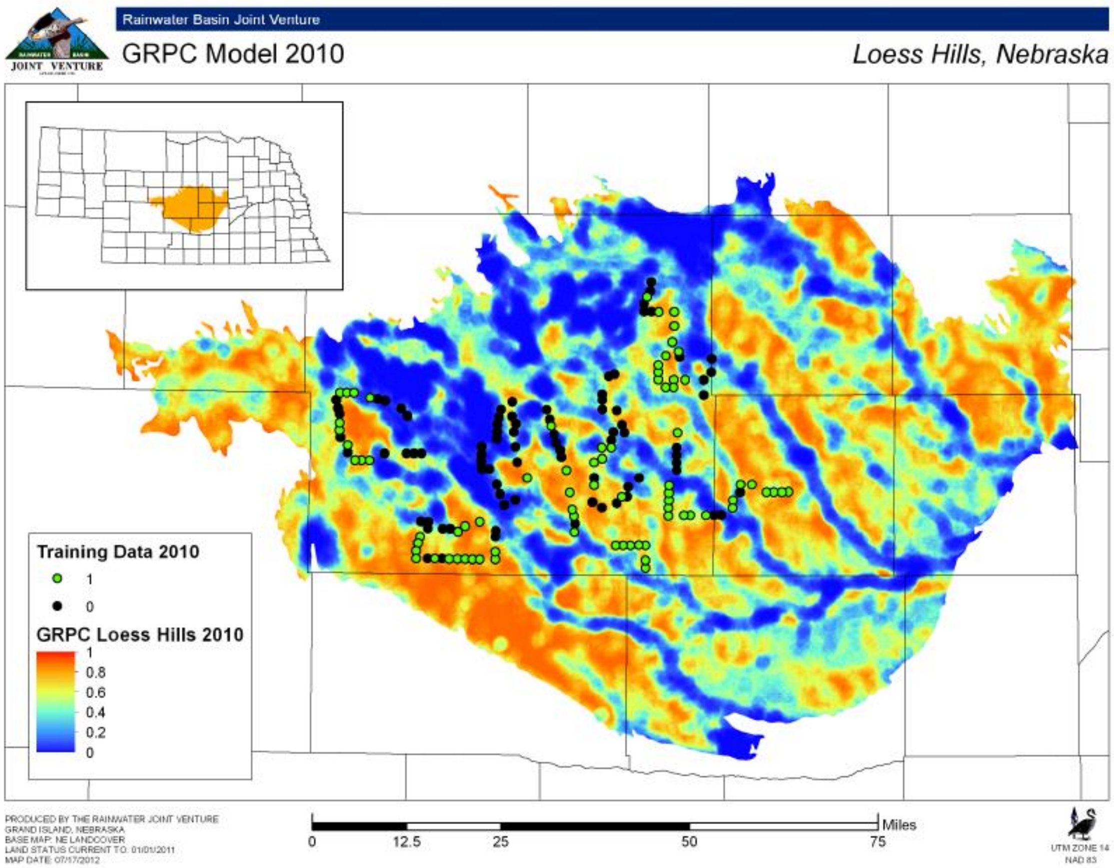

Figure 2. Example of a species distribution model for Greater Prairie-Chicken in the Loess Hills region of Nebraska, USA

To identify optimal regions to implement grassland cropping practices for the benefit of wildlife, we created a scenario to convert 30% of the surrounding row crop agriculture to grassland and applied the scenario on both the Ring-necked Pheasant and Greater Prairie-Chicken species distribution models using a Geographic Information System (GIS). The Ring-necked Pheasant model reflects the predicted relative abundance of the species at a location, and the Greater Prairie-Chicken model reflects the probability of the species occurring at a location on a continuous scale from 0-1. Since species tend to respond and select habitat at various spatial and temporal scales (Cunningham & Johnson 2006), both of which are often associated with body size and mobility (Holland et al. 2004; Fisher et al. 2011), these two species distribution models were constructed with landscape variables (i.e., grassland, woody cover, wetlands, etc.) measured at different spatial scales. These differences in scale between models result in differing amounts of land converted from row crop to grasslands for each model. In the Ring-necked Pheasant scenario, 30% row crop agriculture conversion equates to roughly 5,760 acres within a 19,400-acre landscape. A 30% row crop conversion for the Greater Prairie-Chicken scenario amounted to roughly 600 acres converted in a 2,000-acre landscape. We calculated the predicted abundance of Ring-necked Pheasant and the probability of occurrence of Greater Prairie-Chicken using the updated landscapes, based on the row crop conversion scenarios and subtracted the output raster model from the original species distribution models using GIS. The output raster models reflected the predicted increase in abundance for Ring-necked Pheasants and the predicted increase in probability of occurrence for Greater Prairie-Chicken. The model output for each species was reclassified into four values, using the Equal Interval classification method in ArcGIS 10.0 (ESRI ArcGIS 10.0, Redlands, California). The value 1 in the output model equaled the lowest 25% of the range of predicted increase in abundance/probability of occurrence values, and a value of 4 equaled the highest 25%, in other words, the areas that are most likely to see a population response (Figures 3 & 4). We repeated our methods used to create the predicted increase in abundance for Ring-necked Pheasant and predicted increase in probability of occurrence for Greater Prairie-Chicken under a new scenario, converting 30% of the woody areas (mostly composed of eastern red cedars and riparian tree species) within the service areas to grassland (Figures 5 & 6). The resulting values from both scenarios were used in conjunction with weights assigned to the Ring-necked Pheasant/Greater Prairie-Chicken Predicted Increase Factor in the DSS, establishing priority to properties that have the highest likelihood of benefiting these species, given the addition of grassland cropping practices.

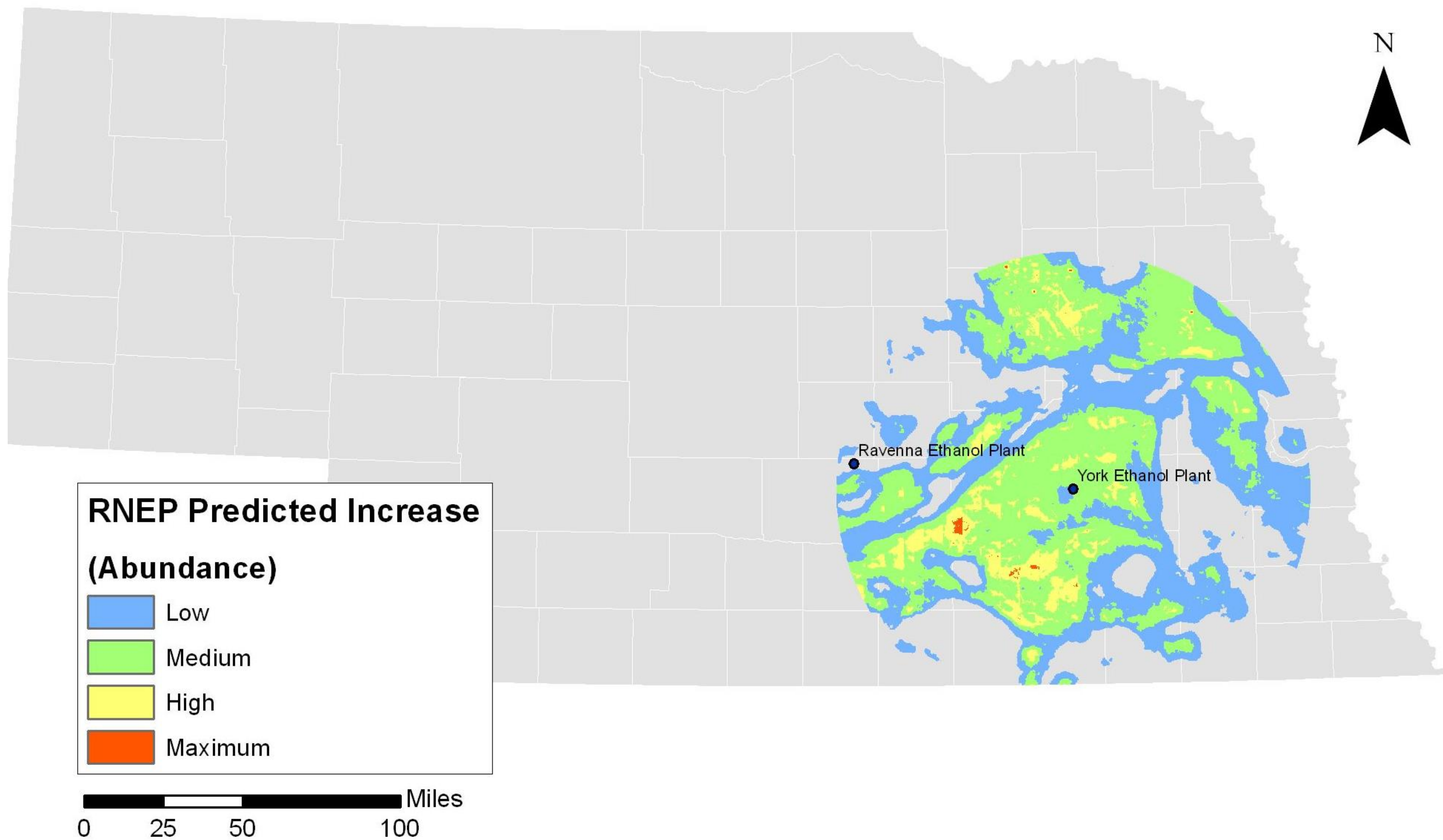

Figure 3. The predicted increase in Ring-necked Pheasant abundance was calculated using a species distribution model in a geographic information system based on a scenario of converting 30% of row crop agriculture in the surrounding landscape (~19,400 acres) to grassland. The predicted increase values in pheasant abundance ranged from 0-28. Values were reclassified into four categories – low, medium, high, and maximum increase in abundance – using an equal-interval reclassification method. A total of 364,044 acres were assigned to the low category; 347,482 acres were assigned to the medium category; there were 68,243 acres assigned to the high category; and 1,419 acres were assigned to the maximum predicted increase category.

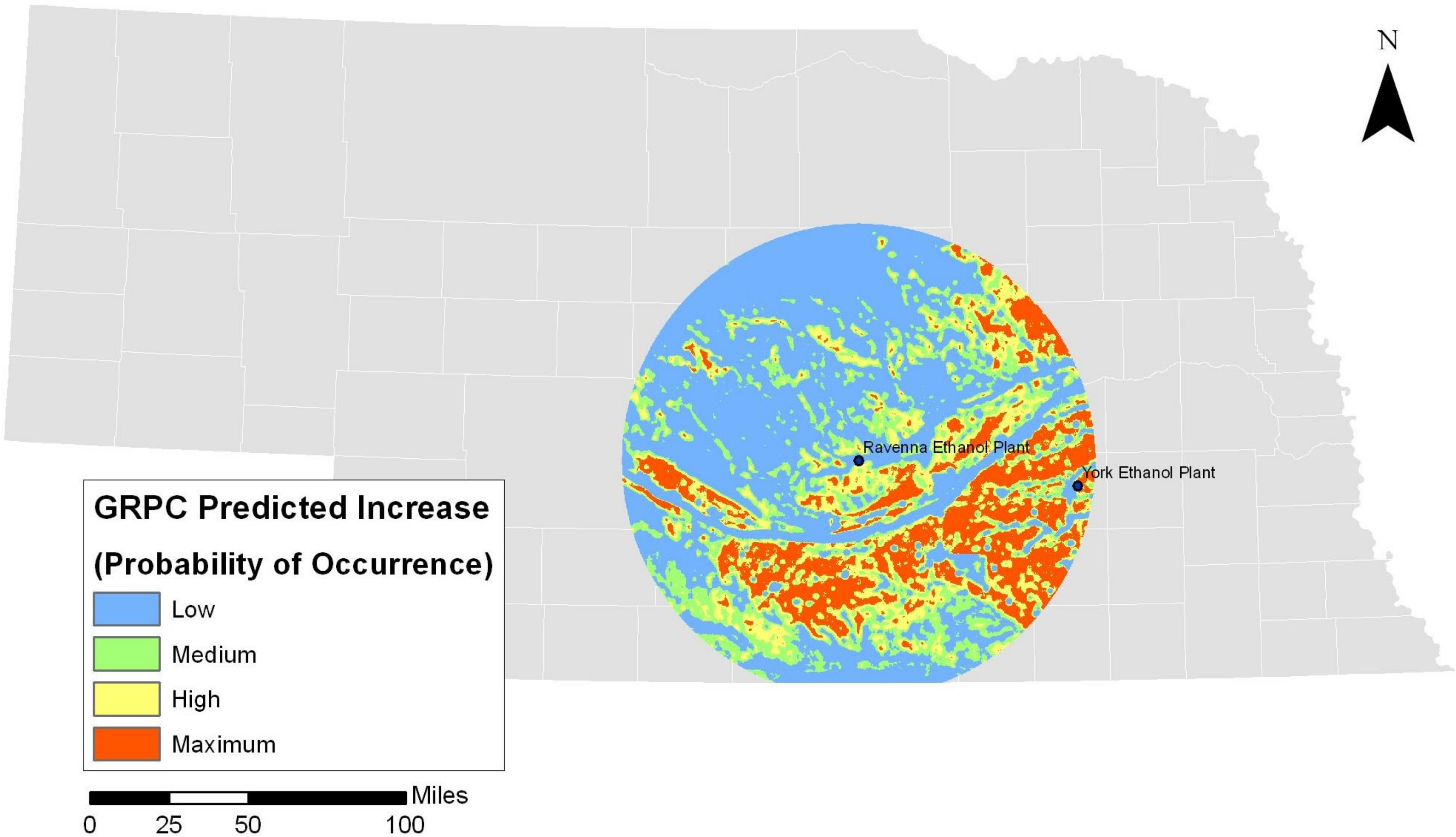

Figure 4. The predicted increase in Greater Prairie-Chicken probability of occurrence was calculated using a species distribution model in a geographic information system, based on a scenario of converting 30% of row crop agriculture in the surrounding landscape (~776 acres) to grassland. The values of the predicted increase in probability of occurrence ranged from 0-0.17, where the highest areas had a 17% increase in predicted occurrence. Values were reclassified into four categories -- low, medium, high, and maximum increase in probability of occurrence – using an equal-interval reclassification method. A total of 618,412 acres were assigned to the low category; 229,217 acres were assigned to the medium category; there were 193,921 acres assigned to the high category; and 203,000 acres were assigned to the maximum predicted increase category.

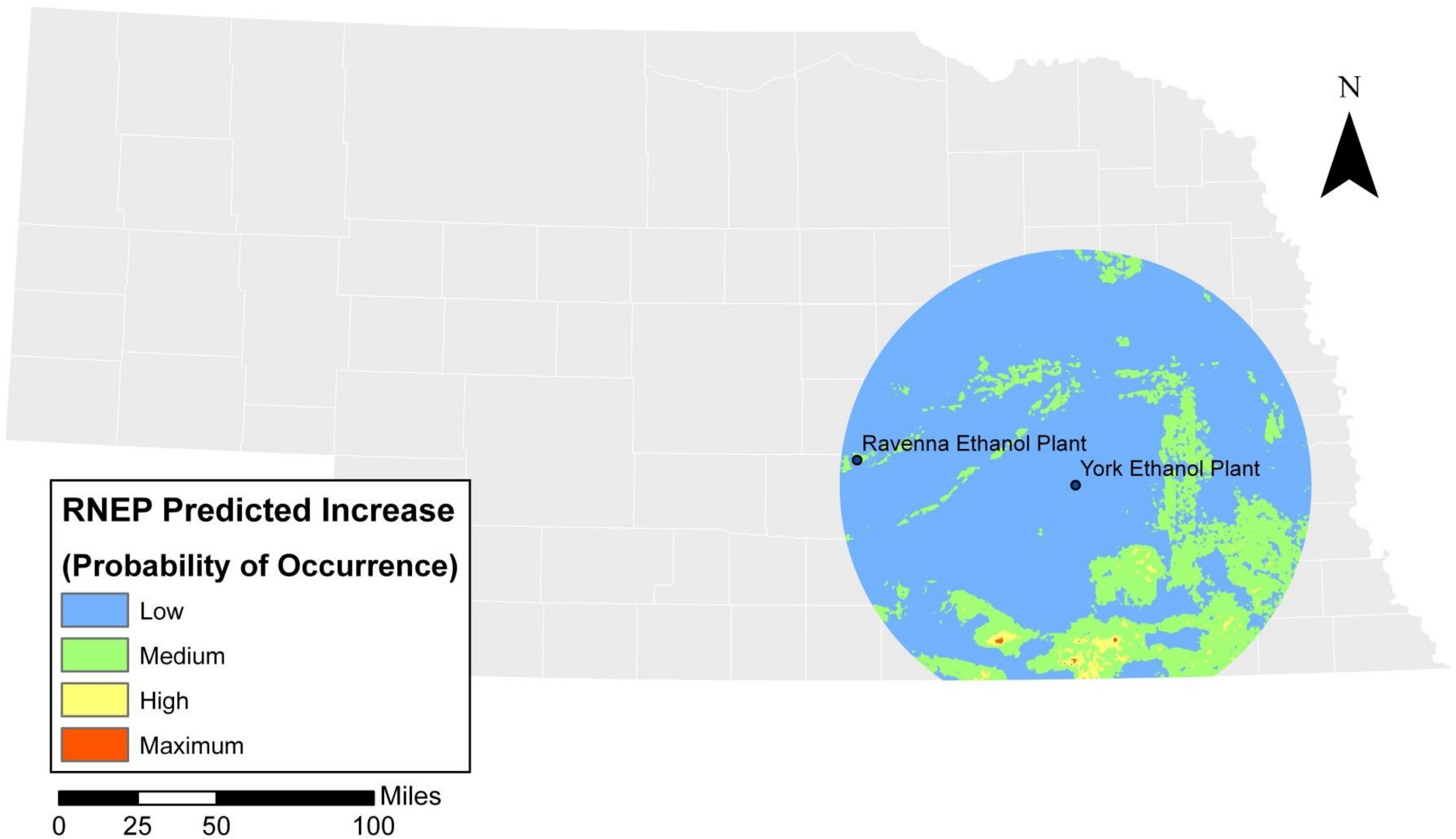

Figure 5. The predicted increase in Ring-necked Pheasant abundance was calculated using a species distribution model in a geographic information system, based on a scenario of converting 30% of woody cover in the surrounding landscape (~19,400 acres) to grassland. The predicted increase values in pheasant abundance ranged from 0-8. Values were reclassified into four categories – low, medium, high, and maximum increase in abundance – using an equa- interval reclassification method. A total of 8,161,827 acres were assigned to the low category; 2,103,242 acres were assigned to the medium category; there were 120,538 acres assigned to the high category; and 4,095 acres were assigned to the maximum predicted increase category.

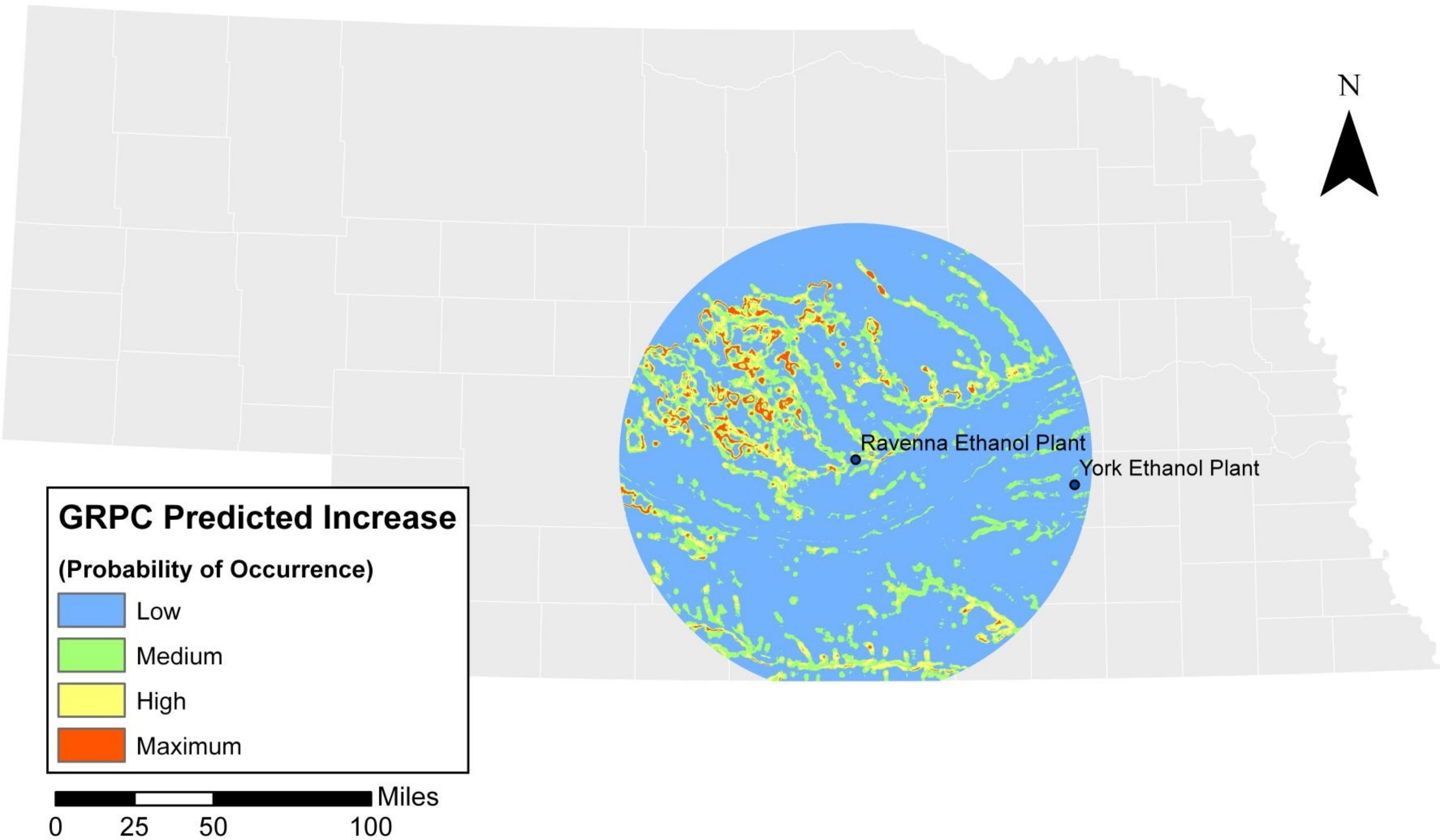

Figure 6. The predicted increase in Greater Prairie-Chicken probability of occurrence was calculated using a species distribution model in a geographic information system, based on a scenario of converting 30% of woody cover in the surrounding landscape (~776 acres) to grassland. The values of the predicted increase in probability of occurrence ranged from 0-0.22, where the highest areas had a 22% increase in predicted occurrence. Values were reclassified into four categories – low, medium, high, and maximum increase in probability of occurrence – using an equal-interval reclassification method. A total of 8,843,335 acres were assigned to the low category; 1,594,526 acres were assigned to the medium category; there were 672,944 acres assigned to the high category; and 198,721 acres were assigned to the maximum predicted increase category.

Wellhead Protection Areas

Various environmental benefits, particularly water quality improvements, can also be obtained by converting fields currently in row crop production to grassland-dominant crops for advanced biofuel production. Grassland crops tend to require less fertilizer and pesticides than traditional annual row crop practices (Mitchell et al. 2010), thus reducing the amount of chemical runoff in critical water supplies. In Nebraska, Wellhead Protection Areas have been established around critical water supplies for communities in response to a 1998 bill passed by the state legislature, LB 1161, which authorized the Wellhead Protection Area Act (Herpel 2008). Since approximately 85% of the drinking water in Nebraska is obtained from groundwater, preventing groundwater contamination is critical. The Wellhead Protection Areas include lands surrounding public water supply wells. Potential sources of groundwater contamination are identified within these boundaries and contaminant sources are managed appropriately. We included Wellhead Protection Areas in our DSS to help target and protect vital water supply wells for communities within the ethanol plants' service areas (Figure 7). These boundaries were used in conjunction with weights assigned to the Wellhead Protection Area Factor in the DSS, establishing priority to land units falling within a Wellhead Protection Area.

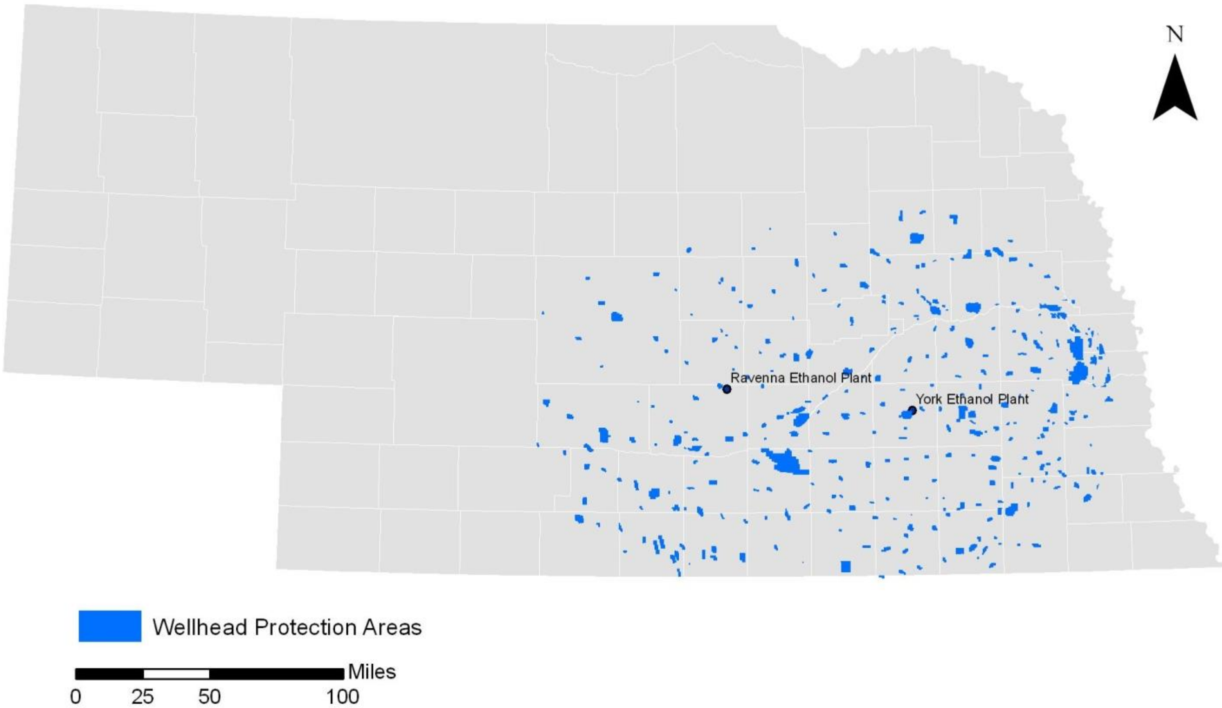

Figure 7. Wellhead Protection Areas were used in the decision support system to help protect water quality in areas surrounding critical water supplies for communities within the Abengoa Bioenergy ethanol plants' service areas.

Groundwater Quality Management Areas

Since grassland cropping practices can have added benefits to water quality, particularly by reducing chemical runoff commonly associated with traditional cropping practices, we targeted land units falling within critical water quality management areas in the service area for grassland production. The Groundwater Quality Phase II and Phase III Areas are regions containing elevated nitrate levels; areas are established by the Natural Resources Districts in the state. Generally, an area is placed in a Groundwater Quality Phase II boundary when 50% of the monitoring wells have nitrogen contaminant levels greater than the defined maximum contaminant level. A Phase III area is one in which 80% of the monitoring wells have nitrogen levels greater than the maximum contaminant level. We assigned all Phase III Groundwater

Quality Areas a value of 100 and all Phase II Areas a value of 50 (Figure 8). These boundaries were used in conjunction with weights assigned to the Groundwater Quality Management Factor in the DSS, establishing priority to land units falling within a Phase III and Phase II Groundwater Quality Management Boundary.

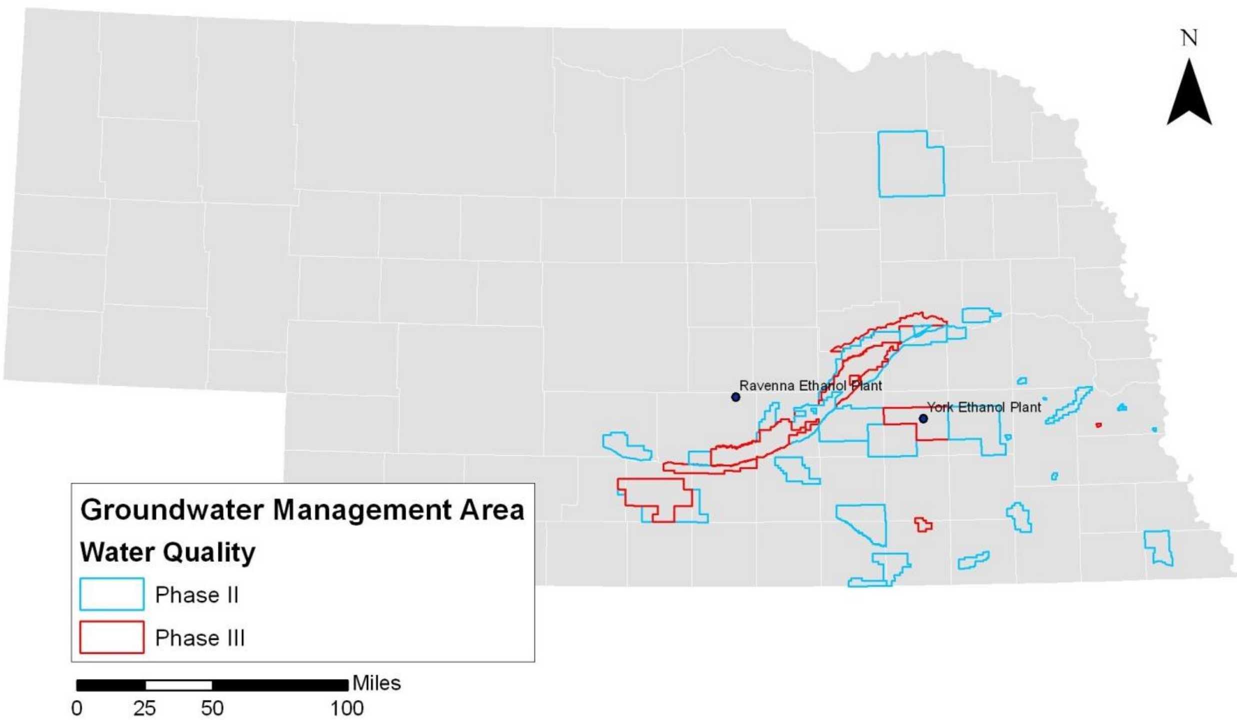

Figure 8. Groundwater Quality Management Areas were assigned values based on whether they were listed as a Phase II or Phase III management status. Phase II areas were assigned a value of 50 and Phase III areas, which are the areas containing the highest level of nitrogen levels within their groundwater, were assigned a value 100. These values prioritized these areas based on the need to reduce nitrogen levels in the groundwater.

Highly Erodible Soils Index

Historically, soil erosion has consistently been an issue in traditional cropping practices. Consequently, in the last century various federal and state programs have been established to offer landowners incentives to reduce soil erosion by taking lands containing highly erodible soils out of production and, in many cases, putting them into grassland systems (e.g.,1956 Soil

Bank program, the 1985 Conservation Reserve Program; Cain & Lovejoy 2004; USDA – NRCS 2012). Although we are more aware of the negative effects and mitigation of soil erosion in today's agricultural practices, soil erosion continues to be an issue. In order to help reduce wind and water erosion, particularly on lands containing highly erodible soils, we included a Highly Erodible Soils Index in our DSS. In cooperation with the U.S. Department of Agriculture's Natural Resources Conservation Service, we constructed a Wind and Water Erodibility Index using the Soil Survey Geographic (SSURGO) database (U.S. Department of Agriculture–Natural Resources Conservation Service 2011). We used a modified version of the Universal Soil Loss Equation (USLE) to produce erodibility indices for wind and water (following methods outlined in Woodruff & Siddoway 1965; U.S. Department of Agriculture 1978), and reclassified the data into a Highly Erodible Soils Index by taking raster values greater than 8 in both indices and reclassifying them to a value of 1, and everything else to a value of 0 (pers. comm. Dan Shurtliff, U.S. Department of Agriculture – Natural Resources Conservation Service; Figure 9). We quantified the percentage of highly erodible soil acres within each land unit. Each parcel containing > 50% erodible soils on the property was assigned a value of 100; parcels containing 33-50% were assigned a value of 75; properties containing 5-33% highly erodible soils were assigned a value of 50; and properties containing less than 5% erodible soils were assigned a value of 25. These final values were used in conjunction with weights assigned to the Highly Erodible Soils Factor in the DSS, establishing priority to land units containing high proportions of erodible soils on the property.

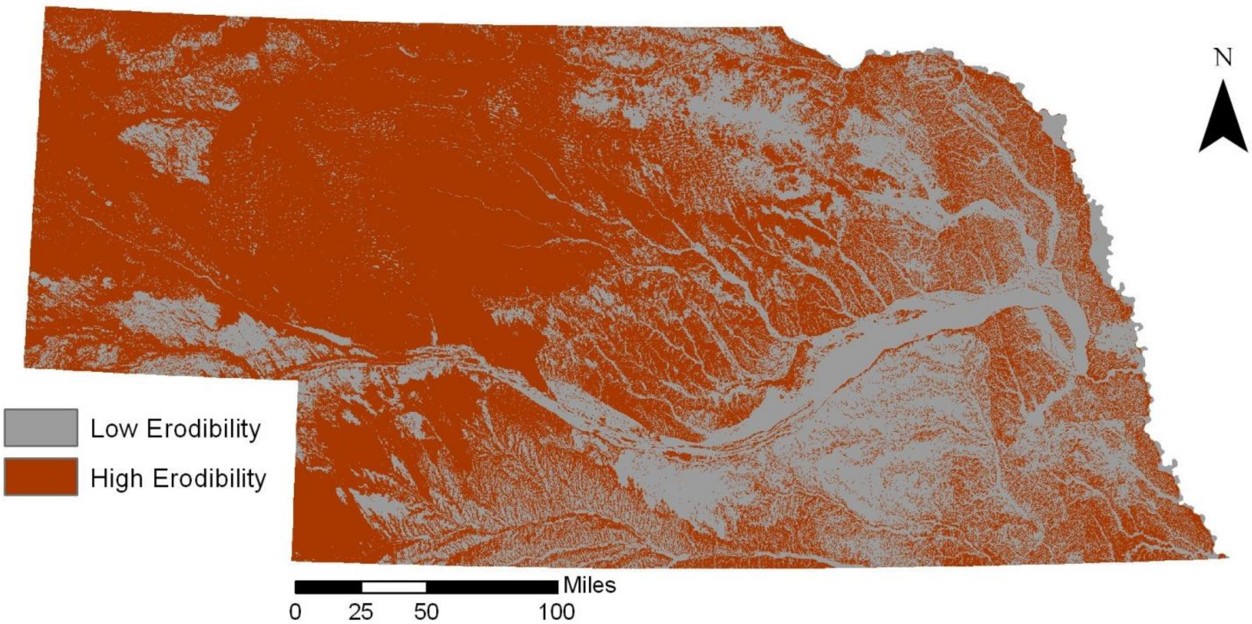

Figure 9. The Highly Erodible Soil Index was constructed by reclassifying Water Erodibility and Wind Erodibility Indices for Nebraska, where any values over 8 were reclassified as highly erodible soils. Areas containing highly erodible soils were weighted according to the percentage of erodible soils contained within the land unit. Areas containing >50% of erodible soils were assigned a value 100; 33-50% were assigned a value of 75; 5-33% were assigned a value of 50; and areas containing < 5% erodible soils were assigned a value of 25. The assigned values prioritized grassland-dominant crop incentives to land units with higher percentages of erodible soils.

Decision Support System Development

To create the final Advanced Biofuels Plant DSS, we first established criteria to appropriately weight each factor in the DSS model. A total of five factors were used in the DSS, including the Ring-necked Pheasant Predicted Increase models using row crop and woody cover conversion for the facility in York, Nebraska, and the Greater Prairie-Chicken Predicted Increase models, using row crop and woody cover conversion for the facility in Ravenna, Nebraska. The other four factors included in the DSS are the Wellhead Protection Area factor, the Proximity factor, the Highly Erodible Soils factor, and the Water Quality Management Areas factor. The values assigned to each factor were weighted accordingly, based on ecological importance and priority according to expert opinion (Table 1). Values and weights were extracted to a Common Land Unit (CLU) dataset, where each boundary within the dataset is the smallest unit of land that has a permanent, contiguous boundary, or contains a common land cover, owner, or producer (U.S. Department of Agriculture – Farm Service Agency 2013). Each land unit contained a total of five values, one for each factor in the DSS. We multiplied each value by its associated weight (Table 1) and summed all products together to form a final weighted value associated with each land unit in the DSS (Figures10, 11, 12 & 13). The final Advanced Biofuels DSS contained four models, two for the facility in York, Nebraska, which focus on increasing habitat for Ring-necked Pheasants (Figures 10 & 12) and two for the Ravenna facility, which focus on increasing habitat for Greater-Prairie Chickens (Figures 11 & 13).

Table 1. The criteria, description, and values of five factors included in the Cellulosic Ethanol Plant Decision Support System.

Factor	Criteria	Description	Value	Weight
RNEP[1,2]/GRPC[3,4] Predicted Increase [1]Based on 30% row crop conversion to grassland within 19,400 acres [2]Based on 30% woody cover conversion to grassland within 19,400 acres [3]Based on 30% row crop conversion to grassland within 1,990 acres [4]Based on 30% woody cover conversion to grassland within 1,990 acres	Maximum	Top 25% of predicted values	100	0.25
	High	Upper-middle 25% of predicted values	75	
	Medium	Lower-middle 25% of predicted values	50	
	Low	Bottom 25% of predicted values	25	
Wellhead Protection Area	Yes	Within boundary	100	0.05
	No	Outside boundary	0	
Proximity	Near	< 25 miles from ethanol plant	100	0.25
	Moderate	25-50 miles from ethanol plant	66	
	Far	50-75 miles from ethanol plant	33	
Highly Erodible Soils[5] [5]Erodibility Index Values >= 8	Maximum	> 50% erodible soils on property	100	0.20
	High	33-50% erodible soils on property	75	
	Medium	5-33% erodible soils on property	50	
	Low	<5% erodible soils on property	25	
Water Quality Management Areas[6] [6]NRD Phase II and Phase III Boundaries	>= 80% of Monitoring Wells are at or above 80% of Max Contaminant Levels	Within a Phase III Boundary	100	0.25
	>= 50% of Monitoring Wells are at or above 50% of Max Contaminant Levels	Within a Phase II Boundary	50	

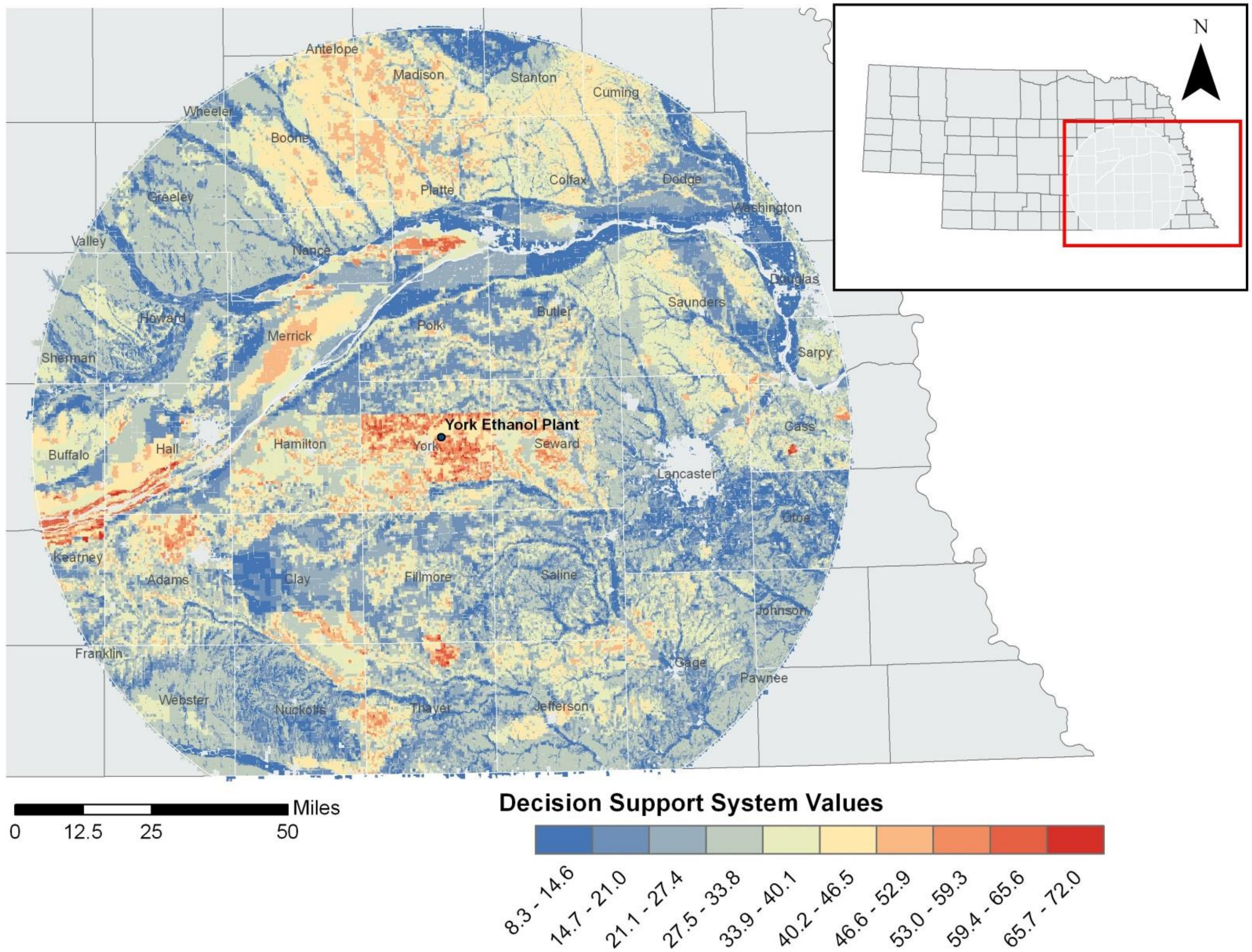

Figure 10. The final decision support system identified regions immediately surrounding the York ethanol production facility as being highly desirable for the establishment of grassland-dominant crop types.

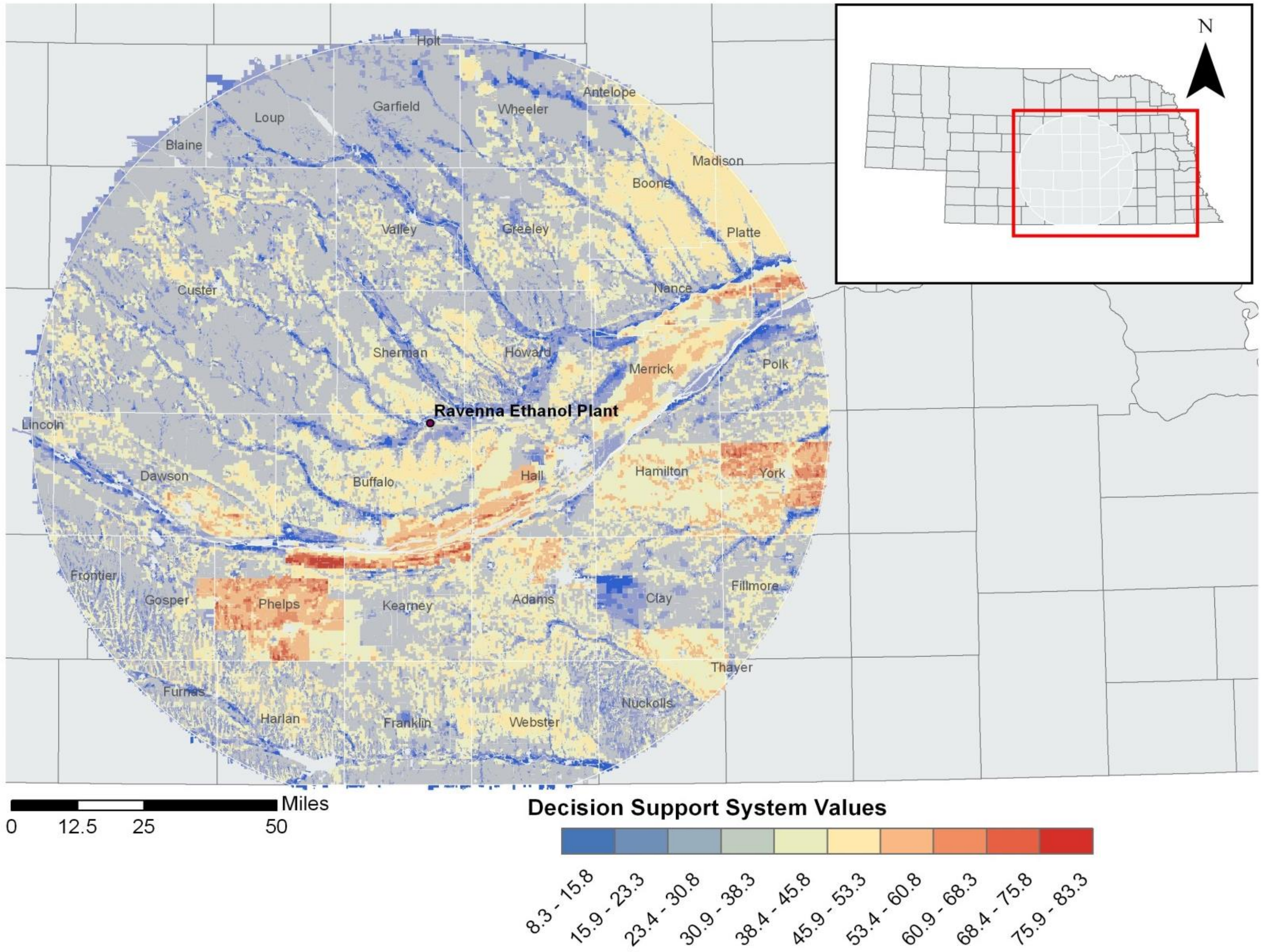

Figure 11. The final decision support system identified regions to the southwest, south, and southeast of the Ravenna ethanol production facility as being highly desirable for the establishment of grassland-dominant crop types.

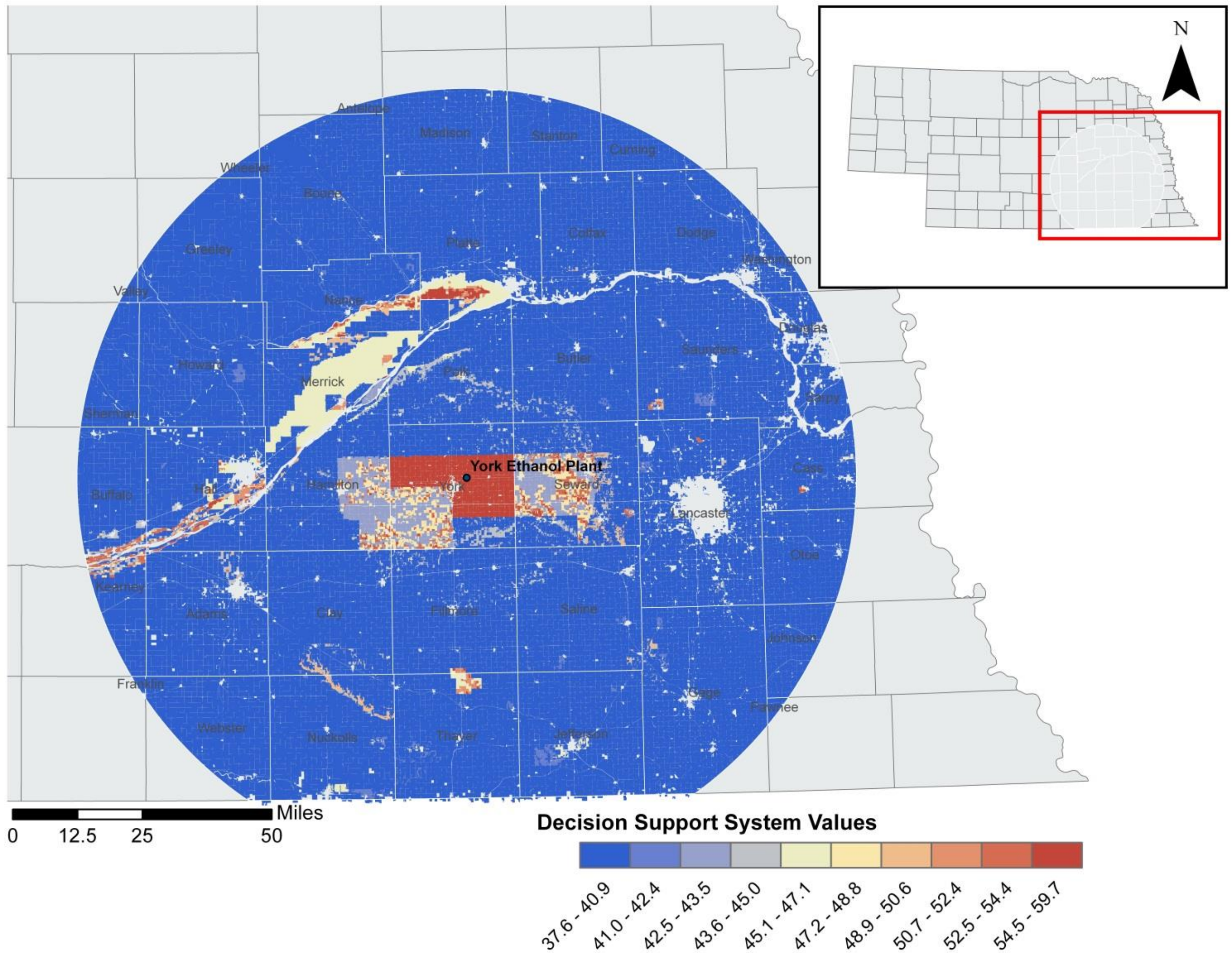

Figure 12. The final decision support system identified regions immediately surrounding the York ethanol production facility as being highly desirable for the removal of woody cover.

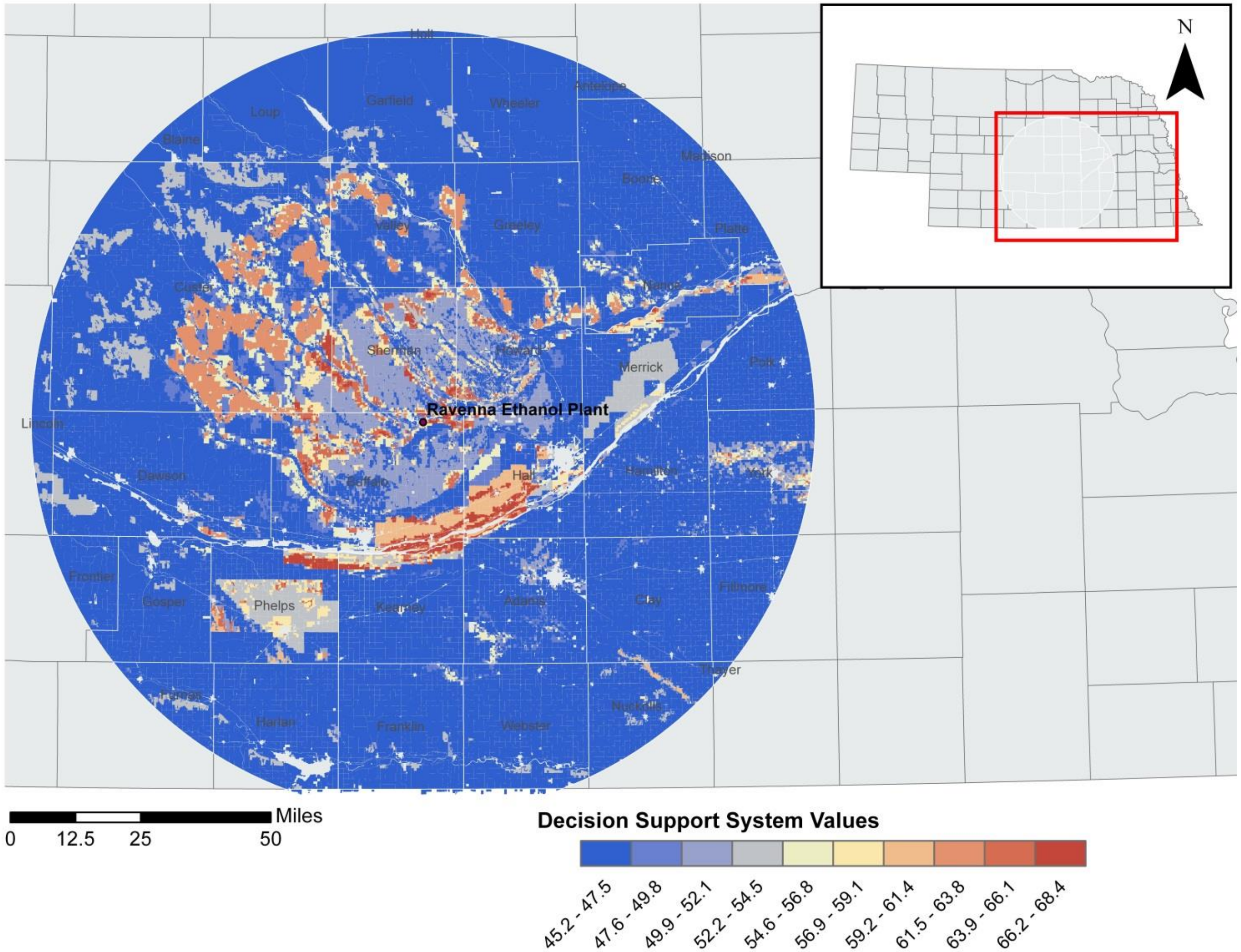

Figure 13. The final decision support system identified regions to the north, northwest, south, and southeast of the Ravenna ethanol production facility as being highly desirable for the removal of woody cover.

CONCLUSION

The final DSS models contain numerous land units throughout the service area that are listed as highly suitable for grassland production, and are indicated as prime targets for possible grassland crop incentives in the future. However, targeting a general region that has an elevated DSS score within the service area will help ensure that all conservation and production goals are met. Failure to saturate a “hot spot” that indicates elevated values in the final DSS can reduce the efficacy of the model. For instance, the row crop conversion scenarios using the species distribution models for both the Greater Prairie-Chicken and Ring-necked Pheasant are scale dependent. The pheasant model assumes that the species responds to landscape composition and configuration within a 19,400-acre landscape, and therefore 30% of the row crop in the landscape must be converted to grassland stands in order to satisfy the scenario used in our modeling efforts, which in a landscape dominated by agriculture equates to ~ 5,700 acres. Saturating specific regions that have elevated DSS scores with grassland-dominant stands before selecting other regions for focus by the initiative will help ensure that all parties have the greatest likelihood of reaching both ecological and production objectives.

The Advanced Biofuels Plant DSS is a tool meant to provide insight to Abengoa Bioenergy and to state and federal conservation agencies on the best areas to implement grassland crop incentives. It is intended to be used as a tool to support experts in the decision-making process. By identifying regions that are most likely to increase wildlife populations and reduce the stressors of current agricultural practices on the environment prior to the establishment of grassland stands, we can increase the overall benefit to not only the ethanol manufacturer, but for all parties involved.

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