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

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Introduction

Second-generation biofuel production is increasingly being promoted and explored by researchers and government organizations. 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 or switchgrass. 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 or other woody species. These multiple objectives established by stakeholders can be effectively addressed and optimized 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; 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, with three distance buffers around each ethanol plant (e.g., 0-25 miles, 25-50 miles, and 50-75miles), using a Geographic Information System (GIS). We assigned values to each distance buffer, where 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, giving priority to properties that are closer to the ethanol manufacturing facilities.

Species Distribution and Scenario Planning

We used species distribution models developed for Ring-necked Pheasant and Greater Prairie-Chicken 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 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, to identify how species respond to changes in habitat connectivity, to forecast biological invasions, to detect biological hotspots, to discover new species' ranges, and to predict species responses to changes in land use.

To identify optimal regions in which 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 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. The model output for each species was reclassified into four values, using the Equal Interval classification method in ArcGIS 10.0. A value of 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%, or the areas that are most likely to see a population response. We repeated the methods used to create the predicted increase in abundance for Ring-necked Pheasant and predicted increase in probability of occurrence for Greater Prairie-Chickens, using 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 . 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, giving priority to properties that have the highest likelihood of benefiting these species given the addition of grassland cropping practices.

Wellhead Protection Areas

Various environmental benefits can also be obtained by converting fields currently in row crop production to grassland-dominant crops for advanced biofuel production, particularly water quality. Grassland crops tend to require less fertilizer and pesticides than traditional annual row crops, 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. Since approximately 85% of the drinking water in Nebraska is obtained from groundwater, preventing groundwater contamination is critical. The Wellhead Protection Areas includes 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.

Water 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 that fall 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; the areas are established by the Natural Resource Districts in the state. We assigned all Phase III Groundwater Quality Areas with a value of 100 and all Phase II Areas with a value of 50.

Highly Erodible Soils Index

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. We quantified the percentage of highly erodible soil acres within each land unit. Each parcel with > 50% erodible soils on the property was assigned a value of 100; parcels with 33-50% were assigned a value of 75; properties with 5-33% highly erodible soils were assigned a value of 50; and properties with less than 5% erodible soils were assigned a value of 25.

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. 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. We multiplied each value by its associated weight and summed all products together to form a final weighted value associated with each land unit in the DSS (e.g., Figure 1).

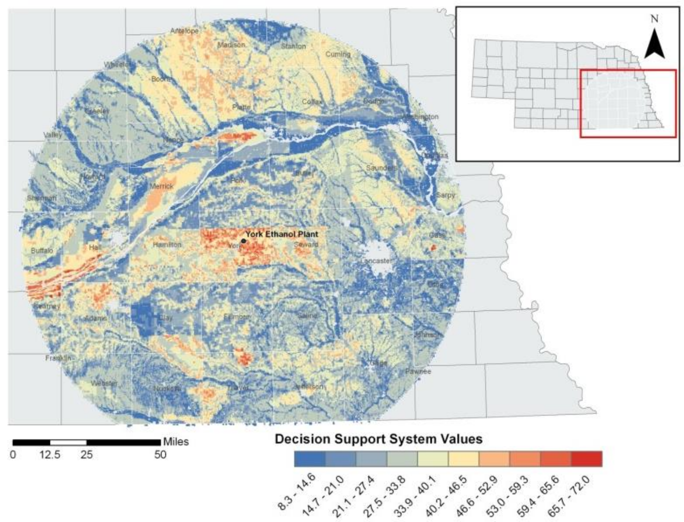

Figure 1. The final decision support system identified regions immediately surrounding the York ethanol production facility as being highly desirable for the establishment of grassland-dominant crop types.

Conclusion

The final DSS models contain numerous land units listed as highly suitable for grassland production throughout the service area, and are indicated as prime targets for possible grassland crop incentives in the future. The Advanced Biofuels Plant DSS is a tool meant to provide insight to Abengoa Bioenergy, and state and federal conservation agencies as to the best areas for implementing 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 not only to the ethanol manufacturer, but for all parties involved.

For additional information regarding the analysis, results and discussion consult the full document.