Locating the Optimum Location to Grow Native Grasses for Biofuel near the Koda Biomass Facility, Shakopee, MN, Using a GIS Model

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Abstract

Native grasses, in particular switchgrass, are a new alternative to corn for biofuel. Native grasses offer better wildlife habitat, require lower fertilizer input, have a higher carbon sequestration and offer better erosion control than cornfields. The Koda Energy plant located in Shakopee, Minnesota, is the first biomass facility in Minnesota that uses only cellulosic fuel. Only recently has the technology become available to extract cellulose from plant materials on a large scale. Corn and sugar cane are processed by fermentation. The Koda plant operated by the Rahr Malting Company is a joint venture with the Shakopee Mdewakanton Sioux. The Mdewakanton are interested in finding a local source of native grasses to feed their plant. This analysis seeks to locate land within a fifty-mile radius of the plant that will protect water resources, enhance wildlife and offer the best conditions to grow native grasses. A suitability model was constructed with ESRI ArcGIS with weights given to the input layers. Two alternative output layers were created and scaled from best to worst conditions to grow native grasses. The acreage for the best categories was then quantified by county. SAS and CART statistical software were used to validate the model.

Introduction

Native grasses, in particular switchgrass are one of the newest sources for biofuel. They are a cellulosic source of ethanol that also includes wood and other plant products. Recently, due to the need for alternatives to fossil fuels, more money and time has been spent developing cellulosic fuel extraction technologies (Rubin, 2008). Corn and sugarcane are starch based, processed by fermentation, and use more energy to produce than cellulosic biofuels.

The Energy Independence and Security Act of 2007 includes a provision that increases the renewable fuel standard from 5.4 billion gallons for 2008 to 36 billion gallons by 2022. Starting in 2016, the increase must be met with advanced (cellulosic) biofuels (Sissine, 2007). All alternative fuel possibilities need to be studied to decrease our dependence on foreign oil and decrease our input to global warming. Native grasses are only one of the many alternative energy resources that need to be considered.

Grasslands are among the most endangered ecosystems in the world. Switchgrass was once a common tall grass prairie species throughout the eastern and central United States and Canada. Early settler's livestock destroyed much of it by grazing. Switchgrass was considered as a forage crop and most recently as a possible biofuel. Big blue stem, little blue stem,

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and Indian grass are other major native grasses with biofuel potential. A native grass mix is also good habitat for wildlife (Harper and Keyser, 2008). A mix of native grasses is found to be more stable, productive and environmentally friendly than monoculture (Kintisch, 2008). A mix is also less susceptible to disease such as leaf spot disease on switchgrass (Krupinsky, 2004). Native grasses, such as switchgrass and big bluestem can grow ten feet tall and have an extensive deep root system that stores (sequesters) carbon dioxide thereby decreasing its release to the atmosphere and contributing to global warming.

Corn, the most common form of biofuel production requires large amounts of herbicides and fertilizers and is not drought, flood or erosion resistant. It uses large amounts of water and is poor wildlife habitat. Corn is a food crop and takes land that could be used for biofuel crops out of production for food crops. A recent study by the Nature Conservancy and the University of Minnesota shows that traditional biofuels such as corn emit more greenhouse gases, such as carbon dioxide than the fossil fuels they replace (Fargione, Hill, Tilman, Polasky, and Hawthorne, 2008).

Unlike corn, monoculture switchgrass fields provide much more wildlife habitat, produce five times more energy per acre than corn, uses less fertilizer and herbicides, tolerates drought and resists flood erosion better than corn and other non-native plants (Rinehart, 2006). In one study, it was shown that switchgrass reduced sediment yield 55 percent. Phosphorus and nitrogen were also reduced 26 and 38 percent, respectively, (Neppel, Tim, Cruse, Braster, and Jacobsen, n.d.). Switchgrass enhances water quality and provides habitat for birds and wildlife (Keshwani and Cheng, 2008). Native grasses such as switchgrass thrive on marginal land and therefore do not compete with food crops grown on healthy soils (Hoff, 2008). Switchgrass helps degrade herbicides in contaminated soil and revegetate and restore degradated soil such as that on mined land (Parrish and Fike, 2005).

Studies conducted in the 1980s determined switchgrass had the highest yield and best quality of biofuel feedstocks (Rinehart, 2006); although recent studies are showing that big bluestem may have better potential. Big bluestem is slower to establish than switchgrass but by the second production year, big bluestem was a more productive species, easier to convert to biofuel and cheaper to reproduce (Anderson, Casler, and Baldwin, 2008).

Koda Energy is a partnership between Rahr Malting Company and the Shakopee Mdewakanton Sioux Community. Together they have built the first power plant in Minnesota that burns only cellulosic biofuels. It began operating May 2009 using oat hulls from General Mills and byproducts from Rahr Malting Company. The energy produced is used by the Rahr Plant and the tribe. Excess fuel is sold to utility companies. They plan to use native grasses and the tribe (along with the University of Minnesota and the Minnesota Department of Natural Resources) has restored 400 acres of former farmland to native prairie for the project (Schill, 2008; Shakopee Mdewakanton Sioux Community, n.d.). The Nature Conservancy is considering a pilot project with Koda Energy to evaluate the conservation benefits of using native grasses for biomass. The results of this new effort will help the Nature Conservancy and Koda Energy identify land suitable for biofuel production for this project.

Data Collection

The data sets used for this study were obtained from a variety of sources. The Minnesota Department of Natural Resources (DNR) Data-Deli provided wildlife, counties, hydrology, and park borders. The MN Board of Water and Soil Resources (BWSR) supplied the Minnesota River Conservation Reserve Enhancement Program (CREP) and Reinvest in Minnesota (RIM) data. The United States Geological Survey (USGS) Seamless Server provided the digital elevation model (DEM). The Fish and Wildlife Service (FWS) National Wetlands Inventory (NWI) website provided the national wetlands inventory data. Soil data were obtained from the Natural Resources Conservation Service (NRCS) soil data mart website. Park data came from the Data Deli as well as from Environmental Systems Research Institute Inc. (ESRI). The cropland data layer (CDL) was downloaded from the National Agricultural Statistics Service (NASS) website. The land use data came from the Multi-Resolution Land Characteristics Consortium (MRLC) website (National Land Cover Data). An in-house Environmental Protection Agency (EPA) agricultural land use layer (Mehaffey, 2009) was also used.

Methods

Data Preparation

A fifty-mile radius area was selected around the Shakopee Malt plant based on the Nature Conservancy's parameters, Koda Energy's parameters, as well as information from Schill (2008) who showed this is the maximum distance to make transportation costs economical. Koda Energy is near the Minneapolis metropolitan area; therefore, the urban area was clipped from the radius to leave just agricultural land (Figure 1). The urban area borders were based on the most recent (2001) National Land Cover Data (NLCD) developed land category. National Agriculture Imagery Program (NAIP) 2008 ortho-photos were also helpful for finding areas of urban expansion since 2001. These regions were also removed from the study area.

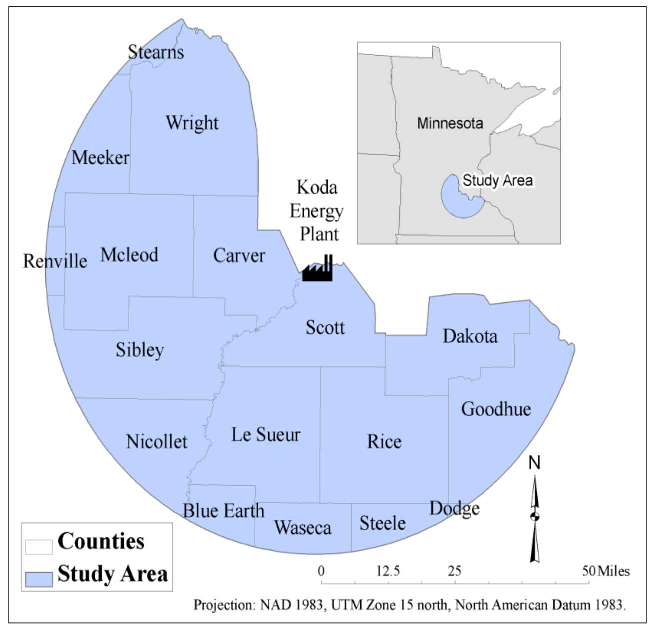

Figure 1. Study Area.

Physical

The soil data viewer (SDV) was downloaded from the NRCS website along with the soil data for the seventeen counties in the study area. The soil data were then joined and clipped to the study area. Texture and pH data were extracted from the SDV using the defaults.

The preferred soil types for switchgrass are sand, loam or clay (Sargent and Carter, 1999). A "Select by" was run on the texture file to exclude muck and muck combinations. The output file included areas of sand, loam or clay (Figure 2).

The data was converted to NAD 1983, UTM Zone 15 North and converted to raster format before analysis. All layers in this study were converted to this projection and to raster before analysis.

According to Wolf and Fiske (1995), the pH for switchgrass production should be 5.0 to be most productive.

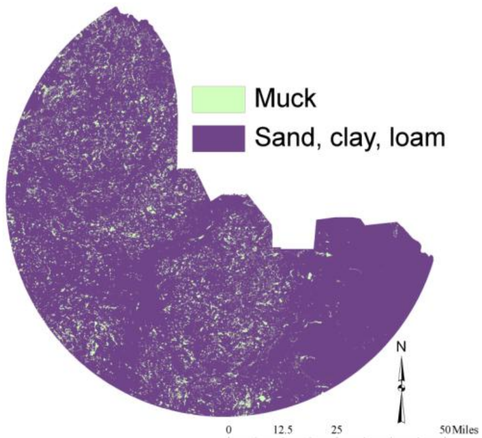

Figure 2. Soil textures desired by native grasses include sand, clay and loam. Muck was masked out of the study.

Another study indicates a pH from four to eight is best in North Dakota (McLaughlin, Kszos, and June, 2005). The entire area had a pH within these parameters; therefore, the pH layer was discarded.

The 30 meter DEMs were mosaiced together and extracted to the study area. Slope was derived with the ESRI *spatial analyst*. Areas with a slope of less than 13 percent were extracted using the ‘reclassify’ tool (Figure 3). Slopes of 13 percent were selected based on the work of Lemus, Brummer, Burras, Moore, Barker, and Molestad (2008). Lemus et al. (2008) evaluated switchgrass fields in Iowa with slopes up to 13 percent. Another Iowa study mentions that land greater than 18 percent should be avoided for growing crops and greater than 25 percent is very steep (Al-Kaisi and Hanna, 2001).

Precipitation and flooding were not included in the model. Native grasses are well adapted to dry and moist conditions as indicated by numerous studies including that of Rhinehart (2006). This area of Minnesota receives an average of 28 to 36 inches of rain per year with the west being somewhat drier than the east (Prism, 2006). Barney, Mann, Kyser, Blumwald, Van Deynze, and DiTomaso (2009) found switchgrass has a high tolerance of soil moisture availability in both moisture deficit and flooded conditions.

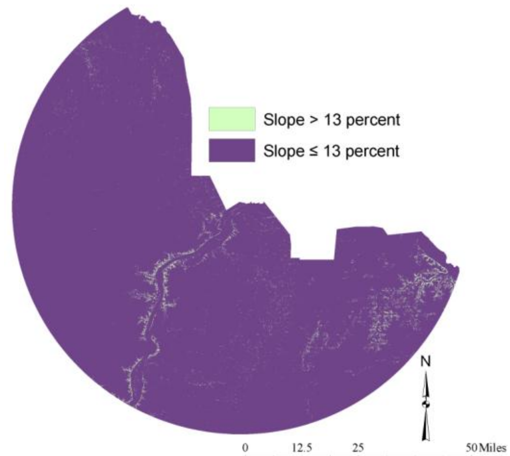

Figure 3. Steeper slopes in the middle and to the east are mostly along riverbanks.

Water

Growing native grass for biofuels can help ground and surface water quality and increase wildlife abundance. Native grasses use less fertilizers and pesticides and have the ability to absorb chemical runoff from nearby areas and therefore serve as a buffer to water resources and natural areas (Graham, Liu, and English, 1995). In *Energy from Biofuels: the Greening of America* (1998) professor Dick Schultz indicates he would like to see buffer zones (including switchgrass) harvested for biomass.

The 1:24,000 NWI and MN Data Deli rivers, lakes, and streams data layers were downloaded and clipped to the study area. The wetlands and lakes were combined into one layer and then the layer was buffered by 300 feet based on the Minnesota Pollution Control Agency's recommended buffer for agriculture (Minnesota Pollution Control Agency and the NRCS, 2005). Castelle, Johnson, and Conolly (1994) suggest literature reveals three meters to 200 meters as an effective wetlands/stream buffer thus the average buffer is 100 meters (or 300 feet). Chang (2006) indicates at least 300 feet is required to protect wildlife habitat.

A 'Dissolve' was used on the output lakes and wetlands buffer layer and then the lakes and wetlands layers were 'erased' from the output as native grasses will not grow in the lakes and wetlands, only in areas surrounding them. Streams were buffered by the same distance. These were then merged with the lakes/wetlands buffer layer and finally converted to a raster layer.

Parks

Parks included state, regional, and county parks as well as Fish and Wildlife management areas (WMA), waterfowl production areas (WPA), permanent wetlands preserves (PWP) and scientific and natural areas (SNAs). Local and regional parks data came from ESRI and the Data Deli GAP (Gap Analysis Program) ownership layer. Protected wetlands were extracted from the BWSR layer.

Minnesota county biological survey data were downloaded from the DNR website. These data represent areas with high quality native plant communities and rare plants and animals (Minnesota Department of Natural Resources, 2010). "Outstanding" and "high occurrence" biodiversity categories were selected by attribute and extracted from the layer. These two categories were selected as the metadata indicated these were the areas with the greatest likelihood of occurrences of the rarest species, rare native plant communities or important functional landscape elements and should therefore be protected. The data were combined into one output parks layer and then buffered by 300 feet, dissolved, erased and converted to a raster as was the water layer in the previous step (Figures 4 and 5).

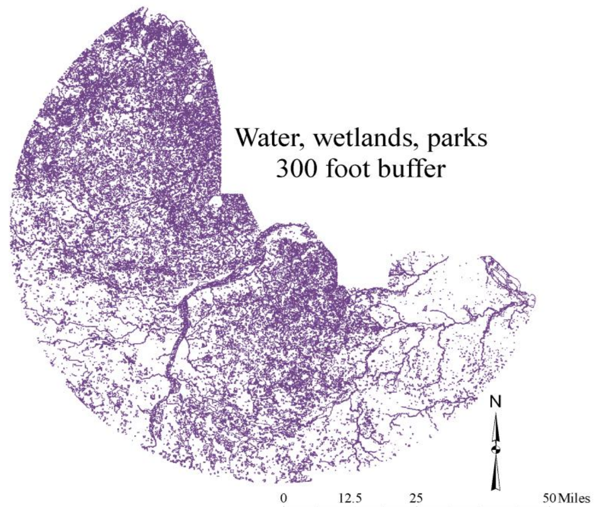

Figure 4. Water, wetlands, parks, outstanding and high biological significance 300-foot buffer. Areas not buffered include agricultural, developed, and forested land.

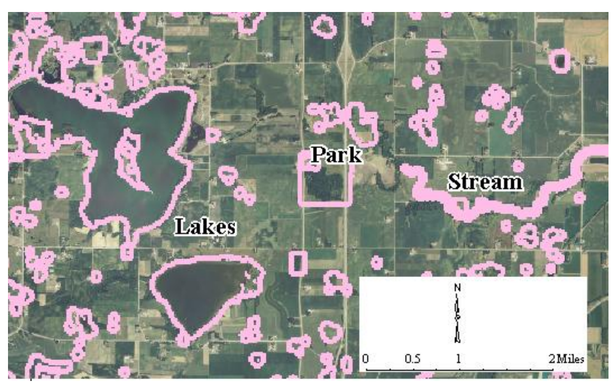

Figure 5. A close-up of the buffer layer overlaying the ortho-photo. Notice the buffer along the stream and lakes. The square buffer is around a state preserve. Smaller areas include parks and wetlands.

Wildlife

“Moderate” and “below” categories of biodiversity from the county biological survey data were extracted from the layer. The metadata indicates that these areas represent landscapes that contain areas of moderately disturbed native plant communities to areas that are potential habitats for plants and animals (MN Department of Natural Resources, 2010). Both categories have the potential for recovery and restoration and thus would make good areas to grow native grasses (Figure 6).

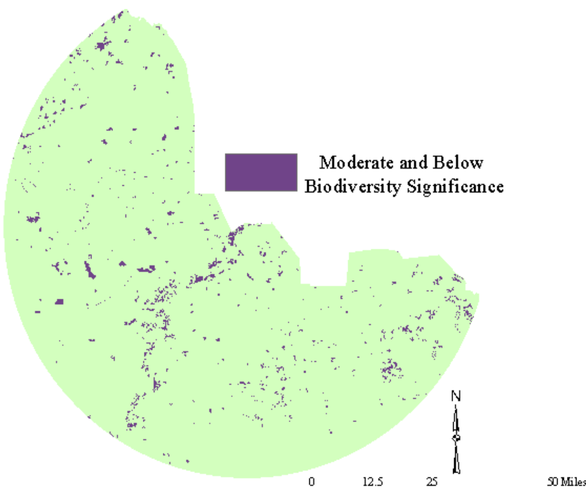

Figure 6. Moderate and below biological significant areas.

A “Select by attribute” was run on wild turkey and deer hunting data from the DNR Data Deli to extract turkey harvest greater than 200 (max 540) for 2008 and deer harvest greater than 1000 (max 2466) for 2007 (Figure 7). These cutoff numbers for analysis were selected based on natural breaks. The data were summarized by permit areas.

Numerous studies show wildlife prefer native grasses. Turkey and deer were selected as the data were available and both have been shown to benefit from native grass fields (Wild Turkey, 1999; Jones-Farrand, Burger, Johnson, and Ryan, 2007; Harper and Keyser, 2008). The moderate and below biologically disturbed areas and the turkey/deer layers were combined and converted to a raster layer.

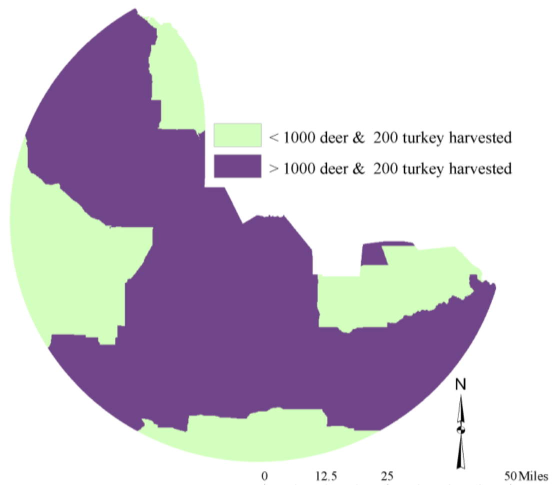

Figure 7. Greater than 200 wild turkey and 1000 deer harvested in 2008 combined into one layer.

Land Use

Regions 6, 8, and 9 were downloaded from the NLCD website. The regions were extracted to the study area and mosaiced together using a weighted blend. The data were reclassified to just grassland. The CDL (cropland data layer) data were downloaded from the NASS website and reclassified to fallow and grassland. The in-house EPA agricultural data layer, a combination of NLCD, NASS CDL and Landfire data was reclassified into fallow and grassland (Mehaffey, 2009).

The three output layers were compared to each other and to the ortho-photos. None of the layers were entirely accurate and the NASS layer resolution was not as high (60 meters) as the others (30 meters). The NLCD layer did not include fallow agricultural land or prairie land.

The EPA layer included prairie grassland and was used to create two output files. The first layer created was the fallow/idle cropland layer (Figures 8 and 9). The second layer included grassland/ herbaceous, undefined agriculture: pasture/hay, bluestem/tall grass prairie and modified managed tall grassland (Figure 10).

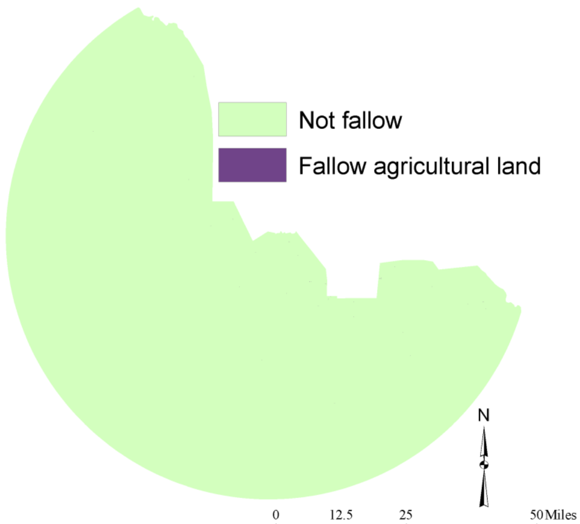

Figure 8. Fallow agricultural land. There were only 256 cells that were fallow (30 meter resolution).

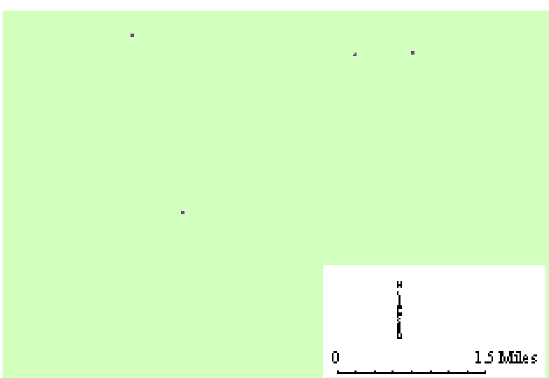

Figure 9. A close-up view of fallow land of an area in the north-central region. Each dot is approximately two pixels (60 by 60 meters).

Land Ownership (CREP)

In the next fifteen years it is estimated that 15 million acres of switchgrass will be grown on Conservation Reserve Program (CRP) land. Corn is predicted to be a crop of choice due to the demand for ethanol (Laws, 2006). The CRP was established in 1985 to reimburse farmers for removing highly erodible cropland from production to help preserve this land. Farmers are required to plant the fields in perennial cover, mostly grasses. Many of these leases will soon be expiring and there is growing concern that this land will be planted into corn. Studies have shown that CRP land is much more productive for wildlife with grass cover than with row crops.

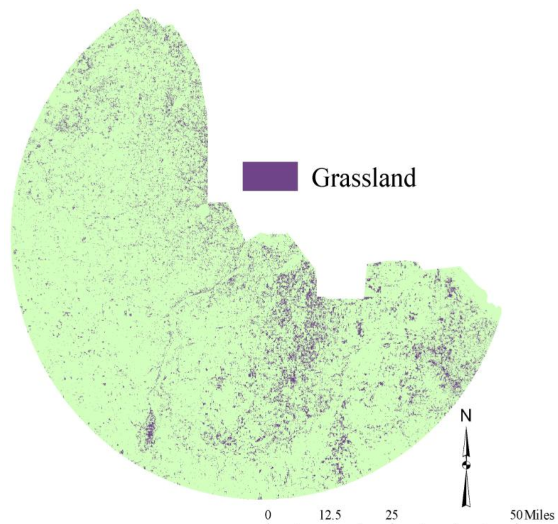

Figure 10. Tall prairie, grassland, and hay.

Conservation Reserve Enhancement Program (CREP) data were extracted from the BWSR layer that was downloaded from their website and was current as of October 2009. The state of MN CREP is similar to the federal CRP program in that it protects fish and wildlife habitat with farmers keeping the land out of production. RIM (Reinvest in Minnesota) data is included with the CREP data (a similar state program). Federal CRP data was not available. A “Select by attribute” was run to select permanent easements and easements set to expire after 2012 or 2018 on the marginal cropland and pasture data (wetlands were excluded). The data was converted to a raster layer using a 30-meter cell size and reclassed into one category (Figure 11).

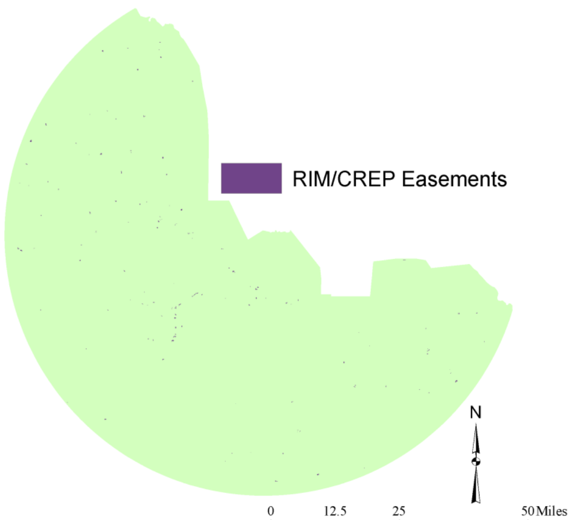

Figure 11. Ownership (easements) layer. There were over 9,000 cells in this category.

Model Development

A suitability model was created in ArcGIS. The layers were assembled in the ESRI Model Builder and then the weighted sum tool was run on them. Four preliminary layers were created. Slope and texture were combined into one layer as these are physical characteristics and have similar priorities.

The water/parks buffer layer and the grasslands were combined into another layer. These layers were given similar priorities because buffer areas and grasslands are both good wildlife transitional zones. The moderate/low biological diversity data and the deer and turkey abundance layers were combined into one wildlife layer. Both of the layers were lower priority wildlife areas and therefore were combined.

Lastly, the CREP easements and fallow agricultural land were combined into a forth layer. Both of these categories are high priority to grow native grasslands because agricultural land enrolled in the state CREP program and fallow land are not used for anything else therefore are most likely to be available for growing native grasses for biofuels. These areas will also continue to be good wildlife habitat and should not be converted to the production of corn.

In the first step (Figure 12), the layers were given the same weights (one) except for the biological layer. The biological survey data were given a higher rating than the deer/turkey layer because the deer/turkey layer was more generalized and not as precise as the biological survey data (Table 1).

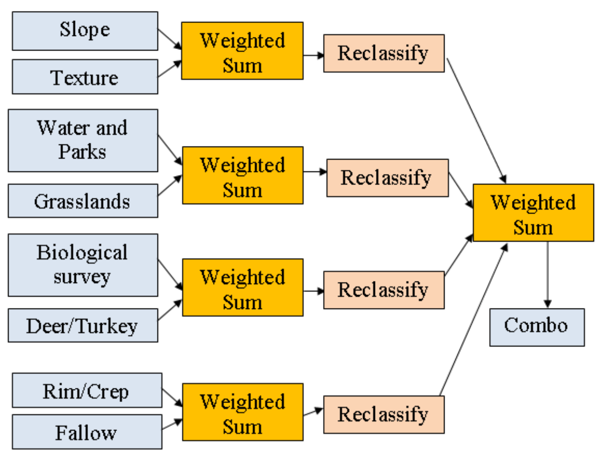

Figure 12. Model structure created in ArcGIS Model Builder.

The layers were then reclassified to ascribe the data to the same scale (1 conditions wanted, 0 conditions not wanted). In the physical characteristics (slope/texture) layer the twos (best characteristics) were reclassified to ones. This excluded the lower priority areas in the lowest class. In the wildlife layer, the values of two were reclassified to ones and the threes were reclassified as twos thus eliminating the lowest class. The other layers only had one category in the output (Table 1).

A “weighted sum” was run on the

four output layers from the previous step to create the final combination layer (Figure 12). A sensitivity analysis was performed using different weight combinations. Some weights did not show much of a difference and others were too dramatic.

Two alternative scenarios were chosen for exploration. The first scenario was based on the priorities mentioned above. The ownership (easements)/fallow layer was given the most important weight of 0.7. The parks/water buffer/grassland layer was give a weight of 0.5 and the biological moderate low/turkey/deer layer was given a value of 0.3 (Table 2). The physical characteristics layer was given a

Table 1. Model input.

Layer	Weight	Output	Reclassed
Slope	1	0	0
Texture	1	1	0
		2	1
Deer/Turkey	1	0	0
Below/Moderate Biological	2	1	0
		2	1
		3	2
Grass Land	1	0	0
Parks/water buffer	1	1	1
		2	2
Ownership	1	0	0
Fallow land	1	1	1

weight of 0.1 as texture and slope are important to native grasses yet grasses are hearty and can grow on steeper slopes and in muddier texture although they would not be as productive.

Once the output layer was generated, some of the water, forest and developed land were still on the map. The NLCD forested and developed land was extracted and then combined with the lakes and river layer. This layer was subtracted from the final output using a condition statement in the raster calculator: (con ([output] >= 0 and [subtraction layer] =0, [output]).

The second alternative assigned the first category the same (ownership/fallow = 0.7), but the slope/texture layer was the next priority with a 0.5 value. The parks layer was give a 0.3 and the biological layer then a 0.1 (Table 2). This output was based on the scenario that areas to grow native grasses/switchgrass should have the best physical characteristics to have the most production. The subtraction layer was then removed from the final output as with the previous alternative.

Table 2. Alternative 1 and 2 input weights. The four layers are the combined outputs from the previous step. Ownership includes the fallow layer and so forth.

Alternative 1		Alternative 2	
Final layer	Weight	Final layer	Weight
Ownership	0.7	Ownership	0.7
Parks	0.5	Slope	0.5
Biological	0.3	Parks	0.3
Slope	0.1	Biological	0.1

Results

Alternative 1

The first scenario output ranged from zero to 2.45. Natural breaks for four categories were used to divide the data into low, moderate, high and excellent native grass production categories. The data were then reclassified into categories one to four, with four being the highest priority (Table 3 and Figure 13).

Alternative 2

The second scenario result ranged from zero to 2.8. Natural breaks for four categories were used to divide the data into low, moderate, high, and excellent native grass production categories. The data were reclassified into four categories with four being the highest priority (Table 4 and Figure 14).

Acres by county were derived and tabulated using the “tabulate area” tool in ArcGIS. Acres per county and by category for both alternatives are presented in Tables 5 and 6 respectively. The data were exported into Excel to visualize the trend in acres per county identified as having good and excellent conditions (Figures 15-18).

Table 3. Alternative 1 output reclassified weights.

values	reclassified	categories
0-0.2	1	Low
0.2-0.8	2	Moderate
0.8-1.3	3	Good
1.3-2.45	4	Excellent

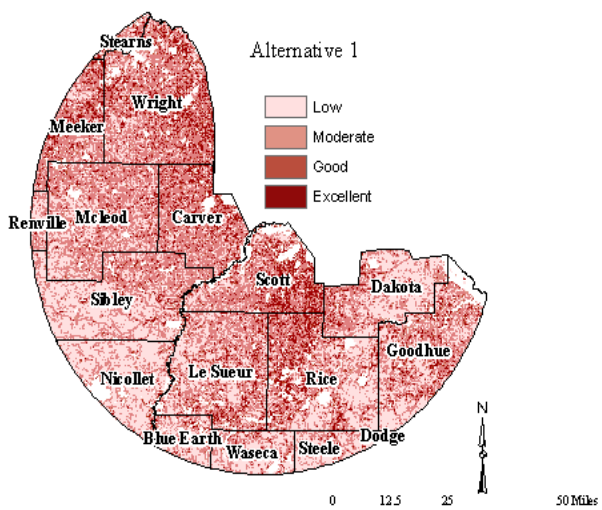

Figure 13. Alternative 1 with ownership/fallow as most important, followed by the parks/grassland layer.

Table 4. Alternative 2 output reclassified weights.

values	reclassified	categories
0-0.2	1	Low
0.2-0.6	2	Moderate
0.6-1.0	3	Good
1.0-2.8	4	Excellent

Model Validation

The four final reclassified layers for each of the combined layers from the model output were converted to ASCII files and imported into SAS (Statistical Analysis System) as well as CART (Classification and Regression Tree) software to determine whether the grouping used could be replicated using the same four final input variables (slope/texture, biological/deer/turkey, parks/grasslands and ownership (easements)/fallow) without any assigned weights.

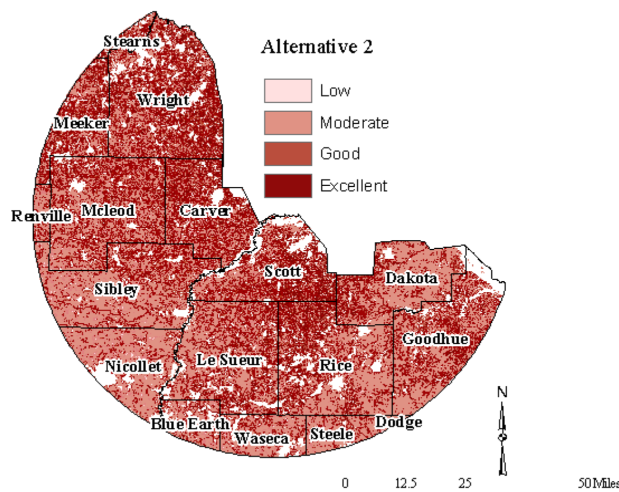

Figure 14. Alternative 2 with ownership/fallow as most important followed by the slope/texture layer.

Table 5. Alternative 1 acres by county and category.

	Low (1)	Moderate (2)	Good (3)	Excellent (4)
BLUE EARTH	35,747	7,157	796	2
CARVER	91,016	53,417	7,787	83
DAKOTA	136,530	29,626	2,988	9
DODGE	3,216	119	2	0
GOODHUE	143,007	39,984	6,056	78
LE SUEUR	165,907	48,576	6,528	47
MCLEOD	192,705	62,364	3,929	105
MEEKER	55,270	32,257	5,213	174
NICOLLET	137,065	14,164	894	17
RENVILLE	18,634	3,738	169	11
RICE	162,968	54,869	11,709	129
SCOTT	78,750	47,099	11,463	120
SIBLEY	211,584	44,026	3,022	81
STEARNS	7,219	5,139	1,057	66
STEELE	50,726	7,290	784	2
WASECA	63,643	10,422	1,084	2
WRIGHT	142,545	88,167	15,218	72
totals	1,696,533	548,415	78,699	997

SAS

This process used un-supervised classification to group pixels based on the four final layers listed above. Unsupervised clustering classifies or groups pixels into clusters without knowing what the clusters are. Three processes were run in SAS (Proc Fastclus, Proc Cluster, Proc Tree) to cluster and graph the tree. The SAS algorithm produced eight clusters (Figure 19) and with the aid of the clustering hierarchy in a clustering tree, clusters were lumped into four classes. The lumping of eight clusters gave different patterns than that of the two alternatives in ArcGIS. SAS showed a clumping of categories 4-6, with 7 nearby and then 1 by itself. Three and 8 were clumped together and then 2 nearby (Table 7). The SAS ASCII output was converted back to raster with its eight categories. Comparing it to alternative one, 1 and 7 were grouped as low, 2 and 4 as moderate, 3, 5, and 8 as good and 6 as excellent. Comparing it to alternative two, 7 was in the low category, 1 was in the moderate category, 2, 4, 5, 6, and 8 were good, and 3 was excellent.

Table 6. Alternative 2 acres by county and category.

	Low (1)	Moderate (2)	Good (3)	Excellent (4)
BLUE EARTH	2,493	34,019	6,536	654
CARVER	9,355	88,585	47,916	6,447
DAKOTA	1,327	136,548	28,572	2,706
DODGE	9	3,211	116	2
GOODHUE	1,331	143,224	39,497	5,073
LE SUEUR	10,230	160,411	44,780	5,637
MCLEOD	13,846	184,229	57,880	3,147
MEEKER	5,871	53,804	29,280	3,959
NICOLLET	11,140	128,425	12,137	438
RENVILLE	1,078	17,983	3,350	140
RICE	6,266	161,771	51,877	9,762
SCOTT	7,262	76,173	43,938	10,059
SIBLEY	14,343	201,692	40,947	1,732
STEARNS	657	7,130	4,951	743
STEELE	3,129	48,269	6,737	667
WASECA	5,920	59,418	8,972	841
WRIGHT	12,598	137,334	82,220	13,851
totals	106,854	1,642,225	509,705	65,858

CART

The CART output classification trees are shown in Figures 20-23. Both alternative 1 and 2 were run separately. Unlike SAS, a supervised classification was used in CART to classify and group pixels into classes compared with that of alternative 1

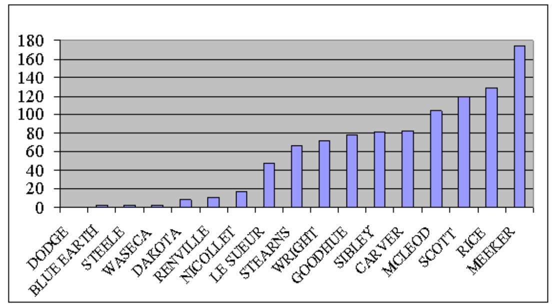

Figure 15. Alternative 1, excellent category by county in acres. Note the small amount of acres.

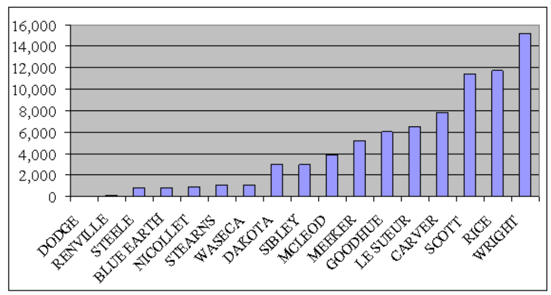

Figure 16. Alternative 1, good category by county in acres.

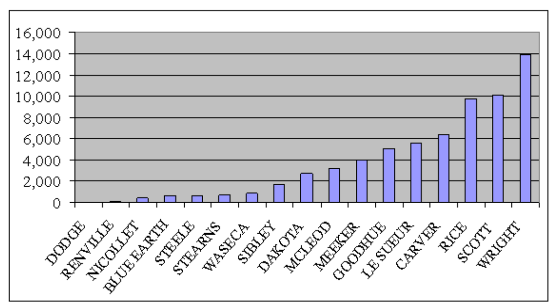

Figure 17. Alternative 2 excellent category by county in acres.

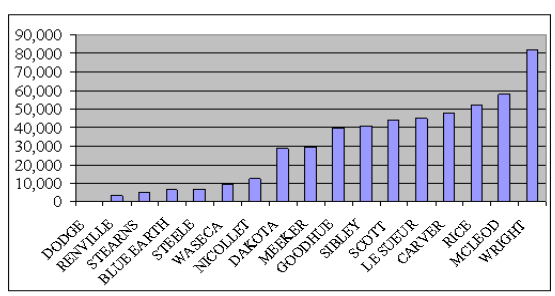

Figure 18. Alternative 2 good category by county in acres. Note the large amount of acres.

and 2. Supervised classification means the clusters are known. One output from CART is a tree that reveals the hierarchal spatial structure in the relationships between the predictors (the four categories- low to excellent). The tree is a binary recursive partitioning method that splits the data into homogenous groups based on a set of logical if-then conditions for classification of the sites. Each branch lists the priorities (1 = low to 4 = excellent) and the percentage in that 'leaf' before it breaks down into another level of leaves. Scoring from CART to the input data were converted to an ASCII file which then was converted to raster, imported into ArcGIS and areas were calculated using 'tabulate area' in ArcGIS (Table 8 and Figures 24 and 25).

Discussion

Trends

Both scenarios, alternative 1 and 2, showed areas toward the northwest (Wright and Meeker counties; McLeod and Carver) and middle and southern middle (Scott, Rice, LeSueur counties), as well as the far east (Goodhue county) as being the best areas to grow switchgrass/native grasses. Alternative 1 had a much smaller area in the excellent category (997 acres/ vs. 65,858 acres for alternative 2) as well as a much larger area in the low category (1,696,533 acres) versus alternative 2 (106,854 acres). This was partially due to alternative 2 having slope and texture as more important whereas alternative 1 had it least important since much of the region has a good slope and texture for switchgrass/native grasses.

SAS Validation

Model validation for SAS showed that although some of the input variables were correctly weighted, more work could be done to refine others. Perhaps using the continuous value of the input variables themselves instead of the discrete data would be useful (Tables 3 and 4). Alternative 2 seemed to be more beneficial as the clumping was not as scattered (Table 7).

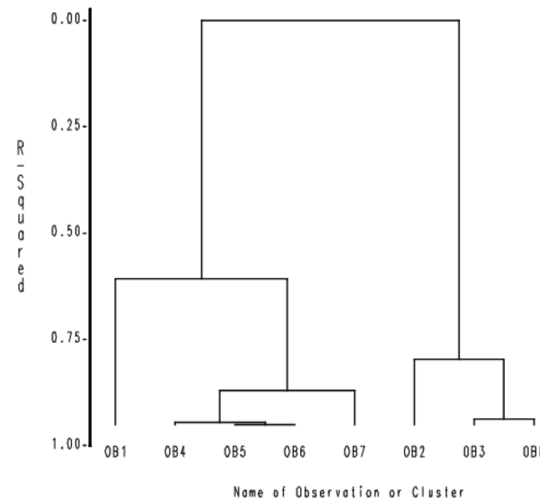

Figure 19. SAS output cluster tree by category. There are two main branches.

Table 7. The variables are the clusters from the SAS tree in Figure 19 by branch. Categories refer to the output categories of the alternatives.

SAS	Alternative 1	Alternative 2
Branch 1:		
1	low	moderate
4	moderate	good
5	good	good
6	excellent	good
7	low	low
Branch 2:		
2	moderate	good
3	good	excellent
8	good	good

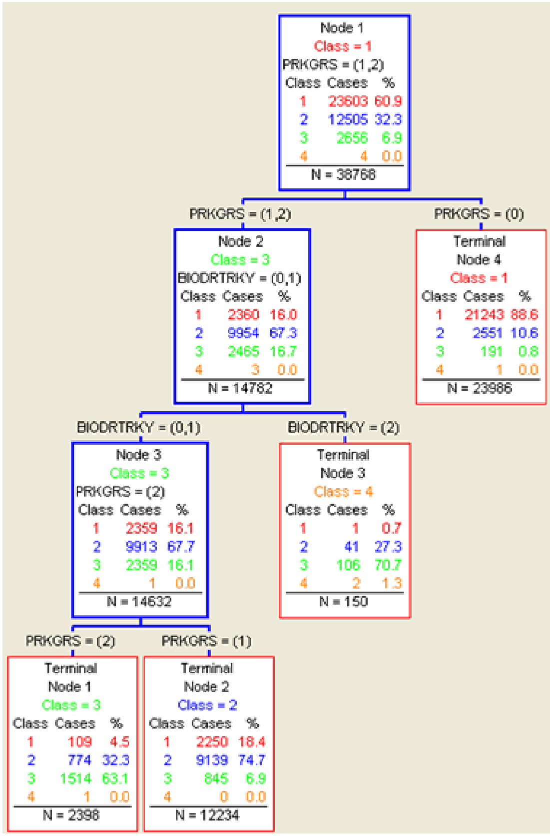

Figure 20. CART output alternative 1. Split from node 1 is based on the parks pixels, while pixels with zero parks are grouped into one final group of a relatively homogenous class. Pixels with the parks category equal to 1 or 2 were further split into many groups based on parks and biological aspects in pixels. The red boxes denote the final (terminal nodes) groups that share relatively similar characteristics of the splitting variables.

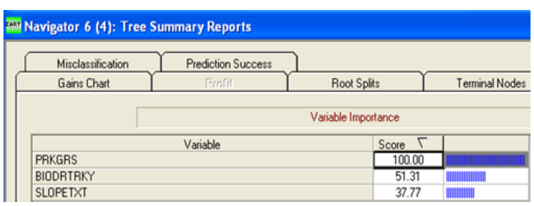

Figure 21. CART summary report, alternative 1. The relative importance of predictors in classification and building the tree is shown in Figure 20. The parks layer was the most important variable followed by biological and slope.

Cart Validation

Model validation for alternative 1 using CART showed that the outputs were somewhat less reliant in ArcGIS for the

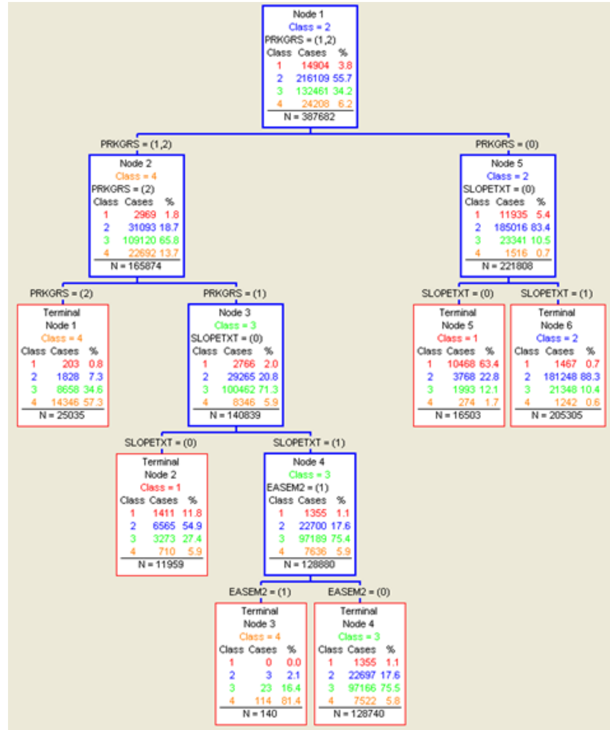

Figure 22. CART output alternative 2. Split one is again based on parks, but this time one more split took place where parks = 0. This time the slope and easement categories play a role in splitting and forming the classes where it was absent in the previous alternative (Figure 20).

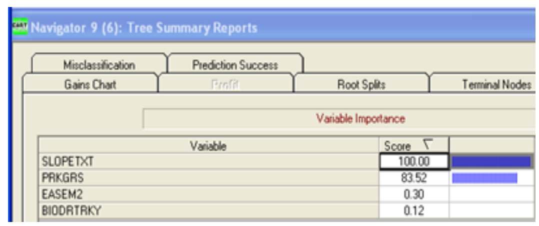

Figure 23. CART summary report, alternative 2. All four variables participated in forming classes or clusters where slope was the most important followed by parks, easements and biological last. The resulting tree is shown in figure 22.

excellent category (Table 5 and 8) that uses ownership/fallow as the highest weight. This could be partly due to the fact CART takes a sample of the data and there were only a small amount of pixels in the "excellent for native grasses production" category. The counties were divided similarly over the excellent category (Figures 15 and 24). Other categories were somewhat closer in similarity of acreage predictions per county (Tables 5 and 8).

In CART alternative 1 parks and then biodiversity were the most important and exhibited the same pattern as the input weights associated with the fallow layer. The slope/texture layer did not appear, as this was the lowest priority in alternative 1. The relative importance of the variables that participated in CART classification for alternative 1 showed parks and biological to be the most important predictors. Ownership (easement) was not listed as a predictor of importance (Figure 21).

For alternative 2, parks appeared first in the CART diagram (Figure 22) but slope was given the highest priority (Figure 23) and then slope was considered with easements added last in the final leaf. Biodiversity had the lowest weight. This followed the weights associated with alternative 2. The excellent category was very similar in both the ArcGIS and CART output (Figures 17 and 25). The totals were quite close as well (Table 6 and 8). Acreage by county for all categories was very close. From these model validations, it appears that alternative 2 was more predictive. Alternative 1 appears to need more refinement.

Future Implications

The next step is to look at these higher priority areas in both scenarios and compare them to ortho-photo quads, visit the locations that look promising and determine who owns the land. The counties closest to the biofuel plant (Carver and Scott) have an abundance of excellent and good land; therefore this would be a good place to start. Wright County may be a good place to look as it is strong in the good and excellent categories in three of the four groupings in the two alternatives. Meeker and Rice County also came up high in the excellent category in alternative 1 and in the CART comparison.

Table 8. Total area (acres) by category for alternative 1 and 2 from CART output.

	Low	Moderate	Good	Excellent
Alternative 1	1,645,293	501,662	62,117	5,134
Alternative 2	151,692	1,539,522	459,835	63,157

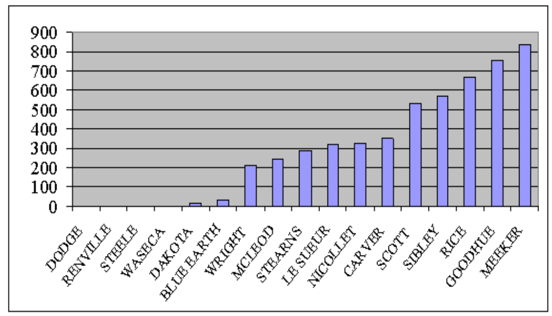

Figure 24. Alternative 1 excellent category CART output in acres per county. Note pattern similarities (but scale differences) with ArcGIS model output (Figure 15).

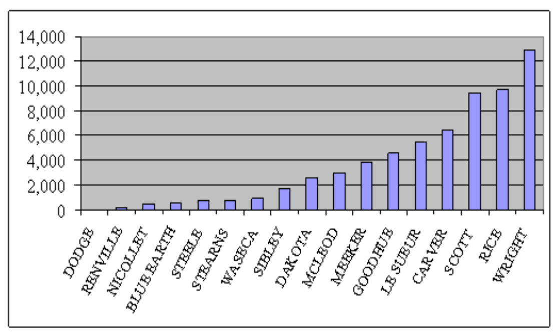

Figure 25. Alternative 2 CART excellent output in acres per county. Note similarities with ArcGIS model output (Figure 17).

Other variables that could be included in future model revisions include transportation routes such as road and railroad access. The USDA Farm Service Agency CRP layer could enhance the model. There has been some concern that native grasses grown for biofuel on CRP land need to be managed for wildlife as this is the purpose of the program as harvest time and pesticide application can effect wildlife (Bies, 2006; De La Torre Ugarte, Walsh, Shapouri, and Slinsky, 2003). Other wildlife data layers could be included. There have been several studies showing how birds prefer a switchgrass environment if managed properly (Murray, Best, Jacobsen, and Braster, 2003; Roth, Sample, Ribic, Paine, Undersander, and Bartelt, 2005).

Graham, English, Noon, Jager, and Daly (1997) evaluated minor crops being converted to switchgrass. In the next fifteen years as the price of switchgrass becomes competitive with other crops, it is estimated 11 million acres of soybeans and 6 million acres of wheat could be converted to switchgrass (Laws, 2006). The twenty percent of corn that goes into ethanol production could also be replaced with native grasses for biofuel. This would enhance the land and not degrade it as planting on CRP land could do (Khanna, 2008; Yates, 2008). Corn and soybean fields could be extracted from the CDL or EPA crop layers and added to the model.

This model could be expanded to other biofuel plants in Minnesota and with a few modifications (such as wildlife input) expanded to other regions of the United States. The model could be used for regions where a biofuel plant is being considered, however economics would then need to be added to the model to make it more useful. There are numerous models and studies that have included the economics of transporting biofuels such as switchgrass from farm to plant.

As mentioned by Haddad and Anderson (2008), each of the variables that go into a suitability model are based on professional judgment and expertise, data availability and site-specific knowledge. Suitability models are highly dependent on the reclassified and weighted values. Different combinations of weights could be modified in this model depending on the persons or groups creating priorities. For instance, having the biological layer as the highest priority or the water/parks buffer or grasslands may offer other alternatives. Grouping the original layers differently is another possibility.

Conclusion

This model was created using several input layers including physical characteristics (slope and texture), a buffer layer (water, parks and outstanding and high biological significant), wildlife data including moderate and low biological significance and deer and turkey data, grassland and fallow land from the EPA land use layer, and lastly State of MN CREP easements (ownership data). The data were given weights in the suitability model and two alternative outputs were produced, each based on different weights. These layers were validated using SAS and CART statistical software.

The two alternatives and their maps will help managers (including the Nature Conservancy and Koda Energy) to visualize spatially areas of interest and locate areas where native grasses might be grown. The production from these areas could be then used by the Koda Energy Plant.

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