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The Role of Payment for Environmental Services toward Encouraging Energy Production in Illinois State Floodplains

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TITLE: The Role of Payment for Environmental Services toward Encouraging Energy Production in Illinois State Floodplains

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The general objective of this research is to analyze different land use scenarios in a specific floodplain region of Illinois that utilizes levees in district setting. The specific objective for this research is as follows: 1) Analyze the current land use of the levee district overtime based on current crop production and farm practices. 2) Analyze alternative land use based on energy crops such as switchgrass.

In this study we will attempt to estimate the potential biomass supply of levees in ten counties of Illinois State. We will focus on studying fifty two levee districts that are adjacent to the Illinois River. The levees are spread to ten counties in the state of Illinois. The data this paper uses is geospatial data to measure the amount of production potential of switchgrass in levee districts.

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INTRODUCTION

Restoring levee districts in Illinois State to their original floodplain may foster local energy crop industry and demand driven payment for environmental service. Demand driven Payment for environmental services (PES) has been identified as an important environmental policy tool that can help farmers to change their behavior for providing ecosystem services (ES). ES are essential services that nature provides in order to sustain human wellbeing on this earth such as biodiversity, nutrient recycling, soil regeneration, air and water purification, flood control, and carbon recycling (Daily et al., 1997). The relationship between humans and nature is so intertwined that any damage to nature will ultimately reduce essential ES such as provision, regulating, supporting, and cultural that nature supplies and that will affect human's welfare (Millennium Ecosystem Assessment, 2005). In this paper we assume PES as only demand driven payments which promotes market-based mechanism for providing demanded ES such as flood control, water purification, energy crops, recreational and cultural services. Unlike supply driven current policy instruments such as government income support and subsidies system for stricter conservation guidelines and land retirement (Smith 2006), PES encourages land owners to explore different kinds of land use that can provide ES while helping land owners maximize their income potential. Although PES has, in the future the ability to foster markets that buyers and providers of ES exchange services, without intermediary medium such as government support-based programs but at early stages it will be necessary to garner substantial public support such as effective regulation (King, 2005) and dedicated resources to created firmly rooted markets. If PES is to be one of the viable instruments for conservation and cost savings for the tax payers it will need initial investment and set of rules that are thoroughly monitored and enforced by the government (Secchi and Soman, 2010) otherwise it is bound to be a castle on the air.

There are problems we need to tackle before using PES as policy instrument such as defining property rights of ES (Lant, Ruhl, and Kraft, 2008) and calculating the correct incentive price that encourages farmers to switch their existing methods to a one that provides ES (Polasky, 2008). Currently common good problems and the tendency to free-ride are discouraging providers of ES to produce those services while policy makers are asking how much incentive should be offered to encourage the production of ES. Agricultural lands, which have well defined legal land ownership rights and known production functions, are also the largest managed ecosystem familiar to humans (Swinton et al., 2007). It can easily be viewed as an exception and the best case scenario to test the viability of PES as a policy instrument (Kroeger and Casey, 2007). Although agricultural lands have the potential to provide ecosystem services such carbon sequestration, water quality, biodiversity preservation, and landscape aesthetics, agricultural lands can be enlisted to produce perennial grasses such as switchgrass for biomass energy (S. B. McLaughlin and Walsh, 1998). This policy not only will enhance energy independence but additionally will augment production of ES as a byproduct.

Floodplains, like rivers, oceans or mountains are essential parts of the world's ecosystem and will certainly result in great environmental disturbance if they vanish. According the floodplains the same importance as the other bodies of our ecosystem, we can conclude that restoring agricultural lands on a floodplain to near its natural state offers great environmental benefits which are highly demanded and quantifiable. (Costanza and et al., 1997) placed swamps and floodplains as the second highest ecosystems total value per hector. Although the paper ignited a lively debate about the total value of ecosystems and attracted both constructive and not so constructive criticism, one that stands out is (Toman, 1998) who pointed out how important is to calculate the opportunity cost that enable the policy makers total information about the options they face. To entice the farmers to take advantage of those demands, it is important to calculate operational costs of planting crops that can nurture floodplains to their original habitat and to determine appropriate amount of PES incentives for providing ES. Planting perennial grasses, such as switchgrass on agricultural floodplains, can present landowners an opportunity to supply demanded energy crop and ES. In this study we will also attempt to estimate the potential biomass supply of levees in ten counties of Illinois State.

LITERATURE REVIEW

Presently, agricultural lands are used to produce food, fuel and fiber as their primary goals. With growing demand of food, fuel and fiber due to increasing global population, it is almost impossible to ask land owners to change their priority of producing those provisions. On the other hand, we know that all the agricultural lands have different yield crop capability and some lands are marginal which require higher inputs or produces higher environmental negative externalities (Lubowski et al., 2006). Moreover, agricultural lands have different potential to provide stacked ES and different environmental yield benefits (Antle and Valdivia, 2006). Considering concepts of marginal productivity and maximum environmental benefit, agricultural lands on floodplains have the right attributes to provide stacked ES and greater environmental benefit by reducing negative externalities in which production agriculture creates (Manale, 2000).

Furthermore, space and scale are essential to achieve greater economic and environmental benefits (Hein et al., 2006) and the location of the agricultural floodplain is vital for determining potential benefits (Rouquette et al., 2009). For example, if the agricultural floodplain is located near farm lands that can produce biomass as a byproduct such as corn stover, it will be economically more attractive than other floodplains.

Switchgrass as potential biofuel that can contribute the national demand of energy were examined by (S. McLaughlin et al., 1999) and found out that not only switchgrass has high yield but also significantly increases soil carbon which improves soil quality and reduces erosion in long term. They also suggested gains of energy return and reduced carbon emission after 18 test sides reported average yield of 16 Mg/ha and minimum costs of $1.78-2.03/MBtu for farm scale production in the Southwest of United States. Although (Pimentel and Patzek, 2005), argued that switchgrass yield more net energy when used as pelletized than converting into ethanol which results negative energy return, but subsequent studies such as (Schmer et al., 2008) found out that switchgrass produced 540% more energy out compared to fossil fuel input.

The environmental benefits of producing switchgrass on cropland instead of conventional crop rotation such as corn-soybean, or corn-soybean-wheat, sorghum-soybean, sorghum-soybean-wheat were reported (Nelson, Ascough II, and Langemeier 2006). Using SWAT model simulation accounted sediment yield, surface run off, NO_3 –N in the surface run off and edge-of-field erosion average reduction of 99, 53, 34 and 98% respectively when applied to N between (0-224kg N ha^{-1}). They also recorded an average of 50% environmental saving for the four variables in every scenario with $22-$27.49 Mg^{-1} at edge-of-field switchgrass price.

RESEARCH QUESTION

This paper will focus on studying fifty two levee districts that are adjacent to the Illinois River. The levees are spread to ten Counties in the state of Illinois. All levees are located on Alton reach and La Grange reach. The key challenges which the farmers face it they decide to change their current crop rotation to energy crop. a) *Unknown production cost function* how much will it cost to plant switchgrass per acre considering Illinois floodplain soil productivity. b) *Unknown yield function* what is the yield considering different types of practice that is suitable to Illinois farm land. c) *Unknown market prices* what is the market price per ton in Illinois. *d) Unknown delivery costs* what is the transportation cost to utility plants and potential ethanol plants in Illinois. As (D. Mooney et al., 2008) purported the choice of switchgrass as biofuel feedstock was based on it is high yield on marginal land although there is little empirical research about cost of production and yield on different environments such as floodplains.

The general objective of this research is to analyze different land use scenarios in a specific floodplain region of Illinois that utilizes levees in district setting. The specific objective for this research is as follows: 1) Analyze the current land use of the levee district overtime based on current crop production and farm practices. 2) Analyze alternative land use based on energy crops such as switchgrass.

DATA AND METHODS

DATA

The data this paper uses is geospatial data to measure the amount of production potential of switchgrass in levee districts. First used is the USDA (NASS) Cropland Data Layer (CDL) for Illinois State 2010 which contains crop specific digital data layers and grid data which is suitable for use in geographic information systems (GIS) applications. The second data used is the Nature's Conservancy selected levee districts which is also geospatial data in the form of shapefile (received from Dr Secchi). The third data set used is the USDA Farm Services Conservation Reserve Program (CRP)– cumulative enrollment by year (Acres). The fourth data set used is the Soil Survey Geographic (SSURGO) database which contains county level developed by the National Cooperative Soil Survey. Finally, the three scenarios of low, medium, and high yield per acre assumptions are based on the three studies covered next. The first study (Duffy and Nanhou 2001b) that was carried out in Southern Iowa assumes a yield of 3.36–13.45 (t ha^{-1}) and after averaging out and converting to acres it is estimated to come to 3.4 ton/acre. The second study (Khanna, Dhungana, and Clifton-Brown 2008) estimates Illinois yield assumption which assumes a yield of 9.42 (t ha^{-1}) on average which converts to 3.8 ton/acre. The final study (English and University of Tennessee 2006) estimated US production of biomass and assumes that the Corn Belt region can have a base yield of 5.98 ton/acre.

METHODS

To determine potential switchgrass production in levee districts and the counties that the levee districts are located in, this paper will use ArcGIS and will follow the following steps. First the research will estimate the levee districts potential production. The second step will estimate the potential production of CRP land that is located in the ten levee district counties. The third step will estimate the pasture land that is located outside the levee districts but located in the rest of the ten counties. The final step will examine the production capacity of different cellulose ethanol plants and match the total production potential of the study area.

1. Estimating Levee Districts Potential Production

Using ArcMap spatial analyst tool and the mask extracted tool, the TNC is selected for the levees shapefile on Illinois Crop Data Layer raster Grid so that we can know exactly what grows on the selected levee districts. We are only interested in crop land, and more specifically the crop land that falls between 1 and 62 NASS classification values. Using attribute extraction to the table of the new TNC Selected levees raster data from step one, we will choose land that is suitable for switchgrass, which is any land that has a classification value of 62 or less (see Map 1).

The placement of each pixel in levee districts to the correct county that it belongs to is crucial in order to merge Soil Survey Geographic (SSURGO) feature data for the ten counties. Converting to raster form so that it can be extracted using TNC selected levees shapefile on the new ten counties Soil Survey Geographic (SSURGO) raster data will give us TNC raster data with specific FIP and Mukey numbers. After combining TNC Selected levees Crop Data Layer raster data and TNC Selected Soil Survey Geographic (SSURGO) raster data, the outcome is TNC raster data with each levee's county FIP number in order to assign each levee to the county it belongs to (see Map 2). Estimation of the switchgrass production potential is achieved by creating a new acreage column in the attribute table and converting the count column to acres and then multiplying the three scenarios of yield assumptions (see Chart 1).

2. Estimating the Potential Switchgrass Production on CRP Land.

Merging of the ten counties shapefile feature class polygon in the Soil Survey Geographic will result in a single ten-county feature data. Then merging the single feature data attribute table with USDA Farm Services conservation reserve program – cumulative enrollment by year (Acres) excel sheet will give us the ten counties' acreage shapefile. Multiplying the three scenarios of yields will produce total switchgrass production potential in CRP land that is located in the ten selected counties (See Map 3 and Chart 2).

3. Estimating the Pasture Land Production.

Step three is almost like step one but this time we are interested the counties instead of levees. To estimate pasture land production, we are only interested in the NASS classification value of 62 pasture/grass and

181pasture/hay plus the pasture land of the ten counties (but that land which is not in the levee districts in order to avoid double counting). First, the selected TNC shapefile is used to erase the levee districts in the ten counties merged shapefile. After step one, we use the new shapefile which is the ten counties minus their levee districts to mask extraction Illinois Crop Data Layer raster data. In order to get the pixels we used attribute extraction to find the areas that have classification values of 62 and 181. We will also want to know which pixels are located in which county when we merge the ten counties' Soil Survey Geographic (SSURGO) feature data so that they can be converted to raster form and then extracted using the ten counties without levee districts shapefile on the new ten counties Soil Survey Geographic (SSURGO) raster data. The new counties without levee districts raster data will have specific FIP and Mukey numbers. After combining both the ten counties without levees Crop Data Layer raster data with values of only 62 and 181 with the ten counties without levees Soil Survey Geographic (SSURGO) raster data, the outcome is ten counties without levees raster data with each county FIP number (See Map 2). Estimation of the switchgrass production potential is achieved by creating a new acreage column in the attribute table and converting the count column to acres and then multiplying the three scenarios of yield assumptions, which can calculate how much each county can produce (See Chart 3).

4. Estimating the Feedstock Needs of A Typical Cellulosic Ethanol Plant

It is very difficult in estimating the feedstock need of a typical cellulosic ethanol plant since the technology is still its infant stage, and there are only a few working cellulosic ethanol plants that exist in the USA. This will potentially cause insufficient data in our estimation, so we will reply on the two cellulosic ethanol plants that are near Illinois and they are DuPont Danisco Cellulosic Ethanol LLC (DDCE) of Vonore, Tennessee (Sheridan, 2008) and POET, LLC of Emmetsburg, Iowa (Coyle, 2010) . The DDCE plant processing started December 2009 at $54MM Project Cost Nominal and a capacity of 250kgal/yr - 40-100X scale up where the primary feedstock is corncobs and switchgrass. The POET plant, which the Department of Energy has given a $105 million loan guarantee, is the first commercial-scale cellulosic ethanol plant in Iowa. The plant will be completed by 2013 and will use corn cobs, leaves, husks and stalks as feedstock. The plant capacity is 25 million gallons per year.

To estimate what is the feedstock need of a typical plant we will use the POET plant that has a capacity of 25 MGY, and also the DDCE plant is scalable up to 100 times which will be 25 MGY, the same as the POET plant capacity. We will assume a typical plant is 25 MGY and we will use that number to calculate how many cellulosic ethanol plants the Levee Districts can supply. According to the DDCE website switchgrass conversation per dry ton is 100 gallons or 380 liters (DDCE 2011).

Table 1 Conversion Rate Ton Switchgrass Gallon of Ethanol

Feedstock	Ethanol Yield per Dry Ton	
	Gallons	Liters
Corncob	113	428
Switchgrass	100	380
Sugar cane Bagasse	112	424
Rice Straw	110	416
Forest Thinnings	82	310
Hardwood Sawdust	101	382

RESULT

Currently the levee districts land that is dedicated to the crop production is 153,547 acres in which corn dominates at 104,294 acres and followed by soybeans which consist of 41,261 acres within the levee district (See table1). Since most of the land in the levee districts is currently under corn and soybean crop, if the farmers change their food crop production to switchgrass their initial investment will be small or none.

Table 2 Each value class at levee district contribution to production in four scenarios

VALUE	CLASS NAME	ACRES	Duffy and Nanhou 2001 3.4	Khanna et al 2008 3.8	English 2006 5.98
1	Corn	104,294	354,600	396,317	623,678
5	Soybeans	41,261	140,287	156,792	246,741
6	Sunflower	2	7	8	12
12	Sweet Corn	5	17	19	30
13	Pop. or Orn. Corn	171	581	650	1,023
24	Winter Wheat	334	1,136	1,269	1,997
26	Dbl. Crop WinWht/Soy	-	-	-	-
27	Rye	12	41	46	72
28	Oats	15	51	57	90
36	Alfalfa	104	354	395	622
37	Other Hay	69	235	262	413
42	Dry Beans	5	17	19	30
43	Potatoes	-	-	-	-
58	Clover/Wildflowers	3	10	11	18
59	Sod/Grass Seed	1	3	4	6
60	Switchgrass	-	-	-	-
61	Fallow/Idle Cropland	24	82	91	144
62	Pasture/Grass	7,247	24,640	27,539	43,337

Using the three scenarios the total levee district feedstock production are 522,060 tons, 583,479 tons, and 918,213 tons of dry switchgrass per year respectively (See table 2). Most production will come from the levees that are located at Cass, Scot and Fulton.

Table 3 Levee Districts Switchgrass Production Potential per County

			Duffy and Nanhou 2001 3.4 /acre	**Khanna et al 2008 3.8 t/acre**	**English 2006 5.98 t/acre**
County	FIP	Levee District Acres	Low Production Tons	Medium Production Tons	High Production Tons
Brown	IL009	5,363	18,234	20,379.40	32,071
Cass	IL017	47,178	160,405	179,276.40	282,124
Fulton	IL057	20,210	68,714	76,798.00	120,856
Mason	IL125	-	-	-	-
Morgan	IL137	11,619	39,505	44,152.20	69,482
Peoria	IL143	324	1,102	1,231.20	1,938
Pike	IL149	10,470	35,598	39,786.00	62,611
Schuyler	IL169	13,921	47,331	52,899.80	83,248
Scott	IL171	30,088	102,299	114,334.40	179,926
Tazewell	IL179	14,310	48,654	54,378.00	85,574
Total		**153,483**	**521,842**	**583,235.40**	**917,828**

If we multiply the 100 gallon per year with the three scenarios the levee districts can produce 52,206,000 gallons, 58,347,900 gallons, and 91,821,300 gallons per year respectively. This kind of potential production can conservatively support two plants of the size of POET plant at Emmetsburg, Iowa which has 25MGY.

Another feedstock supply source that can supplement the levee district's cellulosic production is CRP land. If we consider the current land under CRP in the ten counties, and more specifically located near the levee district, there is more potential feedstock supply (See table 4).

Table 4 CRP Land Switchgrass Production Potential

			Duffy and Nanhou 2001 3.4 t/acre	Khanna et al 2008 3.8 t/acre	English 2006 5.98 t/acre
County	FIP	CRP Land Acres	Low Production Tons	Medium Production Tons	High Production Tons
Brown	IL009	13,486	45,852	51,247	80,646
Cass	IL017	13,638	46,369	51,824	81,555
Fulton	IL057	9,309	31,651	35,374	55,668
Mason	IL125	11,933	40,572	45,345	71,359
Morgan	IL137	8,587	29,196	32,631	51,350
Peoria	IL143	4,467	15,188	16,975	26,713
Pike	IL149	29,993	101,976	113,973	179,358
Schuyler	IL169	16,679	56,709	63,380	99,740
Scott	IL171	6,018	20,461	22,868	35,988
Tazewell	IL179	11,193	38,056	42,533	66,934
Total		125,303	426,030	476,151	749,312

The production capacities of the CPR land in regards to the three scenarios are 426,030 tons, 476,151 tons, and 749,312 tons of dry per year switchgrass respectively. The potential cellulosic ethanol production is 42,603,000 gallons, 47,615,100 gallons, and 74,931,200 gallons per year respectively. The CRP land in the ten counties that the levee districts are located can at least support two POET plant size.

The pasture land in the ten counties also offers another potential energy source that can supplement the feedstock supply. The pasture land is divided as 57,744 acres of Pasture/Grass and 363,485 acres of Pasture/Hay (See table 5). Pasture land can produce 143,208,700 gallons, 160,056,800 gallons, and 251,878,800 gallons per year respectively (See table 6).

Table 5 Total Pasture Land Switchgrass Production Potential without Levees

			Duffy and Nanhou 2001 3.4 t/acre	**Khanna et al 2008 3.8 t/acre**	**English 2006 5.98 t/acre**
Value	Class Name	Pasture Land Acres	Low Production Tons	Medium Production Tons	High Production Tons
62	Pasture/Grass	57,744	196,330	219,427	345,309
181	Pasture/Hay	363,485	1,235,849	1,381,243	2,173,640

Table 6 Pasture Land Switchgrass Production Potential per County

			Duffy and Nanhou 2001 3.4 t/acre	**Khanna et al 2008 3.8 t/acre**	**English 2006 5.98 t/acre**
County	FIP	Pasture Land Acres	Low Production Tons	Medium Production Tons	High Production Tons
Brown	IL009	33,965	115,481	129,067	203,111
Cass	IL017	18,319	62,285	69,612	109,548
Fulton	IL057	74,873	254,568	284,517	447,741
Mason	IL125	23,599	80,237	89,676	141,122
Morgan	IL137	35,102	119,347	133,388	209,910
Peoria	IL143	41,154	139,924	156,385	246,101
Pike	IL149	93,250	317,050	354,350	557,635
Schuyler	IL169	45,210	153,714	171,798	270,356
Scott	IL171	17,722	60,255	67,344	105,978
Tazewell	IL179	38,008	129,227	144,430	227,288
Total		421,202	1,432,087	1,600,568	2,518,788

Currently pasture land in the ten counties can supply feedstock that is larger than the levee feedstock supply and CRP land feedstock supply. Pasture land can supply at least two POET size plant and maximum to five POET size plant.

DISCUSSION

The levee districts which are located in floodplain can offer plenty of opportunity to supply energy and produce environmental services. The cost to transform food crop production to energy crop production will be high but as this study shows building a cellulosic ethanol plant near one of levee district can encourage the farmers to switch. It can also contribute other environmental services such flood protection, ecotourism and wild life reserve.

The study shows, using the conservative number of (Duffy and Nanhou, 2001a) which is the lower number of 3.4 ton per acre switchgrass production, that the levee districts can at least support two cellulosic plants which are the size of POET plant. Although it is expensive initially to set up the plant and it will need a public funding but it will create demand for environmental service which in long run will benefit both the environment and renewable energy technology (See Table 7).

Table 7

	Levee District Production Potential		
Ton	522060	583479	918213
Gallon	52206000	58347900	91821300

It is important to notice that environmental services and economic valuation of their benefits are still not mapped in detail format. But as this modest study shows there the places that we need to put more emphasis such as environmentally sensitive lands like floodplains and levee districts which are capable to produce both energy and environmental service.

The study is a very primitive form in such it did not contain production habits of the farmers, crop rotations, budgets and transportation costs. Considering currently there are more than sixteen power plants are located in the ten counties we studied (See Map 5). The study only examined whether the levees in ten counties of Illinois can supply a cellulosic ethanol plant. It also stipulated in doing so will create demand for environmental services and energy crops. It is important that further research will be conducted in this very exciting topic.

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APPENDICES

APPENDIX

Figure 1

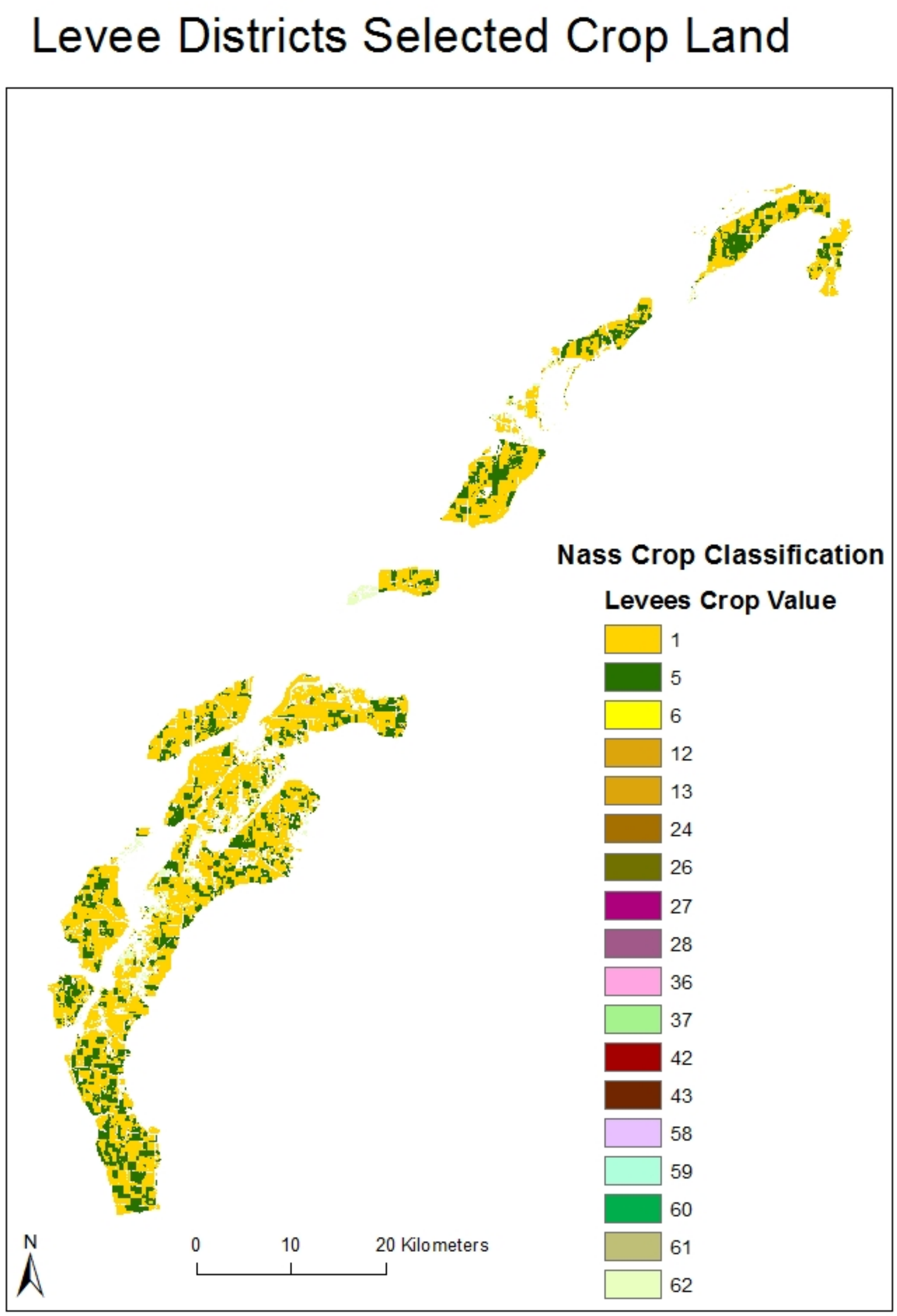


Figure 2. GIS Model of Creating Raster Data to Estimate Switchgrass Production

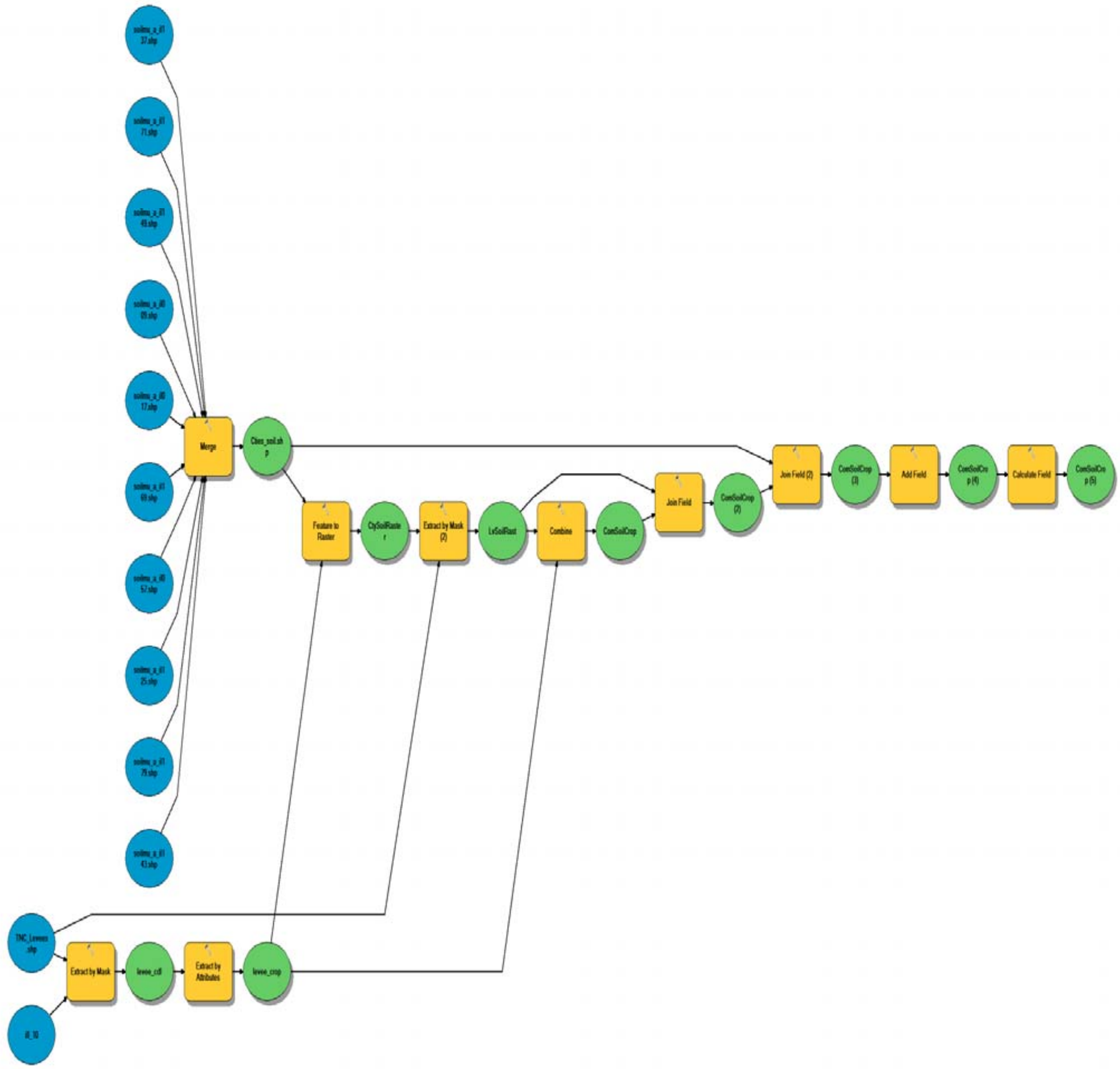


Figure 3

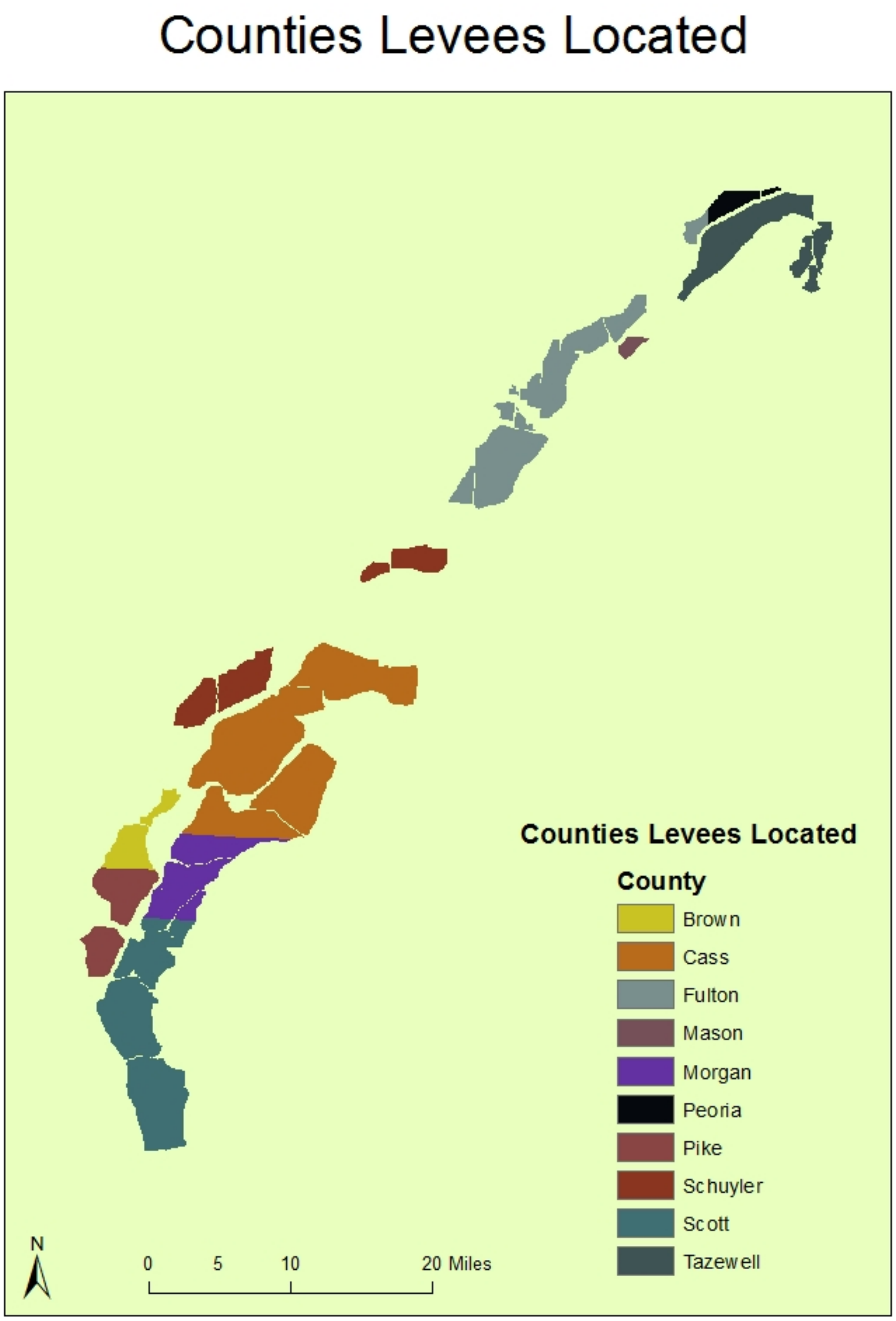

Counties Levees Located
Counties Levees Located
County
Brown
Cass
Fulton
Mason
Morgan
Peoria
Pike
Schuyler
Scott
Tazewell
N
0
5
10
20 Miles

Figure 4 GIS Model Estimating CRP land Switchgrass Production

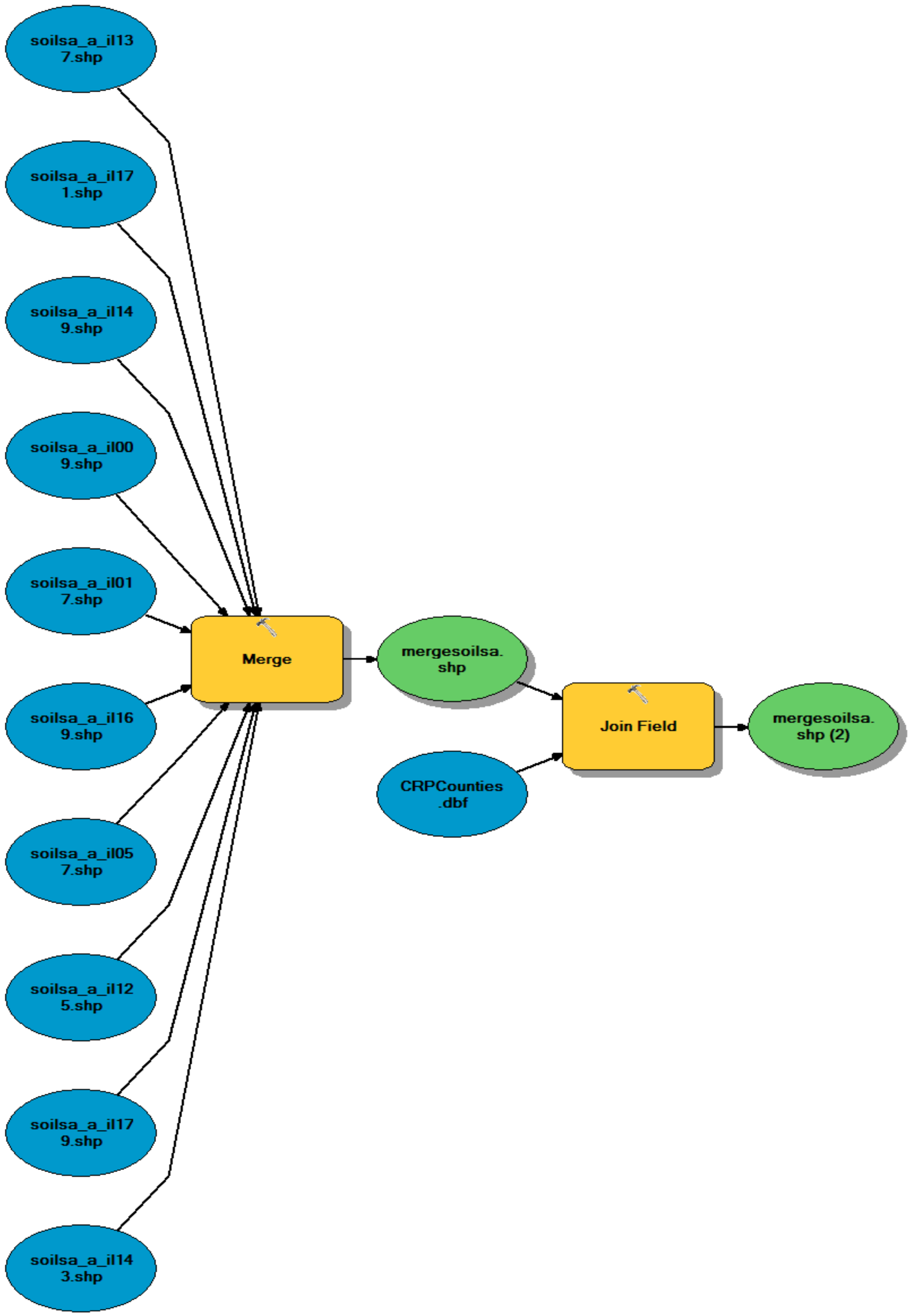


Figure 5

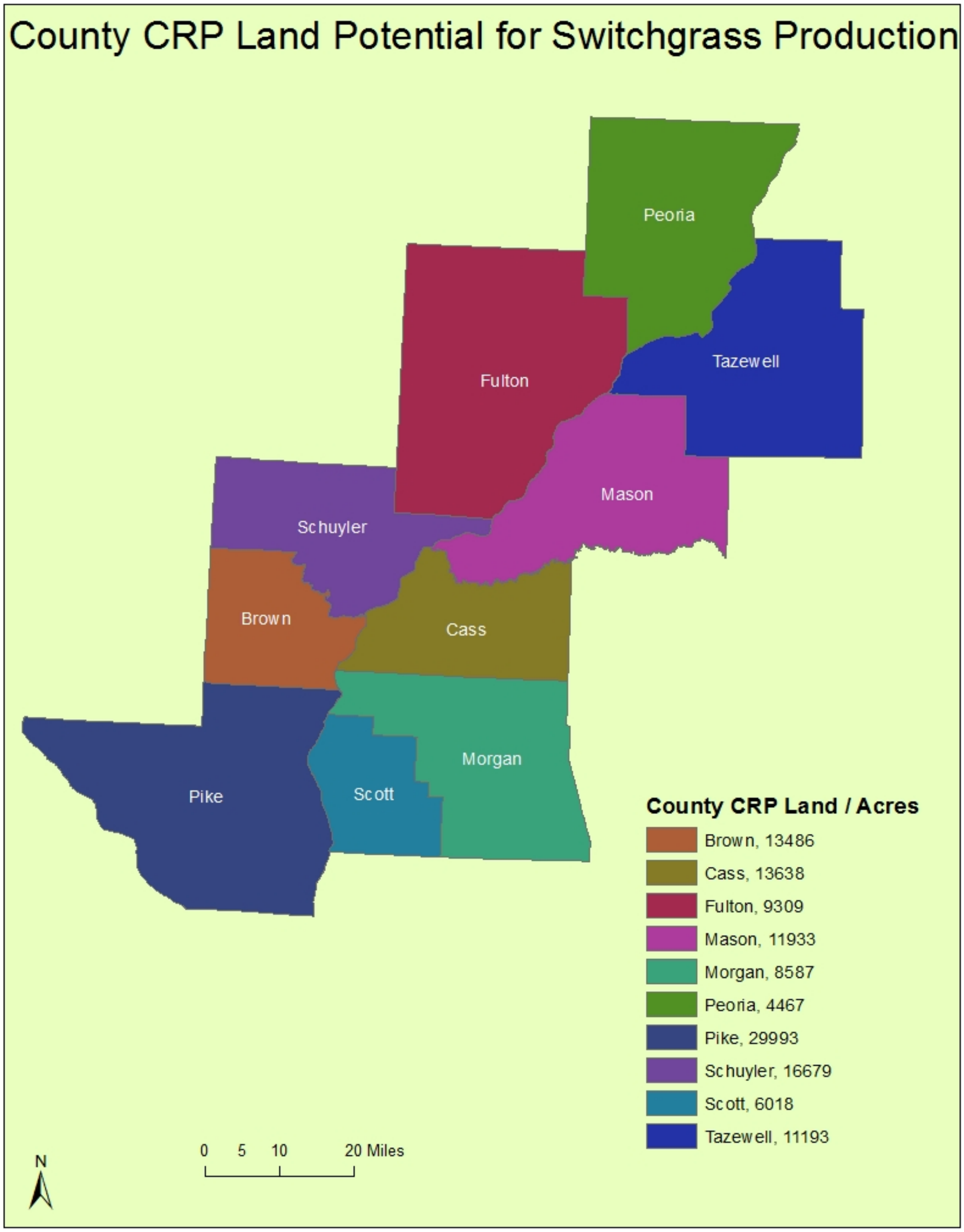

County CRP Land Potential for Switchgrass Production
Peoria
Fulton
Tazewell
Mason
Schuyler
Brown
Cass
Morgan
Pike
Scott
County CRP Land / Acres
Brown, 13486
Cass, 13638
Fulton, 9309
Mason, 11933
Morgan, 8587
Peoria, 4467
Pike, 29993
Schuyler, 16679
Scott, 6018
Tazewell, 11193
0 5 10 20 Miles
N

Figure 6 GIS Model Estimating Pasture land Switchgrass Production

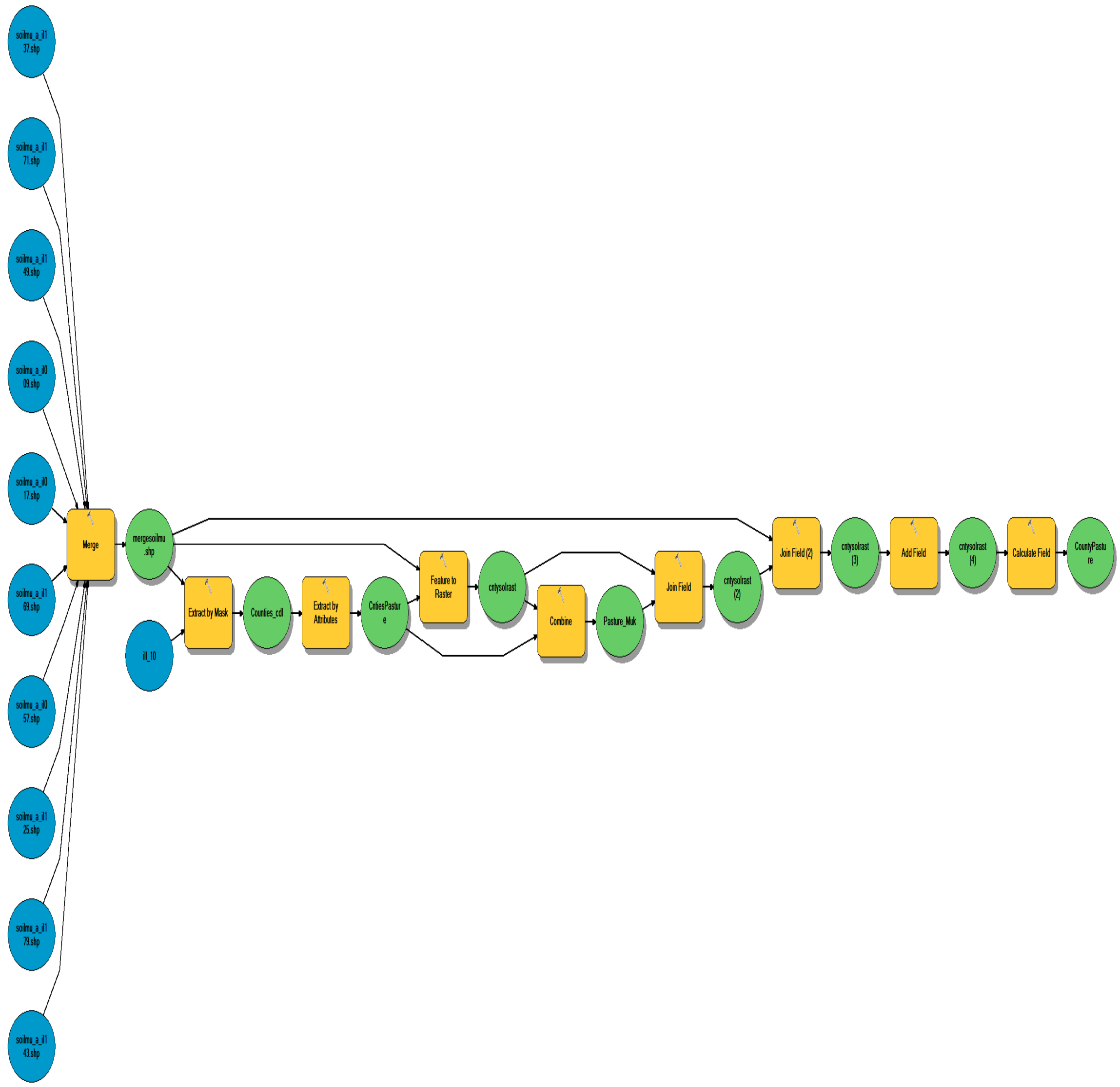


Figure 7

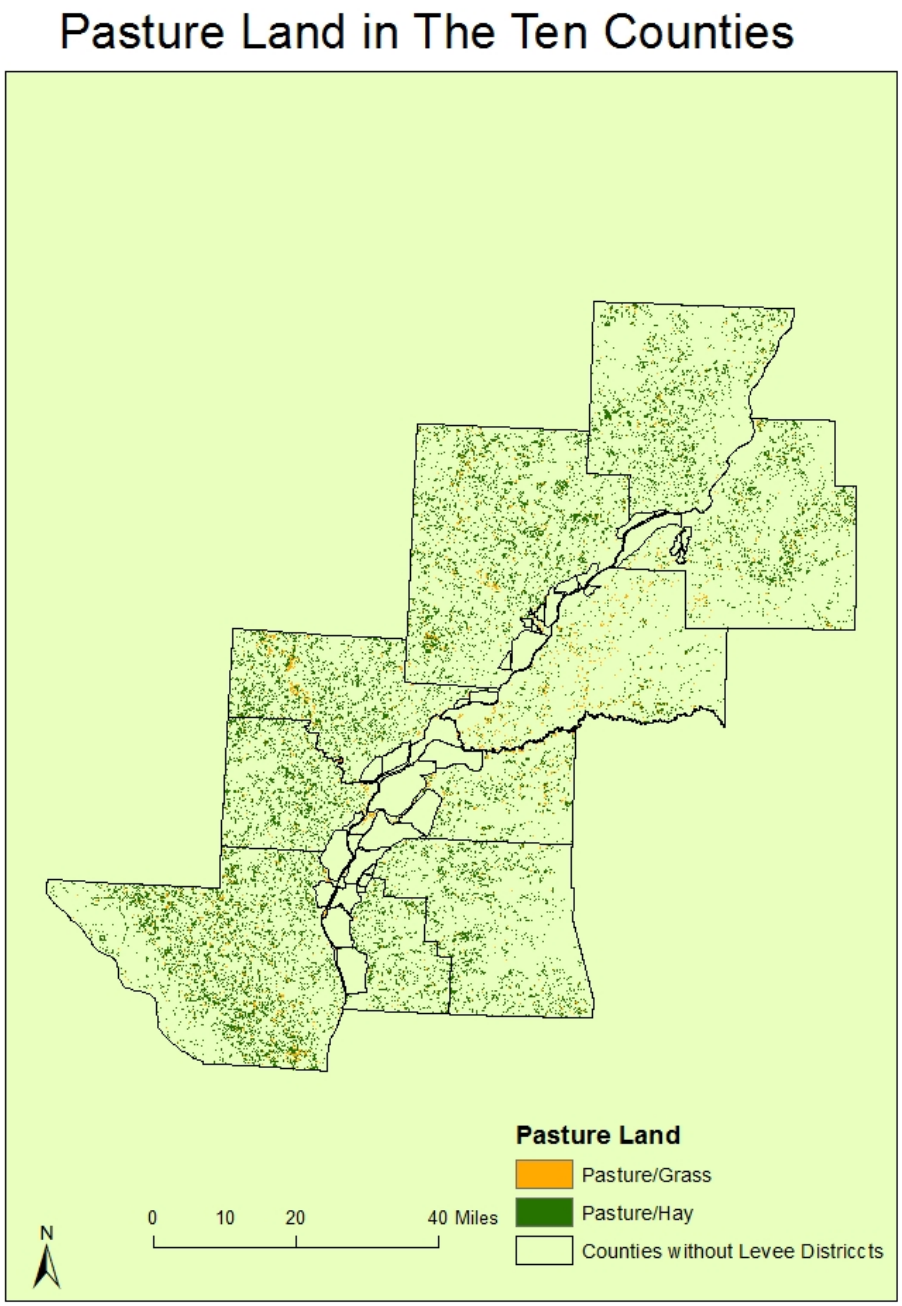
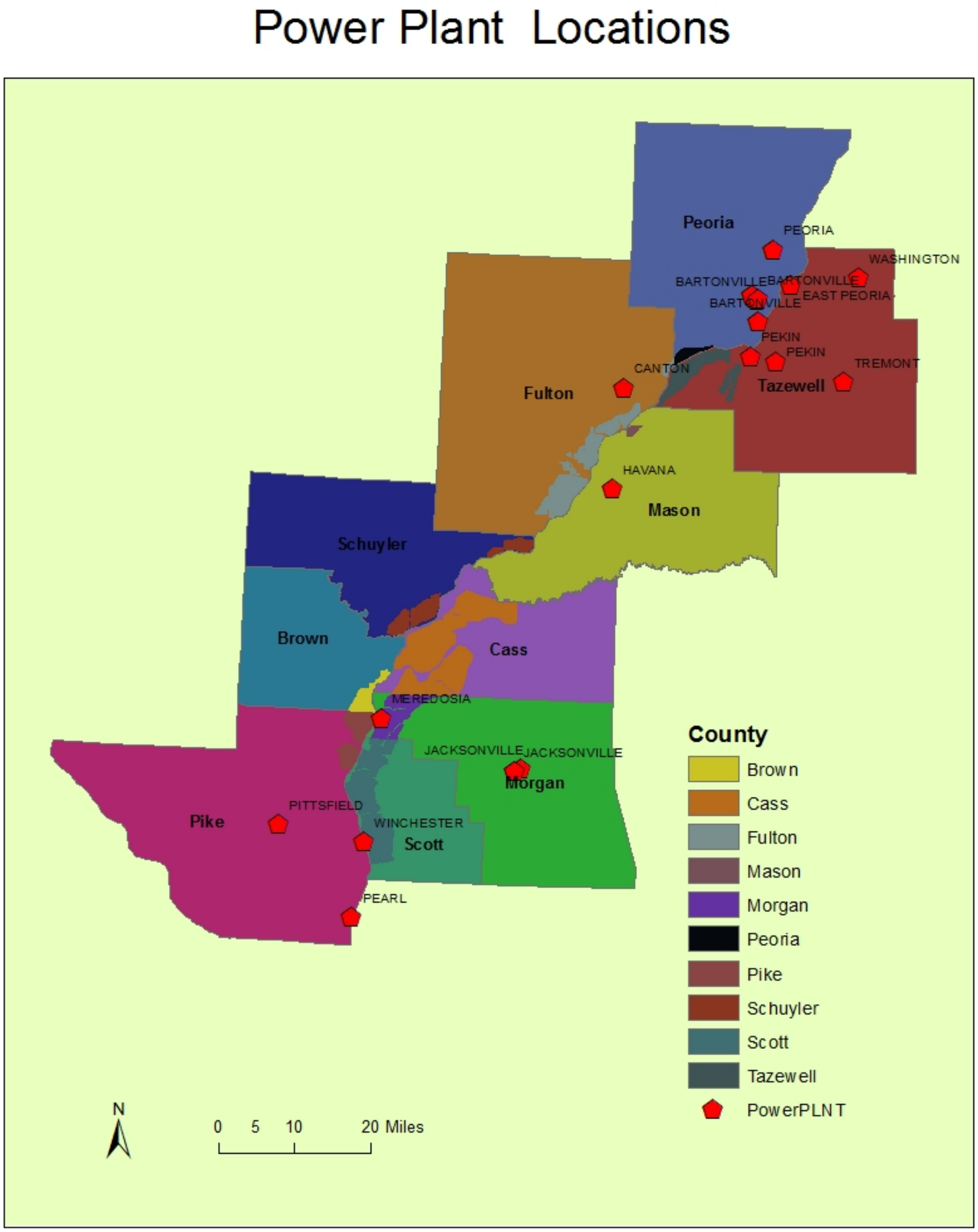

Pasture Land in The Ten Counties
Pasture Land
Pasture/Grass
Pasture/Hay
Counties without Levee Districcts
0
10
20
40 Miles
N

Figure 8


Power Plant Locations
Peoria
PEORIA
WASHINGTON
BARTONVILLE
BARTONVILLE
BARTONVILLE
EAST PEORIA
PEKIN
PEKIN
TREMONT
CANTON
Fulton
Tazewell
HAVANA
Mason
Schuyler
Brown
Cass
MEREDOSIA
JACKSONVILLE
JACKSONVILLE
Morgan
PITTSFIELD
Pike
WINCHESTER
Scott
PEARL
County
Brown
Cass
Fulton
Mason
Morgan
Peoria
Pike
Schuyler
Scott
Tazewell
PowerPLNT
N
0 5 10 20 Miles

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