Potential Biomass Yields in the South Central US

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Abstract

This paper describes research to create a national database of switchgrass supply as part of the biomass program launched by the Department of Energy. The paper provides an estimate of county level switchgrass yield data for the state of Oklahoma. The estimates are made for the top five most productive and abundant soils for each county in Oklahoma. A simple approach of ratio calculation and estimation is used to predict the switchgrass yield of one soil type by comparing it with the yield of several other crops in another soil type. The data for switchgrass yield for a particular soil type are obtained from the state research experiment stations. The yields for other crops for the top five soils are obtained from the NASS data sources. Switchgrass supply for Oklahoma was estimated to be 49.5 million tons from the top soils with the Northeast crop reporting district to be the dominant supplier.

Key words: Biofuel, Switchgrass, Ratio Estimation, South Central, Oklahoma

Background

The renewable fuel standard mandates in the Energy Independence and Security Act of 2007 (EISA) includes a target to achieve a 20% reduction in petroleum consumption by 2015 and increase alternative fuel use by 10% each year. The mandates require 36 billion gallons of ethanol to be produced in 2022 of which 16 of the 36 billion gallons must be produced from cellulosic feedstocks. In order to meet the mandates, the Department of Energy (DOE) has launched the Biomass Program to conduct a geospatial analysis of current and potential bioenergy feedstock supply across the United States. As a part of the national DOE program, this study is undertaken to create a database of potential bioenergy feedstock supplies that may

be available across the South Central U.S. The database for feedstock productivity in the region is required for land use planning, appraisal and identifying accurate locations for establishing future biofuel plants. The potential feedstocks are assumed to be converted into cellulosic ethanol to supplement and enhance the nations' dwindling oil supplies.

In 1991, the DOE selected switchgrass as a renewable feedstock source to produce transportation fuel after extensive evaluations of many plant species in multiple locations (Caddel et al., 2010). However, data on the yields and costs of switchgrass as a feedstock are limited (Dicks et al., 2009). This study creates a database of county level switchgrass yields for top five most productive and predominant soils in the South Central US. The focus of the study is on modeling the geographic variability of switchgrass yields and assessing potential changes that may occur under various soil types. The research is a work in progress and this paper will focus only on producing and analyzing switchgrass yield data for Oklahoma. Estimates for other crops and the surrounding states will be made as methodological improvements are developed.

Several different types of mathematical models have been developed and used to predict crop yields. The most common being the regression-type models. Olson and Olson (1986) used multiple regression methods to estimate average corn yields using selected soils and climatic data from five experimental research plots in New York State. The resulting linear relationship between actual and estimated corn yields had an r^2 of 0.52. Garcia-Paredes, Olson and Lang (2000) used multiple regression to evaluate the relationship between 16 selected soil properties of 34 major soils in Illinois to update the corn and soybean yields. The approach they reported worked well and could be useful in surrounding states or countries. Landau et al (1999) used a parsimonious multiple regression model to estimate wheat yield in response to the environment in UK. De La Rosa, Cardona and Almorza (1980) used a procedure of computing algebraic

equations following analyses by multiple regression to predict crop yield based on soil properties in Sevilla, Spain. Poldaru, Roots and Viira (2005) suggest artificial neural network as an alternative to multiple regression analysis for estimating the parameters of econometric models. Bellow (2003) compared Stansy-Goel, Griffith and standard ratio estimators using simulated NASS survey data for oats and barley in North Dakota. The result of their study favored Stansy-Goel method in almost all comparisons. The NASS ratio estimator reported by Bellow is computed as the ratio between the county estimates of production and harvested area for a given crop and can produce inconsistent yields due to fluctuations in harvested area from year to year.

Efforts have also been made to estimate crop yields using remote sensing data. Doraiswamy et al (2007) described the development of simplified process models and algorithms to supplement the NASS field data collection. In their study, a simple algorithm that uses a near-real time MODIS imagery and products was developed to predict crop yields at county and sub-county level. Prasad et al (2005) used NDVI, soil moisture, surface temperature and rainfall data of Iowa for crop yield assessment and prediction using a piecewise linear regression with breakpoint. They report that the model reasonably minimizes inconsistency and errors in yield prediction giving high R^2 values with maximum accounting of variability in model.

Oak Ridge National Laboratory (ORNL) performed an extensive research on estimating county level switchgrass yields for all the states in the United States. Gunderson et al (2008) at ORNL used a modeling approach based on climatic factors and ecotype to predict potential dry matter yields for a given temperature and weather pattern based on 95^{th} percentile response curves. The predictive equations were used to produce maps of potential yield across the US using PRISM in GIS. They reported that the mapped output using the model was relatively consistent with known switchgrass distribution. Dicks et al, 2009 used the switchgrass yield data

from ORNL and estimated that roughly 24 million acres of cropland would be required in existing uses to shift into the production of switchgrass to meet the cellulosic ethanol production mandates.

Switchgrass and Oklahoma

Cropland has historically been worth more than pasture, but recently the differences between crop and pasture prices per acre have been shrinking (Guiling, 2010). Switchgrass is constantly being bred to improve the biomass production so it can be used to produce a cellulosic ethanol. This species is a warm-season perennial grass native to the Great Plains which means it has adapted to growing in a wide range of climatic conditions and has the ability to outperform a majority of the crops grown in the state. Over many years switchgrass has adapted to the environment, so it has resistance to pests, drought, and flooding. Even though moisture is typically the most limiting factor in switchgrass production, soil depth and fertility are important factors to consider. Without frequent rainfall, biomass will be limited unless there is enough soil depth (water holding capacity) to store an adequate amount of moisture during a drought (Caddel et al., 2010). Although switchgrass may outperform a majority of the crops in Oklahoma it will only be grown on marginal land which cannot sustain a crop that yields a higher profit.

Oklahoma is located in the South Central United States, which is right in the transition of humid to arid climate. Oklahoma's rainfall amount is the highest in the southeast corner and gradually decreases to the northwest corner which is the lowest in the state. As a general rule of thumb east of I-35 is moderately humid to humid and west of I-35 is semi arid to arid. The western half of Oklahoma is predominantly cropland whereas the eastern half is predominantly

pasture and forest land (Guiling, 2010). The eastern half will likely grow more switchgrass than the western half since it is predominantly pasture and receives higher amounts of rainfall.

Materials and Methods

The study employs a simple method of ratio calculation and estimation to determine the yield of switchgrass for the top five soils in each Oklahoma County. The top five soils in each county comprise 35.6% of the total farmland land in Oklahoma. The ratio calculation and estimation method used in this study is different from the ratio estimator traditionally used by NASS to derive county yields. The NASS ratio estimator is computed as the ratio between the county estimates of production and harvested area for a given crop but the ratio estimation used in this study compares the yield of one crop in two different soil types to estimate the yield of another crop in a specific soil types. The estimates in this study are based on available data and improved estimates are made as new switchgrass or other crop yield data becomes available and new modeling approaches are applied.

Data Sources

The major sources of data collected for this study were the yields for crops from state research experiment stations test plot trials and the yield data available from the NRCS web resources. Relevant data were also collected from the published literatures (Taliaferro, 2002 and Thomason et al., 2004).

Experiment Stations

Historical data from the state's research experiment stations that includes climate data, soils data, crops produced and yields, nutrients applied, irrigation used, harvest methods and other relevant data associated with actual field trials for all the eight states in the south central

US were collected. About 2,000 records of county level switchgrass yield data was collected and catalogued for Oklahoma from research stations and literatures. The data was averaged to get an estimated yield based on soil type. We had switchgrass yield data from four different locations (3 counties) and for five different soil types. These switchgrass yield data for five different soil types were used as the basis for estimating switchgrass yield for all the top five soils in each county.

The table below shows the switchgrass yield information collected from the research stations at four different locations in Oklahoma and for five different soil types.

Table 1: Oklahoma switchgrass yield data obtained from research stations

Experiment Station Locations	County	Soil Type	Latitude	Longitude	Average Yield (ton/acre)
Stillwater	Payne	Easpur Loam	36.120	-97.095	6.08
Perkins	Payne	Teller Loam	35.998	-97.048	4.88
Chikasha	Grady	Reinach Silt Loam	35.032	-97.914	5.99
		Dale Silt Loam	35.032	-97.914	8.07
Haskell	Muskogee	Taloka Silt Loam	35.747	-95.640	6.27

NRCS Online Data

The information presented in this project is largely based off of NRCS Soil Data and the Land Capability Classes (LCC). The NRCS spent years collecting data from conservationists, extension agents, and farmers to make the database they have today. The NRCS data were used to aid in predicting crop yields that have the ability to serve as bioenergy feedstocks. Irrigated crop yield, non-irrigated crop yield, specific Land Capability Class (LCC), and county level soil types were used to categorize the NRCS yield data. The irrigated and non-irrigated crop yields were selected to provide two different yield possibilities. The LCC consists of eight classes to designate the different types of land in Oklahoma (Helms, 1992). Farmable land that can sustain crops was determined using the LCCs. The first four classes are arable land, suitable for cropland- with limitations on their use and the need for conservation measures and careful

management as the class increases from I through IV (Helms, 1992). Soils classified as V-VIII were not included since they are not recommended for cropland. The LCC was simply our template to narrow the soils that were capable of crop production. Some of the soils we used may have slopes ranging from 5% to 20%. Some soils in this data collection include eroded soils which require intensive conservation practices. SQL codes were used to obtain county level yield data from the NRCS.

Top Five Soils

The top five soils were based on the criteria of productivity of the soil (Soil Classes I through IV and slopes 8% or less) and predominance in the area. Soil types that are most predominant in the county that fall within Soil Class 1 to 4 with slope less than or equal to 8% were selected as the top five soils. These top five soils were assumed to support switchgrass growth in the region.

Ratio Calculation and Yield Estimation

After the top five soils for each of the counties in Oklahoma were identified, the yields for other forage crops obtained from the NRCS web resources for each top five soils were determined. Not all the top five soils had the yield data for all the other forage crops. There were several forage crops on specific soils with missing yield information. The switchgrass yield for all the top five soils for each county of Oklahoma were estimated using the available yield data of other crops from the NRCS web resources and the historic data from the research stations. Ratio calculation involves calculating the ratio of a particular crop for two different soil types. Then a similar approach is applied to calculate the ratio for another crop for the two soils types

and several ratios are obtained. The ratios are then averaged. This average ratio is used to estimate the switchgrass yield of one soil type by using the switchgrass yield from another soil type.

$$Ratio\ 1 = \frac{Crop\ 1\ Yield\ for\ Soil\ A}{Crop\ 1\ Yield\ for\ Soil\ B}$$

$$Ratio\ 2 = \frac{Crop\ 2\ Yield\ for\ Soil\ A}{Crop\ 2\ Yield\ for\ Soil\ B}$$

$$Ratio\ 3 = \frac{Crop\ 3\ Yield\ for\ Soil\ A}{Crop\ 3\ Yield\ for\ Soil\ B}$$

$$Average\ Ratio\ = \frac{\sum_i^n Ratio}{n}$$

$$Crop\ 4\ Yield\ for\ Soil\ B = \frac{Crop\ 4\ Yield\ for\ Soil\ A}{Average\ Ratio}$$

Table 2 below shows how this method is used to estimate the missing yield data of switchgrass.

Table 2: Estimating switchgrass yield using ratio estimation for Payne County, Oklahoma

Soil Classes	**Bermuda grass**	**Ratio 1** **(Yield 1/Yield 2)**	**Wheat**	**Ratio 2** **(Yield 1/Yield 2)**	**Average Ratio** $\frac{\sum_i^n Ratio}{n}$	**Switchgrass**
Easpur Loam	8.5	**2.42**	35	**1.75**	**2.08**	6.15
Stephenville Darnell Complex	3.5		20			**2.95**

The switchgrass yield data shown above for Easpur Loam was obtained from the research stations at Oklahoma. The switchgrass yield data for the Stephenville Darnell Complex soil has to be estimated. Yield data for Bermuda grass and Wheat for the Easpur Loam and Stephenville Darnell Complex soils was obtained from the NRCS web resources. The Bermuda grass yield for Easpur loam and Stephenville Darnell Complex was divided and the ratio of 2.42 was obtained. Similarly, the wheat yield for Easpur loam and the Stephenville Darnell Complex was divided

and the ratio of 1.75 was obtained. These two ratios were averaged to get 2.08. Then the switchgrass yield for Easpur loam was divided by the average ratio to get the estimated switchgrass yield of 2.95 for the Stephenville Darnell Complex soil.

Similar approaches were used to determine the yield of switchgrass for other soil types. Once the switchgrass yield for all the top five soils for a county was determined, the top five soils for the neighboring counties were compared to determine matching soil types. Matching soil types were given the same switchgrass yield as those determined for the adjoining county. Then the newly assigned switchgrass yield and the yield of other forage crops are used to obtain the ratio and estimate the switchgrass yield for other top 4 soils. The same procedure is applied until the switchgrass yield for all the top five soils for all the counties are estimated.

Results

A projection of 49.59 million tons of total potential switchgrass supply was made for Oklahoma for the top five most abundant and productive soils. The total area for the top five soils in all the counties of Oklahoma was estimated to be 12.48 million acres. The top suppliers of switchgrass in Oklahoma are found to be North East, Central, Panhandle and North Central crop reporting districts. They could supply a total of over 6 million tons of switchgrass. These districts can be referred to as the suitable areas for establishing future biofuel processing plants.

County Analysis

The data obtained from the ratio estimator showed that Texas County in the panhandle district could supply the largest quantity of switchgrass. It could supply approximately 2.5 million tons of switchgrass from the top five soils. Texas County had a highest area of 675,232

acres of the top five soils with an average yield of 3.53 tons/acre. The lowest supply of switchgrass was estimated for Marshall County with a total potential supply estimated at 0.16 million tons. This was because the total area of the top five soils (72,921 acres) and the average yield (2.29 tons/acre) of switchgrass was comparatively low in this county. The average supply of switchgrass for a county was estimated to be about half a million tons from an average area of 162,397 acres (Top five soils).

District Analysis

The district level analysis showed that the North East district can supply the highest quantity of switchgrass. It could supply 7.4 million tons from an area of 1.88 million acres. The Southeast district was found to be the lowest supplier of switchgrass. It could supply 2.99 million tons from an area of 0.59 million acres. The average supply of switchgrass on a crop reporting district basis was estimated to be 5.49 million tons from an average area of 1.38 million acres per crop reporting district.

Table 3: Oklahoma crop reporting districts-Total supply of Switchgrass

Oklahoma Districts	Total Supply (Tons)	Top Five Soils (Total Acres)	No. of Counties	Total Farm Land (Acres)	% of Farmland
North East	7,410,473	1,888,175	10	3,888,067	48.56%
Central	6,641,226	1,574,831	13	5,090,829	30.93%
Panhandle	6,292,770	1,862,584	5	4,714,382	39.51%
North Central	6,236,352	1,703,395	9	5,049,869	33.73%
South West	5,643,748	1,380,778	8	3,814,777	36.20%
South Central	5,561,676	1,435,346	12	4,513,767	31.80%
East Central	5,290,790	1,041,258	9	2,987,821	34.85%
West Central	3,517,203	999,656	6	3,573,477	27.97%
South East	2,999,421	597,872	5	1,454,280	41.11%
Total	**49,593,659**	**12,483,895**		**35,087,269**	**35.58%**

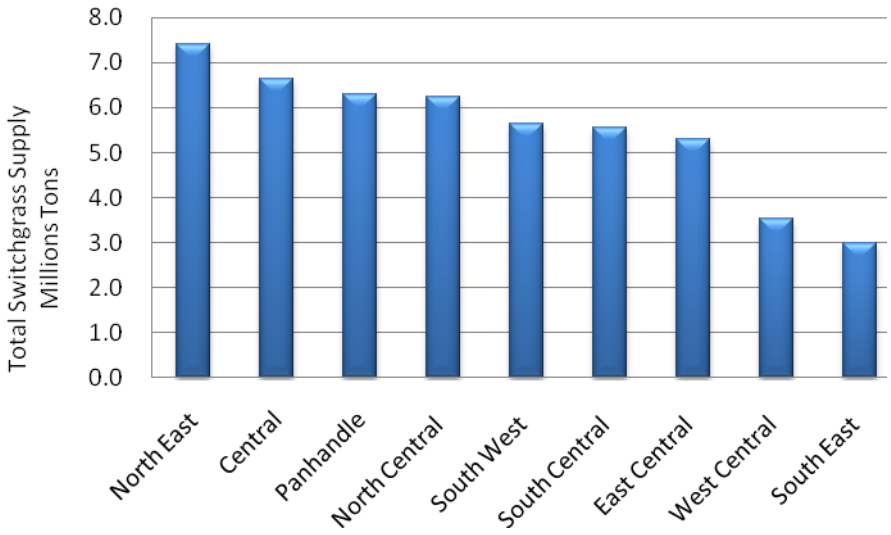

Figure 1: Switchgrass Supply in Oklahoma Crop Reporting Districts

Panhandle District

The Panhandle district could supply a total of 6.29 million tons of switchgrass. Texas County was found to supply the highest quantity of switchgrass. The lowest supply was provided by Ellis and Harper counties. Harper County, although having a high yield compared to the other counties in the district, provides a low supply because of the low acreage of the top five soils.

Table 4: Panhandle District-County Level Switchgrass Supply

County	Total Supply (Tons)	Top Five Soils (Acres)	Switchgrass Yield (Tons/Acre)	Rainfall (Inches)	County Farmland (Acres)	% of Farm Land
Beaver	888,467	282,694	3.17	21.27	1,128,871	25.04%
Cimarron	1,827,103	554,405	3.29	18.6	1,044,528	53.08%
Ellis	536,296	187,634	2.85	25.44	718,058	26.13%
Harper	558,618	162,619	3.48	26.21	616,947	26.36%
Texas	2,482,285	675,232	3.53	18.32	1,205,978	55.99%
Total	**6,292,770**	**1,862,584**		**110**	**4,714,382**	**39.51%**

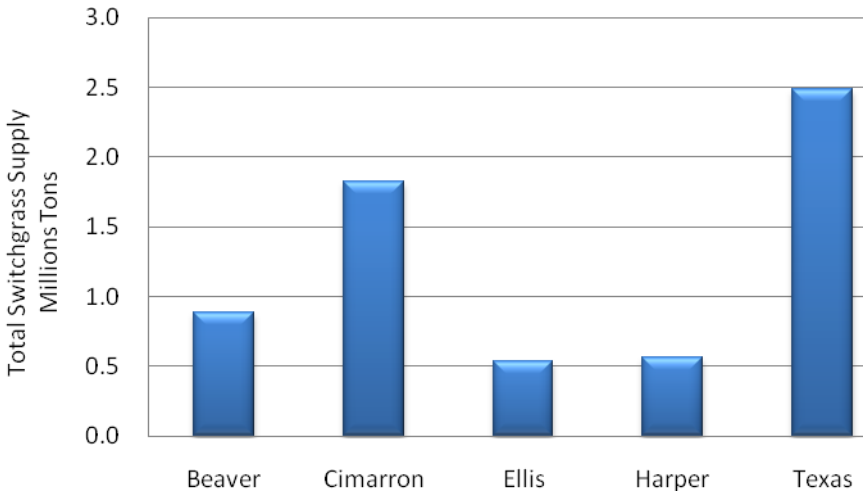

Figure 2: Switchgrass Supply in Panhandle Oklahoma by County

West Central District

The total supply of switchgrass in the West Central District was estimated to be 3.51 million tons of switchgrass from an area of 0.99 million acres. All the counties in this district had almost the same yield and total acreage.

Table 5: West Central District-County Level Switchgrass Supply

County	Total Supply (Tons)	Top Five (Acres)	Switchgrass Yield (Tons/Acre)	Rainfall (Inches)	County Farmland (Acres)	% of Farm Land
Blaine	554,606	110,476	4.98	29.48	585,908	18.86%
Beckham	499,715	164,250	3.06	26.11	519,503	31.62%
Custer	706,761	214,745	3.20	30.01	568,728	37.76%
Dewey	448,796	133,112	3.32	28.92	588,951	22.60%
Roger Mills	527,451	155,880	3.63	27.76	719,356	21.67%
Washita	779,873	221,193	3.32	29.77	591,031	37.42%
Total	**3,517,203**	**999,656**		**172**	**3,573,477**	**27.97%**

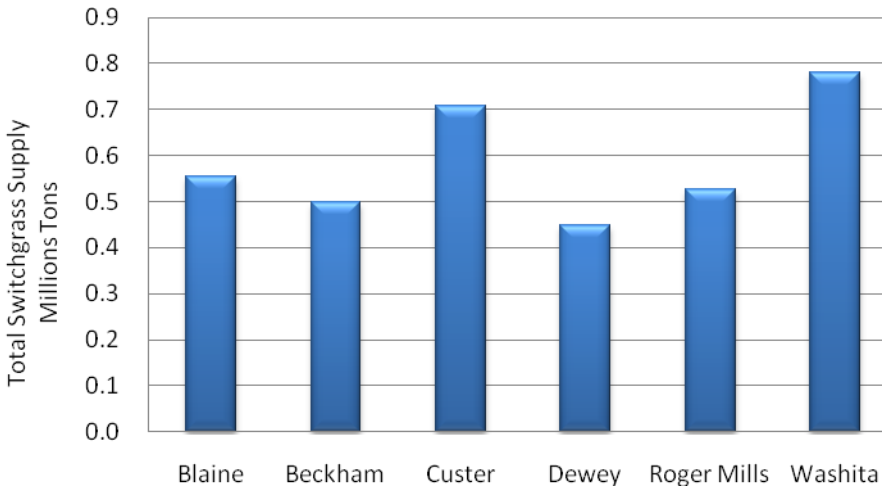

Figure 3: Switchgrass Supply in West Central Oklahoma by County

Southwest District

The South West district had an estimated total supply of 5.64 million tons of switchgrass from an area of 1.38 million acres. Kiowa county could supply the largest quantity of 1.13 million tons and Harmon County could supply the lowest quantity of 0.26 million tons of switchgrass.

Table 6: South West District -County Level Switchgrass Supply

County	Total Supply (Tons)	Top Five (Acres)	Switchgrass Yield (Tons/Acre)	Rainfall (Inches)	County Farmland (Acres)	% of Farm Land
Caddo	985,002	225,389	4.34	31.44	749,918	30.06%
Comanche	830,148	195,571	4.44	31.75	497,502	39.31%
Cotton	844,503	190,779	4.62	34.14	366,651	52.03%
Greer	300,454	87,745	4.09	28	375,447	23.37%
Harmon	261,157	83,672	3.23	25.97	322,222	25.97%
Jackson	675,195	165,359	3.98	29.09	474,502	34.85%
Kiowa	1,133,944	267,408	4.17	28.43	564,592	47.36%
Tillman	613,344	164,855	3.70	31.03	463,943	35.53%
Total	**5,643,748**	**1,380,778**		**240**	**3,814,777**	**36.20%**

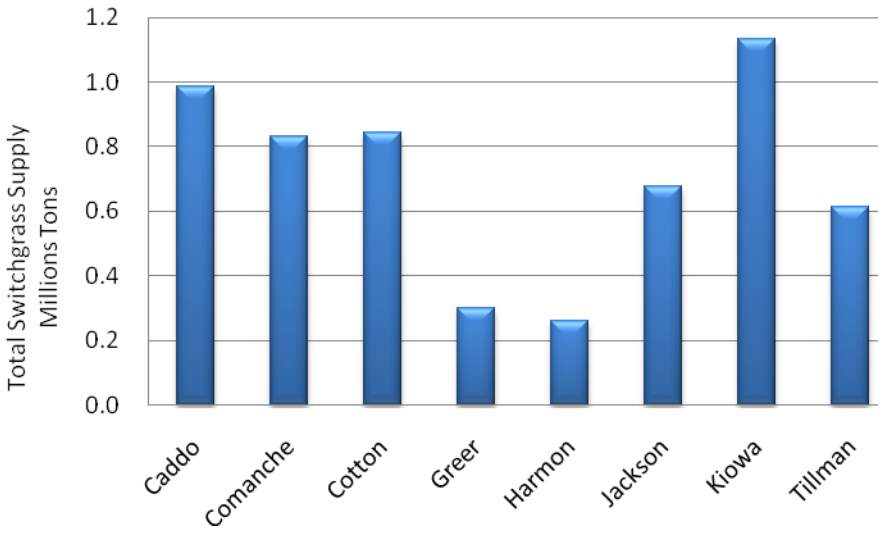

Figure 4: Switchgrass Supply in South West Oklahoma by County

North Central District

The North Central District could supply an estimated 6.23 million tons of switchgrass from a total acreage 1.70 million acres. Grant and Garfield counties could supply the most switchgrass in this district. The lowest supply of switchgrass was projected for Noble and Payne counties as they could supply only 0.2 to 0.3 million tons of switchgrass.

Table 7: North Central District-County Level Switchgrass Supply

County	Total Supply (Tons)	Top Five (Acres)	Switchgrass Yield (Tons/Acre)	Rainfall (Inches)	County Farmland (Acres)	% of Farm Land
Alfalfa	888,154	194,689	4.37	31.64	542,813	35.87%
Grant	1,112,298	257,451	4.60	34.57	633,052	40.67%
Garfield	1,150,883	278,961	4.41	34.18	663,431	42.05%
Kay	857,063	254,434	3.17	38.85	492,178	51.70%
Major	678,830	186,022	3.94	34.67	336,852	55.22%
Noble	304,754	111,973	2.75	36.31	466,947	23.98%
Pawnee	212,792	97,054	2.21	38.77	297,621	32.61%
Woods	439,990	127,937	3.59	27.86	833,775	15.34%
Woodward	591,587	194,874	3.13	25.83	783,200	24.88%
Total	**6,236,352**	**1,703,395**		**303**	**5,049,869**	**33.73%**

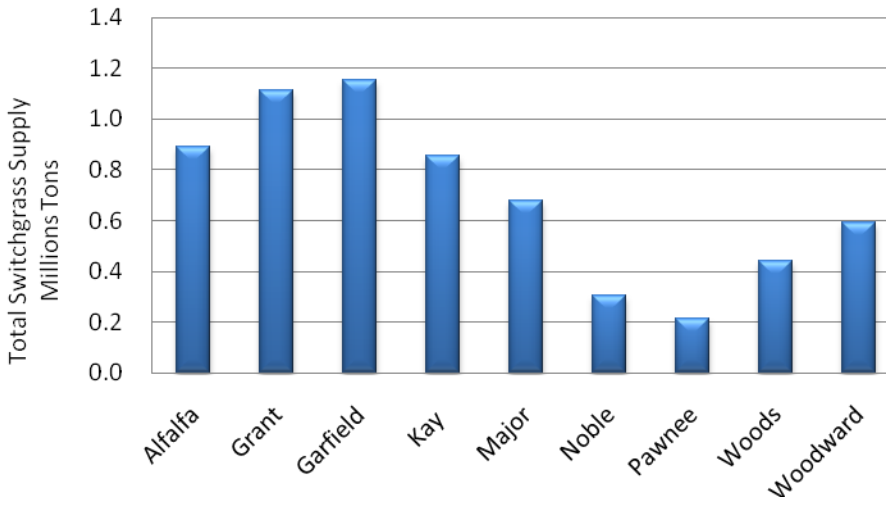

Figure 5: Switchgrass Supply in North Central Oklahoma by County

Southeast District

The South East district was projected to be the lowest supplier of switchgrass in Oklahoma. The projected supply of switchgrass in this district was 2.99 million tons from an area of 0.59 million acres. Le Flore was projected to be the largest supplier of switchgrass and Latimer was projected to be the lowest supplier.

Table 8: South East District-County Level Switchgrass Supply

County	Total Supply (Tons)	Top Five (Acres)	Switchgrass Yield (Tons/Acre)	Rainfall (Inches)	County Farmland (Acres)	% of Farm Land
Choctaw	512,234	127,782	3.91	47.63	326,300	39.16%
Latimer	274,041	48,879	5.55	51.42	213,411	22.90%
Le Flore	971,244	185,259	4.94	46.55	466,406	39.72%
McCurtain	887,291	165,900	5.30	42.18	157,754	105.16%
Pushmataha	354,611	70,052	5.29	45.46	290,409	24.12%
Total	**2,999,421**	**597,872**		**233**	**1,454,280**	**41.11%**

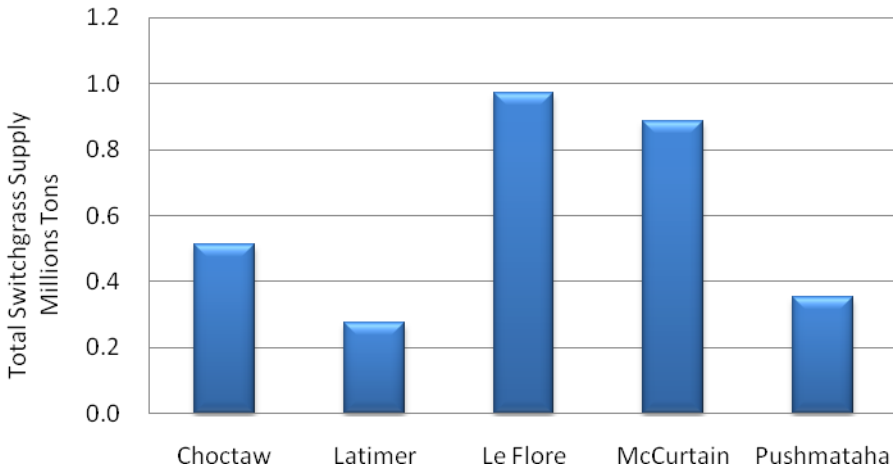

Figure 6: Switchgrass Supply in South East Oklahoma by County

Central District

There are thirteen counties in the Central district with an estimated total area of 1.57 million acres. This district is second in potential switchgrass supply after the Northwest district. The total supply is estimated to 6.64 million tons. Canadian, Creek and Grady counties are the top suppliers of switchgrass in this district.

Table 9: Central District-County Level Switchgrass Supply

County	Total Supply (Tons)	Top Five (Acres)	Switchgrass Yield (Tons/Acre)	Rainfall (Inches)	County Farmland (Acres)	% of Farm Land
Canadian	1,044,282	180,048	5.71	34.08	508,771	35.39%
Creek	829,319	167,279	5.56	40.39	377,437	44.32%
Cleveland	403,007	128,645	3.02	34.67	159,816	80.50%
Grady	701,871	145,269	4.75	35.28	608,373	23.88%
Kingfisher	565,506	177,137	2.98	32.95	566,212	31.28%
Lincoln	511,495	104,405	4.79	37.75	487,858	21.40%
Logan	397,923	95,495	4.03	35.93	403,810	23.65%
McClain	455,044	101,577	4.58	27.52	517,334	19.63%
Okfuske	274,784	64,707	4.35	42.28	298,814	21.65%
Oklahoma	488,205	143,713	3.25	35.97	159,823	89.92%
Payne	262,007	85,124	2.99	36.79	356,765	23.86%
Pottawatomie	403,659	104,713	3.71	40.05	395,065	26.51%
Seminole	304,114	76,719	3.97	40.95	250,751	30.60%
Total	**6,641,216**	**1,574,831**		**475**	**5,090,829**	**30.93%**

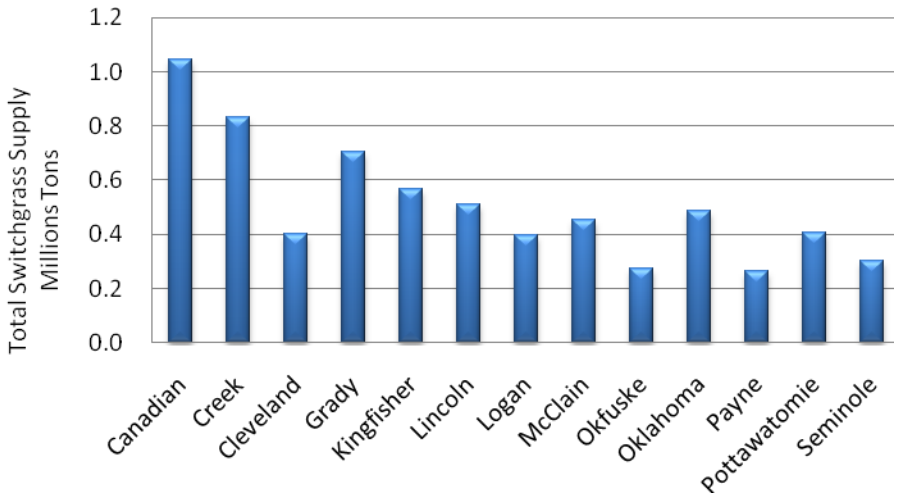

Figure 7: Switchgrass Supply in Central Oklahoma by County

South Central District

There are twelve counties in the South Central District with a total estimated area of 1.43 million acres. The total supply of switchgrass for this district was estimated to be 5.56 million tons. Jefferson County was projected to be the top supplier of switchgrass at 1.30 million tons. Bryan, Pontotoc and Stephens was projected to supply around 0.5 million tons each and all other counties were projected to supply less than 0.5 million tons of switchgrass.

Table 10: South Central District -County Level Switchgrass Supply

County	Total Supply (Tons)	Top Five (Acres)	Switchgrass Yield (Tons/Acre)	Rainfall (Inches)	County Farmland (Acres)	% of Farm Land
Atoka	290,271	102,138	2.95	44.79	408,444	25.01%
Bryan	562,033	138,946	4.19	46.42	490,688	28.32%
Coal	329,756	76,998	4.26	41.54	269,401	28.58%
Carter	339,410	108,998	3.13	38.38	402,831	27.06%
Garvin	439,145	100,093	4.51	38.46	500,804	19.99%
Love	210,175	84,988	2.44	38.46	261,875	32.45%
Marshall	166,903	72,921	2.29	50.45	339,615	21.47%
Murray	216,116	45,730	4.81	41.14	197,022	23.21%
Jefferson	1,308,714	305,215	4.54	31.36	460,207	66.32%
Johnston	449,645	130,369	3.47	44.24	333,944	39.04%
Pontotoc	554,186	86,529	6.12	41.54	379,236	22.82%
Stephens	695,322	182,421	3.72	36.13	469,700	38.84%
Total	**5,561,676**	**1,435,346**		**493**	**4,513,767**	**31.80%**

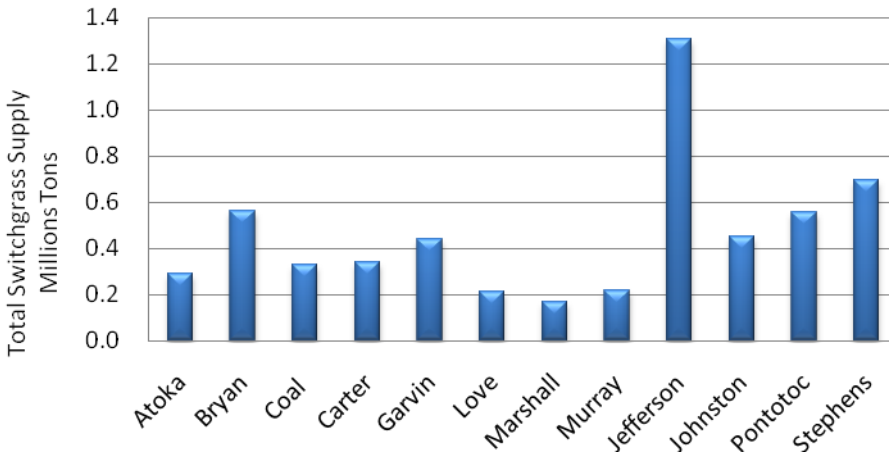

Figure 8: Switchgrass Supply in South Central Oklahoma by County

North East District

The Northeast district is projected to be the top supplier of switchgrass in Oklahoma. This district could supply 7.41 million tons of switchgrass from an area of 1.88 million acres. All the counties in this district are projected to supply more than 0.5 million tons of switchgrass. Craig County was projected to be the top supplier of switchgrass. All the counties in this district had a switchgrass yield of above 4 tons per acre except the Osage county which had a yield of 1.41 tons per acre. However, Osage county had the highest acreage of 0.54 million acres of the top five soils which made it able to supply 0.83 million acres of switchgrass.

Table 11: North East District-County Level Switchgrass Supply

County	Total Supply (Tons)	Top Five (Acres)	Switchgrass Yield (Tons/Acre)	Rainfall (Inches)	County Farmland (Acres)	% of Farm Land
Delaware	670,587	160,651	4.17	48.9	308,970	52.00%
Craig	1,131,492	200,559	5.52	45.8	457,292	43.86%
Wagoner	680,343	137,211	5.00	44.99	262,702	52.23%
Mayes	749,765	158,380	4.68	46.78	246,730	64.19%
Ottawa	725,693	146,464	4.77	44.51	237,986	61.54%
Nowata	730,923	151,496	5.02	41.83	354,636	42.72%
Rogers	770,691	158,080	4.91	44.04	371,349	42.57%
Tulsa	606,109	119,075	4.97	42.47	131,154	90.79%
Osage	839,119	546,586	1.41	43.98	1,290,680	42.35%
Washington	505,751	109,673	4.33	38.93	226,568	48.41%
Total	**7,410,473**	**1,888,175**		**442**	**3,888,067**	**48.56%**

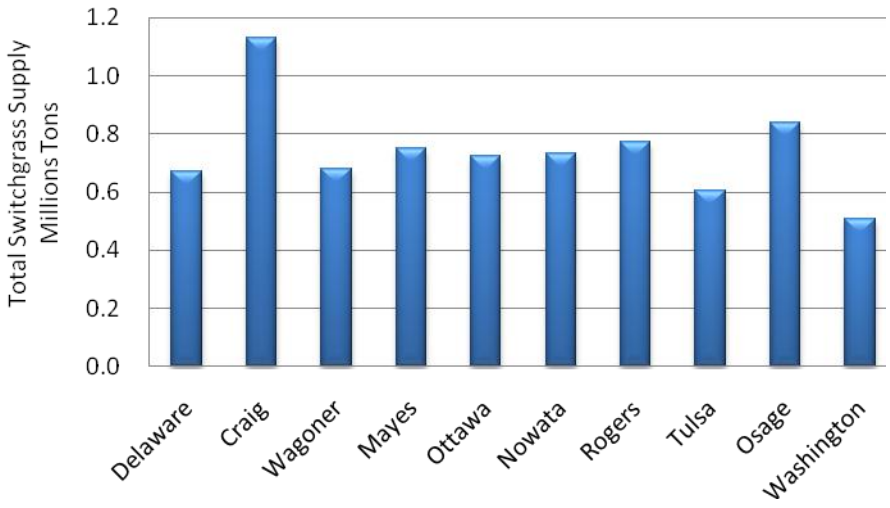

Figure 9: Switchgrass Supply in North East Oklahoma by County

East Central District

The projected total supply of switchgrass from the East Central District is 5.29 million tons from a total area of 1.04 million acres. The range of switchgrass supply for the counties in this district varied from 0.4 to 0.8 million tons. Muskogee and Okmulgee counties were projected to supply the most switchgrass in this district.

Table 12: East Central District-County Level Switchgrass Supply

County	Total Supply (Tons)	Top Five (Acres)	Switchgrass Yield (Tons/Acre)	Rainfall (Inches)	County Farmland (Acres)	% of Farm Land
Adair	458,519	122,425	3.92	49.87	249,280	49.11%
Cherokee	480,080	125,909	4.03	48.04	246,421	51.10%
Haskell	512,792	100,613	4.99	48.73	290,260	34.66%
Hughes	395,106	101,072	3.94	41.16	441,040	22.92%
Muskogee	888,498	156,384	5.66	46.93	374,372	41.77%
McIntosh	662,596	101,333	6.59	44.43	313,131	32.36%
Okmulgee	838,508	144,342	5.80	43.89	294,324	49.04%
Pittsburg	507,366	94,524	5.41	45.24	547,050	17.28%
Sequoyah	547,325	94,656	5.48	46.55	231,943	40.81%
Total	**5,290,790**	**1,041,258**		**415**	**2,987,821**	**34.85%**

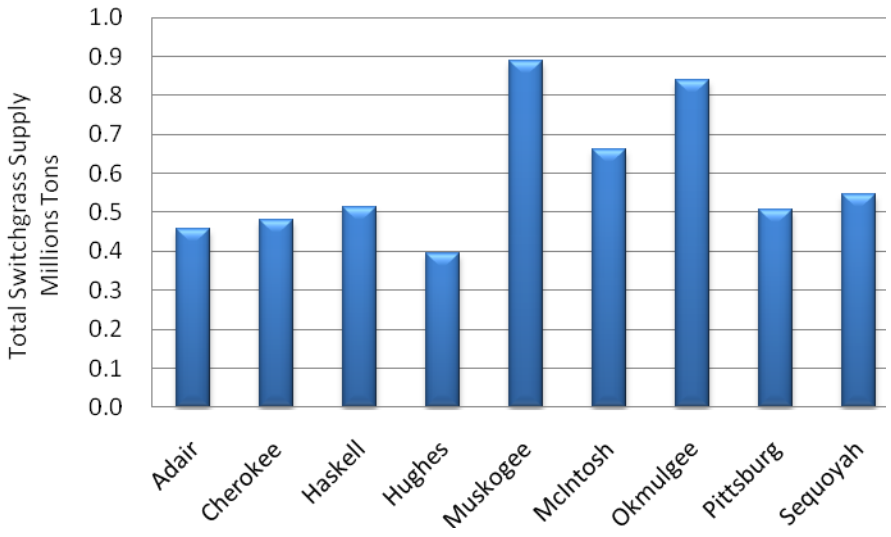

Figure 10: Switchgrass Supply in East Central Oklahoma by County

Conclusions

Given the mandates of the EISA, it is necessary to assess the potential supply of switchgrass for cellulosic conversion to ethanol. However, data on the yields and costs are insufficient to accurately predict the potential of switchgrass as a feedstock. A database of switchgrass yields is important to assess the biomass feedstock resource base and inform potential investors of the regional cellulosic feedstock supply potential. This study creates such databases of switchgrass yields for the top five most productive and predominant soils in Oklahoma counties. Estimating better yields are important in any future economic analyses pertaining to that particular crop. This paper has outlined a methodology to use limited data coupled with soil and crop yield to estimate switchgrass yield. Simple methods of comparing yields of two different crops produced in two different soil types are used to estimate switchgrass yield in one of the soil type. The method was easy to use and helped us estimate the switchgrass yields for top five most abundant and predominant soils in all the 77 counties of Oklahoma. The results show that Oklahoma has a potential to supply 49.5 million tons of switchgrass from the top five soils which accounts for

35% of the total farm land in Oklahoma. It seems reasonable that Oklahoma can support multiple ethanol plants. The best regions to start a biofuel processing plants would be in the north eastern and central Oklahoma based solely on the potential supply of switchgrass by region. Thus the actual distribution and total quantity of supply will depend on the profitability of switchgrass relative to other uses.

Limitations

Limited research has been done on switchgrass in Oklahoma and surrounding states. Switchgrass yields can be found only for limited soil types in Oklahoma. A database of switchgrass yields for 77 counties and roughly 350 different soil types had to be created relying on these limited yield data. Some of the top five soils we sorted from the NRCS online resources had no yield data for any of the crops, complicating the estimate of switchgrass yields for these kinds of soil types as no comparisons of yield could be made. Some of the soil types had to be eliminated from the top five lists as they would fall in the urban category and no yield data for any of the crops could be available for this type of soil. Several switchgrass research plots have been established in Oklahoma. The estimates we obtained are necessary to be verified and refined from the yield observations made in these research plots.

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Table 13: Oklahoma County Switchgrass Supply and Yields

County	Total Supply (Tons)	Acres (Top Five Soils)	Average Switchgrass Yield	County	Total Supply (Tons)	Acres (Top Five Soils)	Average Switchgrass Yield
Adair	458,519	122,425	3.92	McClain	455,044	101,577	4.58
Alfalfa	888,154	194,689	4.37	McCurtain	887,291	165,900	5.30
Atoka	290,271	102,138	2.95	McIntosh	662,596	101,333	6.59
Beaver	888,467	282,694	3.17	Major	678,830	186,022	3.94
Beckham	499,715	164,250	3.06	Marshall	166,903	72,921	2.29
Blaine	554,606	110,476	4.98	Mayes	749,765	158,380	4.68
Bryan	562,033	138,946	4.19	Murray	216,116	45,730	4.81
Caddo	985,002	225,389	4.34	Muskogee	888,498	156,384	5.66
Canadian	1,044,282	180,048	5.71	Noble	304,754	111,973	2.75
Carter	339,410	108,998	3.13	Nowata	730,923	151,496	5.02
Cherokee	480,080	125,909	4.03	Okfuskee	274,784	64,707	4.35
Choctaw	512,234	127,782	3.91	Oklahoma	488,205	143,713	3.25
Cimarron	1,827,103	554,405	3.29	Okmulgee	838,508	144,342	5.80
Cleveland	403,007	128,645	3.02	Osage	839,119	546,586	1.41
Coal	329,756	76,998	4.26	Ottawa	725,693	146,464	4.77
Comanche	830,148	195,571	4.44	Pawnee	212,792	97,054	2.21
Cotton	844,503	190,779	4.62	Payne	262,007	85,124	2.99
Craig	1,131,492	200,559	5.52	Pittsburg	507,366	94,524	5.41
Creek	829,319	167,279	5.56	Pontotoc	554,186	86,529	6.12
Custer	706,761	214,745	3.20	Pottawatomie	403,659	104,713	3.71
Delaware	670,587	160,651	4.17	Pushmataha	354,611	70,052	5.29
Dewey	448,796	133,112	3.32	Roger Mills	527,451	155,880	3.63
Ellis	536,296	187,634	2.85	Rogers	770,691	158,080	4.91
Garfield	1,150,883	278,961	4.41	Seminole	304,114	76,719	3.97
Garvin	439,145	100,093	4.51	Sequoyah	547,325	94,656	5.48
Grady	701,871	145,269	4.75	Stephens	695,322	182,421	3.72
Grant	1,112,298	257,451	4.60	Texas	2,482,285	675,232	3.53
Greer	300,454	87,745	4.09	Tillman	613,344	164,855	3.70
Harmon	261,157	83,672	3.23	Tulsa	606,109	119,075	4.97
Harper	558,618	162,619	3.48	Wagoner	680,343	137,211	5.00
Haskell	512,792	100,613	4.99	Washington	505,751	109,673	4.33
Hughes	395,106	101,072	3.94	Washita	779,873	221,193	3.32
Jackson	675,195	165,359	3.98	Woods	439,990	127,937	3.59
Jefferson	1,308,714	305,215	4.54	Woodward	591,587	194,874	3.13
Johnston	449,645	130,369	3.47				
Kay	857,063	254,434	3.17				
Kingfisher	565,506	177,137	2.98				
Kiowa	1,133,944	267,408	4.17				
Latimer	274,041	48,879	5.55				
Le Flore	971,244	185,259	4.94				
Lincoln	511,495	104,405	4.79				
Logan	397,923	95,495	4.03				
Love	210,175	84,988	2.44				
McClain	455,044	101,577	4.58				