THE OHIO STATE UNIVERSITY EXTENSION

FACT SHEET

Agriculture and Natural Resources

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Determining Location of Cellulosic Ethanol Plants in Ohio, Based on Availability of Crop Residues[1]

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Summary

The availability of corn and wheat crop residues was analyzed for each county in Ohio. Results showed that two clusters in western Ohio, each encompassing 17 counties with a collection radius of 50 miles, could provide feedstock for two ethanol plants at a capacity of 5,000 dry tons per day each. This calculation assumes that 35% of the corn stover and wheat straw per acre would be removed. These two plants could produce a total of 240 million gallons of ethanol per year.

This fact sheet illustrates the process of evaluating where such facilities might be feasible. Naturally, not every acre of corn or wheat residue in a county would be available, nor would every acre have 35% of the residue removed.

World oil prices are the major factor in the demand for ethanol in the U.S. Although low prices for gasoline reduce the demand for ethanol and other bio-based fuels, the long-range prospects are for higher prices; therefore, there is good market potential for these alternative fuels.

Approximately 30% of U.S. corn grain is used in ethanol production. Research is continuing on using crop residues (cellulose in corn fodder and wheat straw, for example) as another economical source of ethanol. Crop residues suitable for cellulosic ethanol production will likely be in high demand in the future.

Other regions of Ohio with fewer acres of corn and wheat could grow energy crops such as switchgrass and poplar trees, and could provide mixed feedstocks for a cellulosic ethanol plant. Wood waste and municipal solid waste could also be a feedstock.

[1]This fact sheet is based on Drs. Yebo Li and Harold Keener's publication titled "County level analysis of crop residues availability for fuel ethanol production in Ohio" published in *Transactions of the ASABE* 52(1): 313–318.

Crop Data

Ohio corn production for grain in 2005 and 2006 was about 470 million bushels per year. Among Ohio crops, corn has the greatest potential for cellulosic ethanol production. Corn stover includes stalks, leaves, cobs, and husks and contains approximately 35% cellulose, 22% hemicellulose, and 18% lignin (EERE, 2007). Nationally, the amount of corn stover that can be sustainably collected is estimated to be 80–100 million dry tons per year (Kadam and McMillan, 2003).

Soybean is the second major crop in Ohio, with an annual average harvest of 209 million bushels, but the relatively small amount of residue rapidly degrades in the field and is not considered as a potential feedstock for ethanol production.

Wheat is the third major crop, with 62 million bushels produced per year in 2005 and 2006. Wheat straw contains approximately 33% cellulose, 23% hemicellulose, and 17% lignin and is the second best source among grain crops for cellulosic ethanol production.

OSU researchers studied the distribution of usable crop residues among Ohio counties and calculated amounts of wheat straw and corn stover for each Ohio county (Jeanty et al., 2004).

This fact sheet summarizes the availability of major crop residues (sustainable amount per square mile) in Ohio at the county level (Table 1). The sustainable amount of crop residue in each county was calculated based on the residue yield and a collection factor of 35%. Counties were clustered for the purpose of identifying potential feedstock supply areas for future cellulosic ethanol plants.

Sustainable Crop Residue

Crop residues play an important role in protecting the soil surface from water and wind erosion and in helping to maintain nutrient levels, so removing them comes at a cost. Currently in the U.S., most corn stover is tilled or left undisturbed on the field. Previous research has estimated that 20%–35% can be removed without unduly harming the soil (Nelson, 2002). A collection factor (percentage of crop residue removed from the field) of 35% was used in this study.

To estimate the crop residue available, the ratio of corn grain to corn stover was assumed to be 1:1. For wheat, the ratio of grain to straw was assumed to be 1:0.8. Average grain production in 2005 and 2006 was used in our calculations. Accurately estimating the amount of biomass available is essential to evaluate the collection cost for ethanol production.

Ethanol Production Potential

How much ethanol can be produced from a ton of corn stover or wheat straw? The amount varies depending on the composition of the crop residues and the ethanol production technologies.

The National Renewable Energy Laboratory (NREL, 2007) estimates the theoretical ethanol yield for corn stover at 113 gallons per dry ton for an average corn stover composition and assuming that both hexose and pentose sugars are fermented. For this analysis, we assumed an ethanol yield of 73 gallons per dry ton, which is about 64% of the theoretical yield. For wheat straw, we used an ethanol yield of 70 gallons per dry ton, based on a study by Kadam and McMillan (2003).

Table 1 summarizes the data for the 43 counties in Ohio with the greatest potential to support cellulosic ethanol production. The hydrolysis technologies assumed are either dilute acid hydrolysis or enzymatic hydrolysis. The fermentation process should be able to convert hexose and some of the pentose.

Biomass Availability

The total sustainable amount of corn stover and wheat straw in Ohio is estimated to be 4.6 and 0.7 million dry tons per year, respectively. The majority (85%, or 4.5 million tons) of these crop residues are located in 43 counties in northwestern and west central Ohio.

Figure 1 shows the amount of corn stover for each Ohio county. Figure 2 shows the total amount of corn stover and wheat straw by county.

The corn and wheat biomass availability of each county is distinguished with a different color based on the sustainable amount of crop residue per square mile of total area. Fulton County has the highest total biomass availability at 380 dry tons per square

mile. The biomass availability in seven other counties (Henry, Crawford, Mercer, Darke, Van Wert, Wood, and Putnam) exceeds 300 dry tons per square mile.

Bioethanol Production Potential

Total bioethanol potential from crop residues in Ohio was estimated to be about 340 million gallons per year. The bioethanol potential from crop residues in the 43 northwestern and west central counties of Ohio was estimated to be about 300 million gallons per year, or about 85% of the total ethanol potential from crop residues in Ohio.

The delivery cost of biomass is the most important factor for the bioethanol producer. Nearly one-third of the biomass ethanol production costs is attributed to the costs of the feedstock, which includes handling costs and payments to the landowner/tenant. Perlack and Turhollow (2003) estimated that corn stover can be collected, stored, and transported to ethanol facilities for about $43–$60 per dry ton using conventional baling equipment. Transportation, collection, baling, and farmer payments accounted for over 90% of that total cost.

The scale of the bioethanol conversion facilities is relatively significant for the economy of bioethanol production. Generally, capital costs for ethanol plants increase by 60%–70% for each doubling of output capacity (Perlack and Turhollow, 2003). As plants increase in capacity, the cost saving from economies of scale will be offset somewhat by increased transportation costs associated with hauling feedstock greater distances. Consequently, determining the ideal location of an ethanol plant involves striking a balance between larger handling capacities and higher feedstock costs.

Based on considerations of economies of scale and biomass availability, the optimal locations of potential ethanol plants in Ohio were determined. Counties with high biomass availability were clustered to provide two ethanol plants with feedstock demands of 6,800 and 5,700 dry tons per day, respectively (Figure 3).

Cluster 1 consists of 17 counties: Crawford, Fulton, Henry, Van Wert, Wood, Putnam, Hardin, Wyandot, Hancock, Sandusky, Seneca, Paulding, Allen, Williams, Defiance, Ottawa, and Lucas. These 17 counties can sustainably produce almost 7,000 dry tons of residues per day, which can supply an ethanol plant with a capacity of 130 million gallons of ethanol per year. The equivalent collection radius for this ethanol plant was estimated to be 50 miles. The equivalent collection radius was calculated based on the total area of the counties in the cluster. The transportation cost for this cluster was estimated to be about $33.75 per ton. Naturally, the actual cost is affected by current fuel prices.

Cluster 2 consists of 17 counties: Mercer, Darke, Auglaize, Madison, Preble, Shelby, Fayette, Miami, Warren, Champaign, Clinton, Clark, Logan, Greene, Union, Montgomery, and Butler. These 17 counties can sustainably produce close to 6,000 dry tons of residues per day, which can supply an ethanol plant with a capacity of 110 million gallons of ethanol per year. The equivalent collection radius for this cluster was estimated to be 50 miles. The transportation cost for this cluster was estimated to be about $34.50 per ton.

These clusters of counties are examples of how to combine counties to provide feedstock for a potential ethanol plant. The location of any future ethanol plant should be determined using the biomass availability of each county.

Ohio counties with fewer crop acres might have other cellulosic biomass such as wood waste or municipal solid waste. It is possible to provide mixed feedstock for a cellulosic ethanol plant in those areas.

A key to improving the economics of transporting the crop residue will be the development of a packing system that increases the density above that of a conventional baler. If the stover and straw were packed to a density of, say, double that of the current big square bales, then the feasible distance to the ethanol plant could be increased and the farmer might receive a higher return.

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Table 1. Biomass Availability and Ethanol Potential for the Top 43 Counties of Ohio.

	County (ranked by biomass/mi^2)	Area (mile^2)	Collectable Biomass (tons)			Biomass Availability (ton/mi^2)	Ethanol Potential (gal)
			Corn Stover	*Wheat Straw*	*Total*		
1	Fulton	407	136,013	18,714	154,727	380	10,073,000
2	Henry	417	117,285	31,156	148,441	356	9,664,000
3	Crawford	402	118,968	18,841	137,809	343	8,972,000
4	Mercer	463	131,830	19,775	151,605	327	9,870,000
5	Darke	600	172,484	17,480	189,964	317	12,367,000
6	Van Wert	410	109,298	19,425	128,723	314	8,380,000
7	Wood	617	145,284	43,429	188,713	306	12,286,000
8	Putnam	484	107,734	37,974	145,708	301	9,486,000
9	Hardin	470	122,026	14,701	136,727	291	8,901,000
10	Wyandot	406	97,613	19,681	117,294	289	7,636,000
11	Hancock	531	117,459	31,664	149,123	281	9,708,000
12	Auglaize	401	93,257	19,345	112,602	281	7,331,000
13	Madison	465	121,426	8,894	130,320	280	8,484,000
14	Sandusky	409	98,040	16,070	114,110	279	7,429,000
15	Preble	425	113,157	5,210	118,367	279	7,706,000
16	Shelby	409	97,489	13,326	110,816	271	7,214,000
17	Fayette	407	99,173	8,704	107,877	265	7,023,000
18	Miami	407	100,571	6,838	107,409	264	6,993,000

Table 1. Biomass Availability and Ethanol Potential for the Top 43 Counties of Ohio (cont'd).

	County (ranked by biomass/mi^2)	Area (mile^2)	Collectable Biomass (tons)			Biomass Availability (ton/mi^2)	Ethanol Potential (gal)
			Corn Stover	*Wheat Straw*	*Total*		
19	Seneca	551	114,389	30,198	144,587	263	9,413,000
20	Pickaway	502	107,669	18,061	125,729	251	8,185,000
21	Paulding	416	70,082	34,103	104,185	250	6,783,000
22	Allen	404	86,146	14,727	100,873	249	6,567,000
23	Champaign	429	101,613	4,863	106,476	248	6,932,000
24	Clinton	411	92,760	4,460	97,220	237	6,329,000
25	Clark	400	88,666	3,381	92,046	230	5,992,000
26	Huron	493	97,161	16,240	113,401	230	7,383,000
27	Marion	404	82,422	10,219	92,641	229	6,031,000
28	Williams	422	75,949	19,466	95,415	226	6,212,000
29	Logan	458	93,897	7,860	101,757	222	6,625,000
30	Greene	415	84,574	4,123	88,697	214	5,774,000
31	Defiance	411	68,667	16,874	85,541	208	5,569,000
32	Erie	255	46,618	6,213	52,830	207	3,439,000
33	Union	437	72,507	10,220	82,727	189	5,386,000
34	Morrow	406	57,296	9,691	66,987	165	4,361,000
35	Ottawa	255	30,470	10,555	41,025	161	2,671,000
36	Fairfield	505	69,638	10,172	79,811	158	5,196,000
37	Delaware	442	52,800	8,830	61,629	139	4,012,000
38	Wayne	555	69,750	7,409	77,159	139	5,023,000
39	Knox	527	65,085	4,002	69,087	131	4,498,000
40	Lucas	340	36,558	5,425	41,983	123	2,733,000
41	Ashland	424	42,678	5,537	48,215	114	3,139,000
42	Montgomery	462	49,708	2,511	52,219	113	3,400,000
43	Licking	687	64,797	4,912	69,709	102	4,538,000
	Total	19,142	3,921,005	621,280	4,542,284	237	295,714,000

Figure 1. Availability of Corn Stover in Ohio on a County Basis.

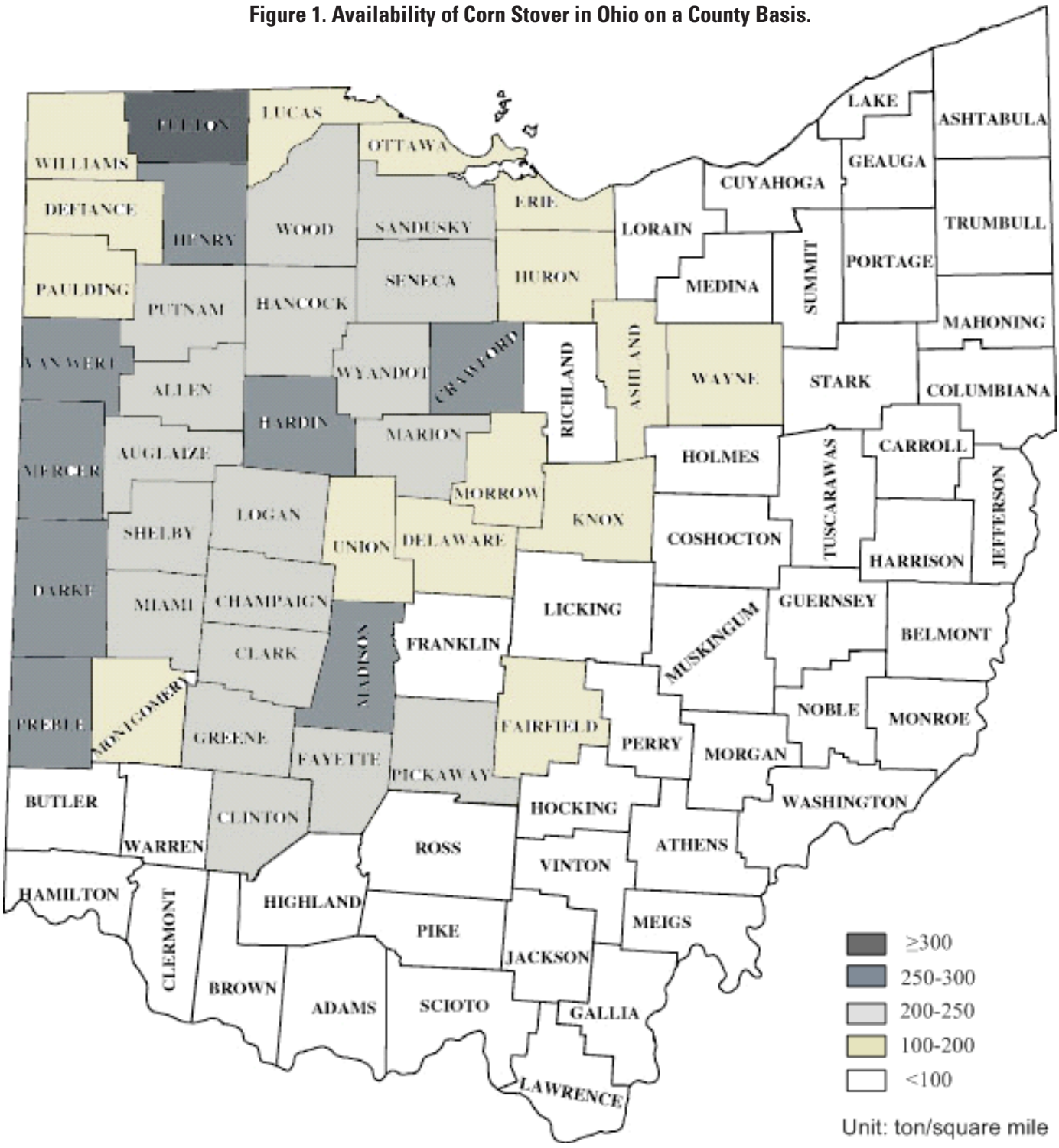

Figure 2. Availability of Crop Residues (Corn Stover and Wheat Straw) in Ohio on a County Basis.

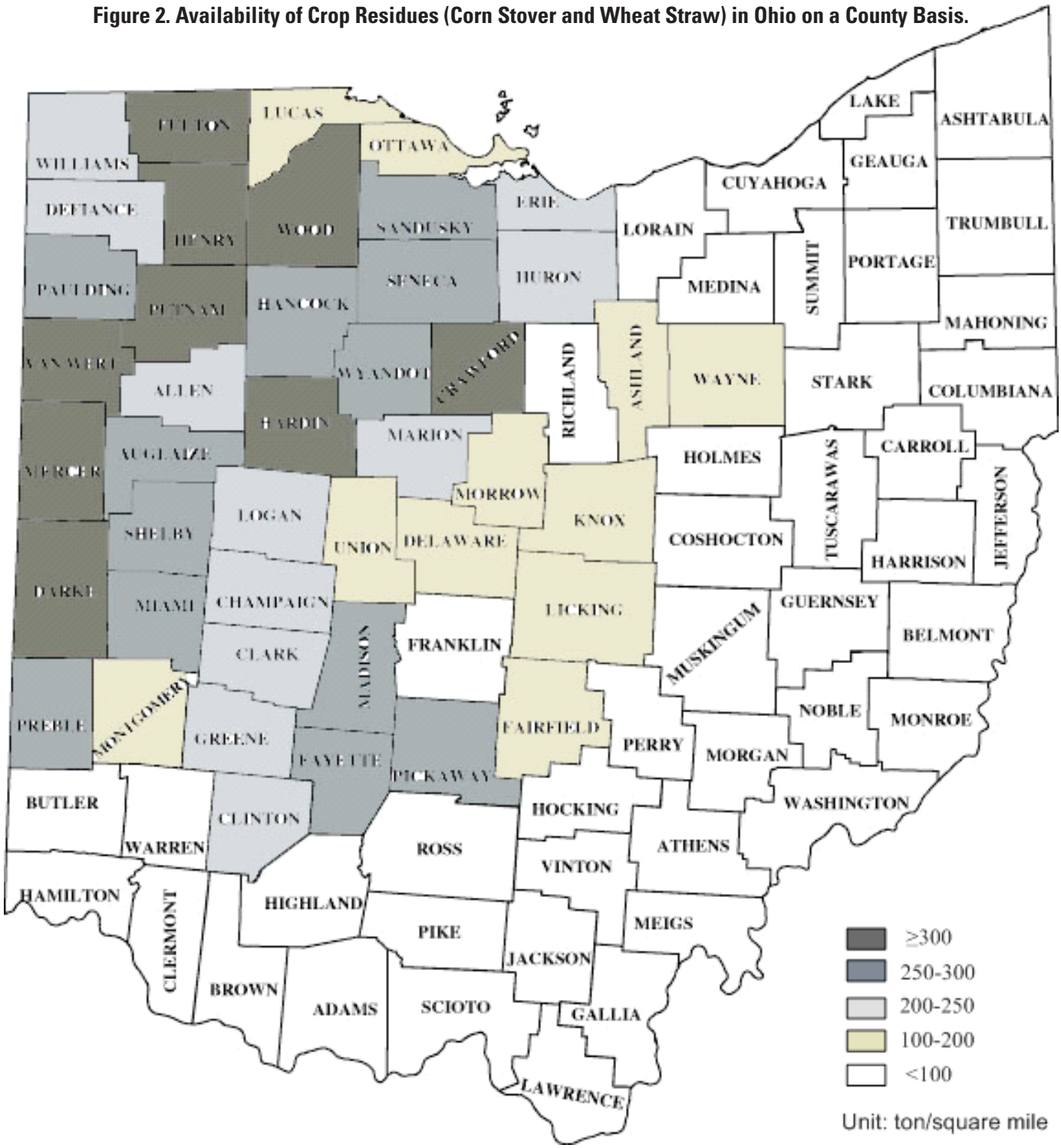

Figure 3. Clusters of Counties for Ethanol Production in Ohio.