An Assessment of the Feasibility of Electric Power Derived from Biomass and Waste Feedstocks

November 1998

KRD-9513

By

Joseph E. King, AIA
Coriolis

J. Mark Hannifan
Heritage Technologies

Richard Nelson, Ph.D.
Engineering Extension Service
Kansas State University

For

Kansas Electric Utilities Research Program
P.O. Box 1007
Topeka, Kansas 66601-1007

Kansas Corporation Commission
Energy Programs Division
1500 SW Arrowhead Road
Topeka, Kansas 66604-4027

Western Regional Biomass Energy Program

TABLE of CONTENTS

Appendix C
BIOPOWER Analysis of Case Studies

Disk Appendix (KRD-9573) Directory

ALMANAC
SSURGO
Erosion Index
BEPCEE
BIOPOWER worksheets, etc. can not be included in an electronic media for distribution due to license restrictions of EPRI.

TABLES

FIGURES

ACKNOWLEDGEMENTS

Project Team

Joseph E. King, AIA, Coriolis, 123 West Eighth Street, Lawrence, Kansas 66044, 785-841-1906 jeking@idir.net .

Dr. Richard Nelson, Kansas Industrial Extension Service, Ward Hall, Kansas State University, Manhattan, Kansas 66506-2508, 785-532-4999 rnelson@oz.oznet.ksu.edu .

J. Mark Hannifan, Heritage Technologies, 12404 Catalina, Leawood, Kansas 66209, 913-451-9616 hannifan@heritage-corp.com .

Jay Hutton, GIS Consultant, 1512 ½ Kentucky Street, Lawrence, Kansas 66044 jhutton@sunflower.com .

Kansas Electric Utilities Research Program (KEURP)

We owe particular gratitude to Jerry Lonergan, Executive Director of the Kansas Electric Utilities Research Program for his determined support for the KEURP renewable energy R&D program and his patience throughout what became a much longer than anticipated project timetable. Thanks are also extended to Lois Tully-Gerber who patiently supported and encouraged us. The KEURP Renewable Energy Task Force helped launched this project and offered constructive input as it neared conclusion. The KEURP Technical and Executive Committees must ultimately address how to proceed with renewable energy resource development, including biomass, in a turbulent time for electric utilities.

Kansas Corporation Commission (KCC)

Jim Ploger, Manager of the Kansas Corporation Commission's Energy Program, has been a persistant advocate of seeking pragmatic strategies for developing Kansas' renewable energy resources. His encouragement and the KCC's funding support were important factors in completion of this project.

KEURP Member Utilities

Bob Fackler, Director of System Operations and Dispatch Support for Western Resources, Inc. and Dr. Alex Hapka, Manager of Research for Kansas City Power & Light Company provided valuable information on the performance characteristics of power plants operated by their respective companies, which was used in the assessment of the competitiveness of co-firing biomass with coal.

Blackland Research Center (BRC)

Corporations threatened by unwelcome acquisition often seek a "white knight." A year into this project we were threatened by failure to devise a credible strategy for rigorously estimating biomass energy crop yields, a critical factor in the financial viability of plantation biomass for electric power, or any other application. We found the "white knights" in the Blacklands. Scientists at the U.S. Department of Agriculture's Blackland Research Center (BRC) near Temple, Texas provided invaluable assistance in developing and executing a strategy for evaluating the many complex variables that affect plant growth, yield, and environmental impact. Dr. Verel Benson provided technical assistance in plant growth modeling, making extensive computer runs on biomass and grain crops for hundreds of soils across six Kansas climate

regions. Dr. Jim Kiniry, the principal author of ALMANAC, the rigorous computer model used for plant growth analysis, assisted in developing detailed plant characterizations for switchgrass and black locust. Dr. Srini Srinivasn closed doors through which we had long stared regarding GIS analysis of soils and land use, while just as quickly opening others that ultimately allowed us to make progress. Other staff members at the BRC helped in many ways to allow the project to proceed. Without the friendly, persistent, and effective assistance of the BRC staff, the results of this project would have sorely suffered.[1]

Kansas State University
Dr. Mike Langemeier, is an associate professor with the Department of Agricultural Economics at Kansas State University (KSU). His area of expertise is conventional commodity and hay crop production economics. Dr. Langemeier provided valuable insights and inputs regarding the dynamics and interaction between agricultural and bioenergy crop production.

Dr. Wayne Geyer a professor in the KSU Department of Forestry and has over 30 years experience in the development, maintenance, harvesting, and use of short-rotation woody crops in Kansas. Dr. Geyer helped outline the establishment, maintenance, and harvesting procedures associated with black locust and his past yield determination experiments on various species throughout the state provided a valuable source of data used for comparison with the ALMANAC model.

Dr. John Fritz, associate professor in the KSU Department of Agronomy, provided yield data for several varities of switchgrass at two different sites (climatic and soil type) in Kansas. These data were used to help calibrate the ALMANAC model. Dr. Fritz also helped critique the yield data output from the ALMANAC model.

Dr. Gary Naughton, Professor Emeritus of the KSU Department of Forestry, provided helpful advice regarding potential yields of promising short rotation woody crops.

Oak Ridge National Laboratory (ORNL)
Dr. Mark Downing is the research leader for ORNL's Biofuel Feedstock Development Program (BFDP) and evaluates the technical and economic feasibility of herbaceous and short-rotation woody crops as alternative energy sources for electric generation. Dr. Downing provided documentation on potential attainable yields for switchgrass and black locust for several locations throughout the United States, as well as providing economic and energetic data concerning establishment, maintenance, and harvesting of bioenergy crops. His prior work on the TVA region was a valuable resource in developing our analytical approach. Dr. Marie Walsh provided documentation on ORNL's BIOCOST computer model which proved valuable in the development of production cost analysis methods.

[1] Grassland, Soil and Water Research Laboratory is the official US Department of Agriculture (USDA) Agricultural Research Service (ARS) name and Blackland Research Center is the official Texas Agricultural Experiment Station (TAES) name. Dr. J. R. Kiniry is USDA, ARS, Dr. R. Srinivasan is TAES and Dr. V. W. Benson is USDA, NRCS. Dr. J. R. Williams is TAES, formerly USDA, ARS. In this report the lab and is generally referred to as USDA Blackland Research Center or BRC.

Dr. Robin Graham, a research scientist with the Biofuel Feedstock Development Program, with expertise in evaluating environmental impacts associated with bioenergy crop production and use, helped review the environmental data output from the ALMANAC model. Dr. Graham also helped evaluate various technical and economic merits associated with black locust production.

Anne Ehrenshaft, also a research scientist with BFDP, provided the project team with a database of short-rotation woody crop yield and production data for several species investigated in Kansas.

Others

The Chariton Valley project in south central Iowa represents the largest switchgrass for energy trial in the U.S. Alan Teel, for many years a key participant in the project, shared his first hand practical experience with us, first by phone, and later during a long afternoon meeting in Atlantic, Iowa. His keen insights were extremely helpful. Marty Braster of Chariton Valley RC&D provided valuable reports generated by their program, including a useful report on the engineering requirements for co-firing switchgrass in a utility boiler. Scoot Coon of RW Beck, a consulting firm collaborating with Chariton Valley RC&D, also provided useful and updated information on the engineering requirements for co-firing switchgrass.

Staff of the Data Access and Support Center at the Kansas Geological Survey provided compact disks with SSURGO, Landcover, and Tiger road files for the Kansas counties being investigated.

George Wiltsee of Appel Consulting served as project monitor on behalf of the Western Regional Biomass Energy Program (WRBEP). His assistance and that of Chuck McGowin of the Electric Power Research Institute in acquiring the current version of the EPRI BIOPOWER computer program used for case study analyses is greatly appreciated.

DISTRIBUTION

This report is available in Adobe Portable Document File (pdf) format from the KEURP web page at http://www.keurp.com. Copies of the report have been distrtibuted on CD-ROM, in pdf format, to the list below. A limited number of paper copies of the report, including extensive appendices and a detailed 11 x 17 map gazateer, are available directly from KEURP.

KEURP

Staff

Jerry Lonergan. keurpjl@cjnetworks.com
Lois Tully-Gerber keurpltg@cjnetworks.com

Executive Committee

Gene Argo, Midwest Energy, Inc., Hays, Kansas geneargo@mwenergy.com
Tom Bryant, Kansas Board of Regents, Topeka, Kansas tom@kbor.state.ks.us
Frank DeBacker, UtiliCorp United, Inc., Kansas City, Missouri fdebacke2@utilicorp.com
Alexander Hapka, PhD, Kansas City Power & Light Company, Kansas City, Missouri arh3119@kcpl.com
Tony Stark, Empire District Electric Company, Joplin, Kansas tstark@empiredistrict.com
Carrol L. Waggoner, Sunflower Electric Power Corporation waggoner@sunflower.com
John Wine, Kansas Corporation Commisssion j.wine@.kcc.state.ks.us
David Wittig, President and CEO, Western Resources, Topeka, Kansas

Technical Committee

DeWayne Backhus Emporia State University, Emporia, Kansas backhusd@emporia.edu
Louis Caplan, PhD, Fort Hays State University, Hays, Kansas dolc@fhsuvm.fhsu.edu
Bill Dowling, Midwest Energy, Inc., Hays, Kansas bdowling@mwenergy.com
Robert Egbert, PhD, Wichita State University, Wichita, Kansas bobe@ece.twsu.edu
Les Evans, Western Resources, Inc., Topeka, Kansas les_evans@wstnres.com
Richard Hayter, PhD, Kansas State University, Manhattan, Kansas rhayter@ksu.edu
Jim Keating, PhD, Kansas State University – Salina, Salina, Kansas jkeatin@ksu.edu
Larry Holloway *(KCC liason)* l.holloway@kcc.state.ks.us
Carla Maxwell, Kansas City Power & Light Company, Kansas City, Missouri cam4370@kcpl.com
John Neagle, Empire District Electric Company, Joplin, Missouri jneagle@empiredistrict.com
Wayne Penrod, Sunflower Electric Power Corporation, Garden City, Kansas wepenrod@sunflower.net
James Roberts, PhD, Univeristy of Kansas, Lawrence, Kansas jroberts@eecs.ukans.edu
William Studyvin, PhD, Pittsburg State University, Pittsburg, Kansas wsudyvi@pittstate.edu

Renewable Energy Task Force

Robert Egbert, PhD, Wichita State University, Wichita, Kansas bobe@ece.twsu.edu
Mike Engel, Midwest Energy Inc., Hays, Kansas mengel@mwenergy.com
Bob Fackler, Western Resources, Inc., Topeka, Kansas bob_fackler@wstnres.com
Robert Glass, PhD, The University of Kansas, Lawrence, Kansas bob@ippbr.wpo.ukans.edu
Alex Hapka, PhD, Kansas City Power & Light Company, Kansas City, Missouri arh3119@kcpl.com
Tom Hestermann, Sunflower Electric Power Corporation, Hays, Kansas tkhestermann@sunflower.net
Larry Holloway, Kansas Corporation Commission, Topeka l.holloway@kcc.state.ks.us
Bill Howell, Empire District Electric Company, Joplin, Missouri whowell@empiredistrict.com
Richard Nelson, PhD, Kansas State University, Manhattan, Kansas rnelson@oz.oznet.ksu.edu
Frank Potter, PhD, Fort Hays State University, Ft Hays,Kansas bifp@fhsu.edu
Rod Sobieski, PhD, Emporia State University, Emporia, Kansas, sobieski@esumail.emporia.edu
William Studyvin, PhD, Pittsburg State University, Pittsburg, Kansas wstudyvi@pittstate.edu
Ray Taghavi, PhD, The University of Kansas Lawrence, Kansas rtaghavi@aerospace.ae.ukans.edu
Paul York, PhD, Wichita State University, Wichita, Kansas paul@ece.twsu.edu

Kansas Corporation Commission
John Wine, Chairman j.wine@kcc.state.ks.us
Jim Ploger, Energy Programs Director j.ploger@kcc.state.ks.us
Larry Holloway *(KCC liason)* l.holloway@kcc.state.ks.us

Western Regional Biomass Program
George Wiltsee, Appel Consulting g.wiltse@earthlink.net
Jeff Graef, Program Administrator, Nebraska Energy Office jgraef@mail.state.ne.us

U.S. Department of Agriculture
Dr. Verel Benson, Blacklands Research Center, Temple, Texas benson@brcsun.tamu.edu
Dr. Jim Kiniry, Blacklands Research Center, Temple, Texas kiniry@brcsun.tamu.edu

Oak Ridge National Laboratory
Dr. Mark Downing, Oak Ridge National Laboratory E39@ornl.gov
Dr. Robin Graham, Oak Ridge National Laboratory aeg@ornl.gov
Dr. Marie Walsh, Oak Ridge National Laboratory mwalsh@ornl.gov

U.S. Environmental Protection Agency
Ethan McMahon, State and Local Climate Change Program, McMahon.Ethan@epamail.epa.gov

Kansas State University
Dr. Wayne Geyer, Department of Forestry
Dr. Mike Langemeier, Department of Agricultural Economics
Dr. John Fritz, Department of Agronomy

Kansas Department of Health and Environment
Don Snethen, Chief, Nonpoint Source Section, dsnethen@state.kdhe.us.ks

Kansas Department of Agriculture
Greg Krissek, Assistant to the Secretary, Gkrissek@kda.state.ks.us

Kansas Water Office
Al LeDeoux, Director, al@fog.kwo.state.ks.us

State Conservation Commission
Tracy Streeter, Executive Director

Others
Alan Teel, Iowa State University Extension Service, Atlantic, Iowa x1teel@exnet.iastate.edu
Marty Braster, Chariton Valley RC&D
Chuck McGowin, EPRI, cmcgowin@epri.com
Ray Costello, US DOE, raymond.costello@hq.doe.gov

0.0 EXECUTIVE SUMMARY

Approximately 1.3% of America's 776,000 MW of electrical generating capacity was fueled by biomass or waste resources in 1997. About 64 billion of the 3,123 billion kWh hours generated that year were biomass or waste fueled.[2] The U.S. Department of Energy hopes to increase that figure to 30,000 MW by 2020, primarily through a program to reduce biomass production cost. Yet there is no biomass fueled generating capacity in Kansas today, and the most optimistic plant gate energy costs of $1.64 per MMBtu (2% cofiring at LaCygne No. 1) in Kansas today exceeds average coal and nuclear fuel costs by 60% and 100% respectively. In 1993 the Union of Concerned Scientists published a report titled ***Powering the Midwest***, in which they concluded Kansas could produce 40 million dry tons of herbaceous energy crops annually. The real extent to which biomass fueled electric power is developed in Kansas will depend on green pricing programs, continuation of the federal plantation biomass energy tax credit, and government mandates, for the foreseeable future. As part of the Kansas Electric Utilities Research Program's (KEURP) multi-year renewable energy development program, a major goal of this project was to develop a rigorous, repeatable, analytical process permitting KEURP member utilities to aggressively prospect for the lowest cost biomass fueled generation available in Kansas today, and again in the future should circumstances affecting the viability of biomass fueled generation change.

Plantation Biomass. The increasingly competitive electric utility market makes fuel cost a critical factor in biomass use for power generation. The strategy driving this analysis was to prospect for the lowest cost biomass energy resources. A detailed investigation of potential biomass energy crop yields, total production, and edge of field cost per million Btus has been performed, focusing on 74 counties in that portion of Kansas with greater than 22 in. annual rainfall (east of Highway 183). The analysis divided this portion of the state into six climate regions. ALMANAC, a rigorous plant growth model developed by scientists at the U.S. Department of Agriculture, was used to estimate the annual yield for 24 years, fertilizer use, and environmental impact for the most promising herbaceous energy crop (HEC), switchgrass *(Panicum virgatim)*, and the most promising short rotation woody crop (SRWC), black locust *(Robinia pseudoacacia)*, for each of 315 soil series within the six climate regions.

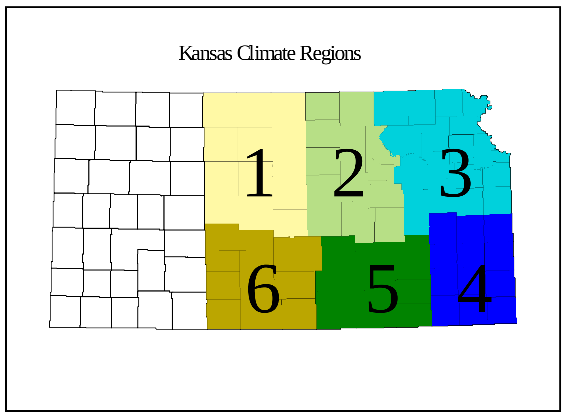

Figure 0.1 Kansas Climate Zones

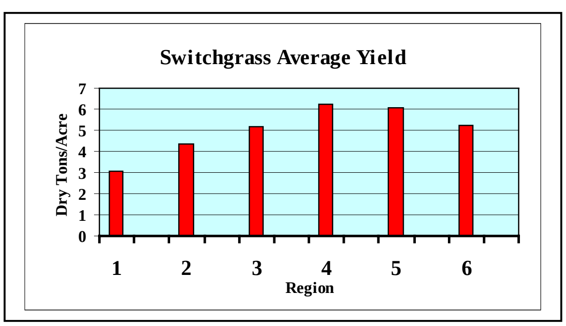

Figure 0.2 Average Switchgrass Yield

Energy Crop Yields. Yield is a major factor in determining biomass energy costs. The cost of many field operations is essentially constant, changing only slightly as yield increases.

[2] http://www.eia.gov/cneaf/electricity

Exclusive of land value, a doubling of yield nearly halves cost. Average annual switchgrass yields (tons/acre) were substantially higher than for black locust. Under drought conditions some soils in the two western regions produced almost nothing. The single year highest yield of 14.9 dry tons/acre occurred on a Kansas River valley soil in Shawnee County. Yields were higher for the eastern regions and highest overall for the southeast. Yields varied significantly by year and individual soil series. A detailed review of switchgrass yields is in Section 2.8.1 with region and soil specifc detail in Appendix B.2.

While hybrid poplar has become the favored SRWC for much of the U.S., extensive research conducted in Kansas in the early 1980s indicated black locust may perform better under Kansas climate and soil conditions. Black locust offers significant potential for genetic improvement, but regrettably, research has been essentially discontinued in the U.S. Yields were based on eight year harvest intervals with the tree regrowing from the stump after harvest (coppice). The eight year cycle allows SRWCs to avoid years of extremely low harvest except for long term droughts. While black locust average annual yields were generally about one third lower than switchgrass, the pattern between regions was similar. The maximum average black locust yield of 5.8 dry tons/acre/yr (eight year cycle) occured in Wilson County. A detailed review of black locust yields is in Section 2.8.1 with region and soil specific detail in Appendix B.5.

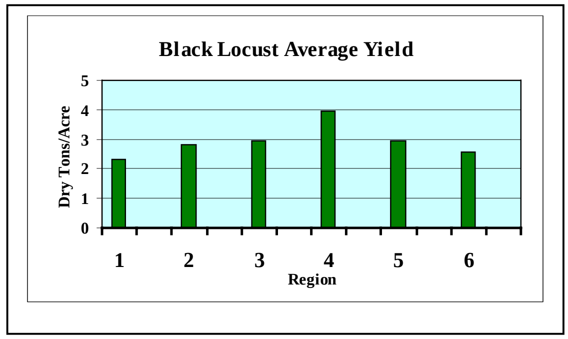

Figure 0.3 Average Black Locust Yield

Biomass Cost. A detailed Excel workbook, Biomass Energy Production Cost and Embodied Energy (BEPCEE) was developed to estimated all phases of production cost and the associated embodied energy. In addition to yield, land cost is a significant factor in total production cost. Production cost was evaluated without land cost, and with two distinct land cost scenarios. The first was based on land used for biomass production paying conventional land rent, plus yielding a profit equal to the profit yielded by the most profitable grain crop. This scenario was intended to set the upper bound of estimated cost. The second scenario was intended to set a lower bound on estimated cost by assuming use of land potentially eligible for the federal Conservation Reserve Program (CRP). Current eligibility criteria for CRP enrollment are complex, and an erosion index greater than eight was used as a screening factor for potential CRP eligibility. A rent payment of 40% of the CRP rate and a profit of 10% were used for this scenario, the goal of which was to outline a strategy through which the government (taxpayer) would pay less (half of the

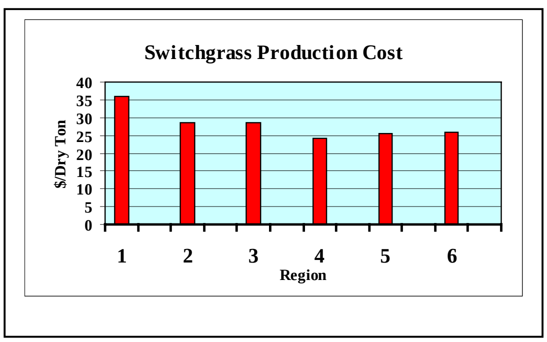

Figure 0.4 Average Switchgrass Cost
(edge of field, regular land rent, no profit)

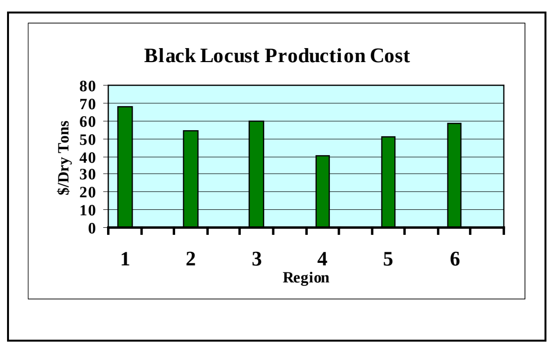

Figure 0.5 Average Black Locust Cost
(edge of field, regular land rent, no profit)

40% rent could be used to reduce the federal payment), the land owner would make more (the other half of the 40% rent), and biomass fuels could better compete with fossil fuels. Figures 0.4 and 0.5 show the average edge of field cost for all soils by region based on conventional land rent, before profit. The lowest average regional cost of switchgrass ($24.11/dry ton - $1.52/MBtu) and black locust ($40.20/dry ton - $2.38/MBtu) occur in southeast Kansas where yields of both are highest. Black locust average cost is generally nearly double that of switchgrass due to lower yields, and the cost of deferring recovery of establishment costs and land rent for eight years. Edge of field cost under the two other land value scenarios (biomass vs. grain and CRP) are significantly different and identifying the lowest cost biomass requires evaluation at the soil series level for each region, issues discussed in Section 2.8.1 and 2.8.4 and detailed in Appendix B.2.

Market conditions would likely preclude a high percentage of land of a particular soil type or of the total land area within a county being dedicated to biomass production. Furthermore, land area covered by water, roads, urban development, public ownership, and woodland are not available for potential biomass production. To exclude these incompatible land uses and to track land parcels by the soil types corresponding to those for which yields and costs were calculated, an extensive set of geographic information system (GIS) maps were developed. These included county level and regional maps of soils from the SSURGO detailed soils database with areas of incompatible land use identified in the Landcover database and road rights-of-way identified in the Census Bureau Tiger road files excluded.

Biomass Production and Generation Potential. Total biomass energy production potential was estimated by region, using the yields described above and limiting biomass land access to a

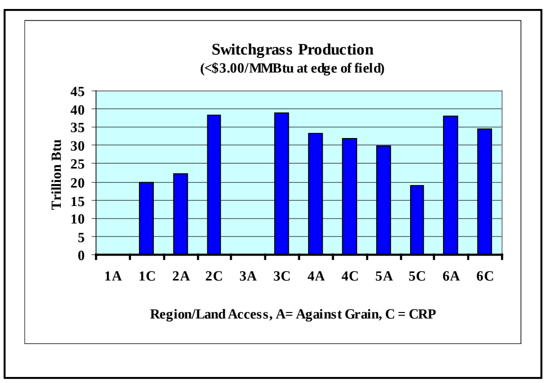

Figure 0.6 Switchgrass Production
(<$3.00/MBtu edge of field)

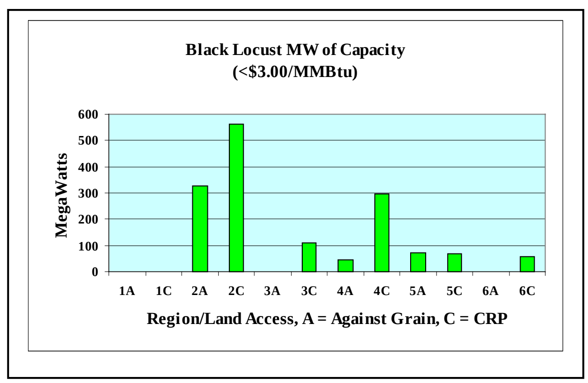

Figure 0.7 Black Locust Production
(<$3.00/MBtu edge of field)

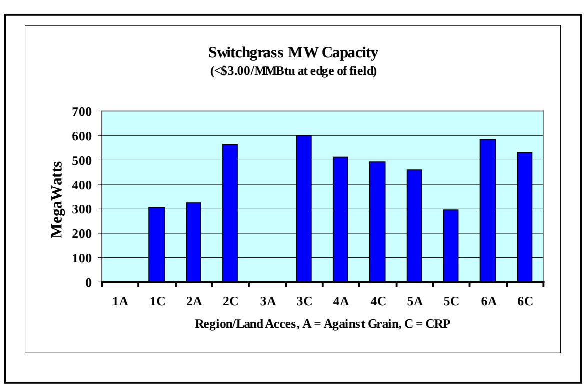

Figure 0.8 Potential Switchgrass Generation
(<$3.00/MBtu edge of field)

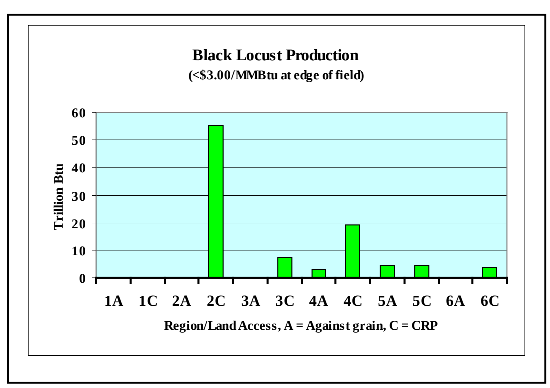

Figure 0.9 Potential Black Locust Generation
(<$3.00/MBtu edge of field)

maximum of 50% of any soil series and 10% of the potentially eligible land within each county. Within these constraints the average annual edge of field energy production for all six regions at a cost less than $3.00/MBtu totalled 182.3 trillion Btus on land potentially eligible for CRP and 121.1 trillion Btus on all land suitable for switchgrass. For black locust comparable values were 72.9 trillion Btus on land potentially eligible for CRP and 27.0 trillion Btus on all suitable land. Figures 0.6 and 0.7 break down the energy production by region for switchgrass and black locust vs. grain on land potentially eligible for CRP. In regions one and two the amount of land on which switchgrass can equal the profit potential of the most profitable grain is very small. The lower yield and higher cost of black locust results in substantially lower total production potential and very little production when competing against grain in regions 1, 3, and 6 or land potentially eligible for CRP in region 1.

Biomass Potential Contribution to Kansas Electricity Consumption. At a conversion efficiency of 30% and an annual plant factor of 65% the total generating capacity in all six regions that could be fueled with biomass with an edge of field cost less than $3.00/MBtu is estimated at 2,787 megaWatt (MW) on land potentially eligible for CRP and 1,885 MW for all suitable land for switchgrass and 1,099 MW on land potentially elible for CRP and 441 MW for all suitable land for black locust for black locust. Figures 0.8 and 0.9 provide a regional breakdown of generation potential. These numbers represent an estimated maximum, and do not account for transportation costs from the field edge to the plant gate or the cost of fuel processing. Some land parcels may also be too small or too spatially dispersed to be useable.

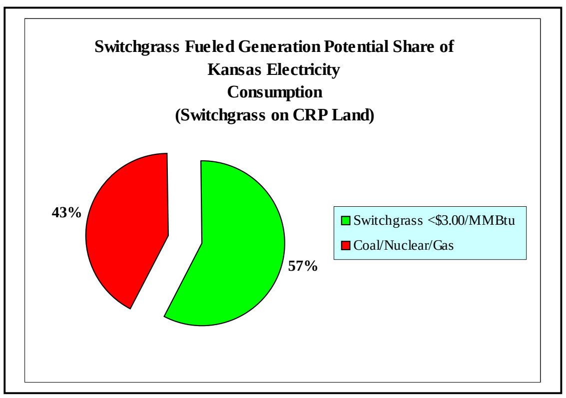

Figure 0.10 Potential Switchgrass Share of Kansas Electricity Use

The biomass fueled generation described above could produce the equivalent of approximately 57% (switchgrass) or 23% (black locust) of Kansas 1995 electrical energy consumption. This high number serves only to characterize the maximum technical potential within the parameters outlined for this project. It is not an indication of currently economically viable biomass fueled generation. The options presented for switchgrass and black locust are generally exclusive of each other, and can not be added together because they are competing for the same land area.

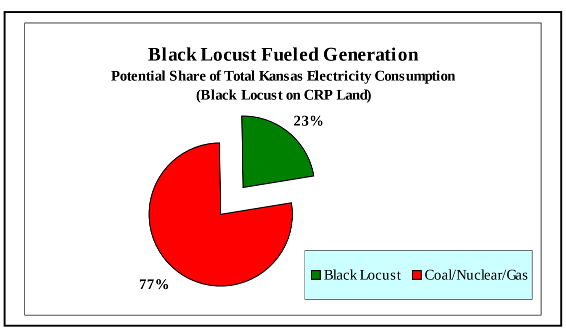

Figure 0.11 Potential Black Locust Share of Kansas Electricity Use

Waste Energy Resources. Waste resources in Kansas are diffuse due to the lack of large population centers. Municipal solid waste, landfill gas, tires, wood waste, and agricultural residues were inventoried and evaluated. Compared to plantation biomass, the indiviual and aggregate generation potential of waste resources is limited.

Co-firing Case Studies.

After reviewing detailed maps of switchgrass and black locust yield and cost, and conversations with utility members of the the KEURP renewable energy task force, Jeffrey Unit 1, a 734 MW pulverized coal plant and LaCygne Unit 1, a 688 MW cyclone boiler coal plant, were selected for further case study evaluation. Transportation cost was estimated for each SSURGO soil parcel within 50 miles of the plant (in Kansas), based on a fixed $4.00/ton load/unload fee plus ten cents per ton mile. Soil series were sorted by plant gate cost (area weighted) and cost increments. The lowest cost production was selected, limited by not more than 50% of the area of any soil series/cost increment block, and not more than 10% of the total land area in any one county, until the tons required were identified for 2% and 5% co-firing. Results for switchgrass and black locust, including field edge and plant gate biomass cost and energy profit ratio (energy produced divided by energy invested), are summarized in Table 0.1 below.

Table 0.1 Biomass Cost and Energy Profit Ratio (EPR) for 2% and 5% Cofiring

			Edge of Field			Plant Gate		
Crop	Land	Tons	$/ton	$/MBtu	EPR	$/ton	$/MBtu	EPR
Jeffrey – 2% Co-fire								
Switchgrass	CRP Land	58,730	$23.14	$1.46	16.58	$28.31	$1.79	15.40
Switchgrass	Vs. Grain	58,730	$23.22	$1.47	16.01	$28.87	$1.82	13.71
Black Locust	CRP Land	55,631	$45.23	$2.68	40.92	$50.18	$2.98	29.66
Black Locust	Vs. Grain	55,631	$54.87	$3.25	37.49	$63.38	$3.76	26.88
Jeffrey – 5% Co-fire								
Switchgrass	CRP Land	146,788	$23.22	$1.47	16.60	$28.87	$1.82	15.19
Switchgrass	Vs. Grain	146,788	$39.81	$2.51	15.60	$48.22	$3.04	13.36
Black Locust	CRP Land	139,078	$48.87	$2.90	41.47	$55.49	$3.29	32.11
Black Locust	Vs. Grain							
LaCygne – 2% Co-fire								
Switchgrass	CRP Land	52,028	$19.75	$1.25	15.87	$26.00	$1.64	14.33
Switchgrass	Vs. Grain	52,028	$32.68	$2.06	14.57	$38.50	$2.43	13.41
Black Locust	CRP Land	48,966	$36.65	$2.17	56.83	$42.91	$2.54	41.72
Black Locust	Vs. Grain	122,415	$49.36	$2.93	51.49	$56.48	$3.35	36.52
LaCygne – 5% Co-fire								
Switchgrass	CRP Land	130,070	$19.75	$1.25	15.87	$26.09	$1.65	14.29
Switchgrass	Vs. Grain	130,070	$32.68	$2.06	14.67	$38.83	$2.45	13.38
Black Locust	CRP Land	122,415	$37.01	$2.19	57.15	$43.53	$2.58	41.08
Black Locust	Vs. Grain	122,415	$53.50	$3.17	52.58	$60.08	$3.56	38.47

Environmental Impact of Biomass Energy Crops. The use of switchgrass and black locust results in reduced soil erosion due to rainfall as well as general reductions in nutrient loss in runoff and subsurface flow versus all conventional commodity crops. Soil erosion due to rainfall was reduced an average of 99% and runoff was significantly reduced by bioenergy crop production with the exception of one case. Percent reductions in organic nitrogen and phosphorus loss with sediment due to switchgrass and black locust production exceeded 96% versus the most profitable grain crop.

Average percent reductions in soluble phosphorus loss in runoff and NO_3 loss in surface runoff were generally in the low 90 percent range for both bioenergy crops for all soil types considered. Average reductions in mineral nitrogen loss in subsurface flow were in the upper-80 to mid-90 percent for switchgrass, but ranged from the low 90 percent to plus one percent for black locust production in several cases.

Reductions in mineral nitrogen loss with percolate were generally positive for switchgrass production with the exception of several soils in region 2; however, black locust production showed a marked increase in mineral nitrogen loss with percolate with the exception of region 5.

Overall, the effect of using switchgrass and black locust has a postive impact when considering the loss of nitrogen and phosphorus to sediment, subsurface flow, and percolation when compared to the four conventional commodity crops.

Co-Firing at Jefrey and LaCygne: BioPower Results

BIOPOWER, a computer program developed by the Electric Power Research Institute (EPRI), was used to evalute inside the plant gate performance of switchgrass co-fired with coal at rates of 2% and 5% for Jeffrey Unit 1 and LaCygne Unit 1. Based on the costs of coal and biomass feedstocks, operational characteristics of a power plant, and capital requirements to handle and process biomass materials in a co-fire mode, BIOPOWER reports in a comparative manner the levelized cost of electricity generated and resulting atmospheric emissions for "coal-only" and "co-fired" cases. Based on the delivered costs of switchgrass shown in Table 0.1, operational characteristics of the two plants provided by Western Resources and Kansas City Power & Light Company (as presented in Section 5), and estimated capital requirements to handle and process switchgrass in a co-fire mode (also presented in Section 5), BIOPOWER indicates that the levelized cost of switchgrass-fired electricity ranges from $0.050 to $0.085/kWh, as opposed to a levelized cost of coal-fired electricity of $0.025 to $0.028 per kWh. BIOPOWER also provides a breakeven cost for the fuel substituting for coal in a co-fire mode – in this case switchgrass – which ranges from $1.34 to -$33.24, indicating that switchgrass would need to be delivered to the plants at no cost or a negative cost to offset capital requirements and recurring O&M costs associated with switchgrass co-firing. Even though switchgrass delivered to Jeffrey Unit 1 may cost more than switchgrass delivered to LaCygne Unit 1, Jeffrey Unit 1 appears to be a better candidate for switchgrass co-firing (based solely on economic considerations) due primarily to the difference in coal costs at the two plants.

The low sulfur characteristic of switchgrass and other biomass feedstocks has been a significant factor in utility interest in co-firing biomass with coal. In the Jeffrey Unit 1 and LaCygne Unit 1 cases, the sulfur-reduction benefits of using switchgrass as a co-fire material were not as pronounced as anticipated due to two factors: first, both Jeffrey Unit 1 and LaCygne use coal that is relatively low in sulfur content, and second, capping the co-fire rate of switchgrass at 5% (for operational reasons) intrinsically limits the amount of sulfur that can be reduced by a co-fire strategy. When prevailing sulfur allowances ($/ton of sulfur avoided) were input to BIOPOWER to determine the impact on the economic feasibility of switchgrass co-firing, the impacts were found to be negligible.

In order for co-firing switchgrass to be an attractive option for Kansas utilities in the near term, two important economic conditions should be in place. First, the renewable energy production tax credit for "closed loop" biomass must be extended beyond July 1, 1999, as the $0.015/kWh credit narrows the economic gap between coal-fired electricity at $0.025 to $0.0275/kWh and co-fired electricity using switchgrass at $0.05/kWh or higher. Just as important as the extension itself is the broadening of the definition of "qualified facility" to allow utilities to obtain the production credit when co-firing biomass in pre-existing power plants. The second economic

For the best case scenarios using switchgrass as a co-fire material in Kansas, a green pricing program may need to raise $0.01 to $0.015 for each kWh of switchgrass-fired electricity in order to compete with coal.

condition that should be in place is a green pricing program that serves to cover the incremental cost differences that remain after the renewable production credit is applied. For the best case scenarios using switchgrass as a co-fire material in Kansas, a green pricing program may need to raise $0.01 to $0.015 for each kWh of switchgrass-fired electricity in order to compete with coal. While an explicit assessment of the prospects for green pricing support for biomass-fired electrical generation in Kansas is beyond the scope of this assessment, other research efforts conducted by KEURP have indicated many Kansas ratepayers may be supportive of green pricing programs.

1.0 THE STATUS of BIOMASS ENERGY

1.1 Background

Continued interest in renewable energy, now driven primarily by global environmental concerns, has motivated proposals for state and federal mandates for electric utilities to provide a minimum portion of the energy they sell from renewable resources. Midwest examples include:

Minnesota

Northern States Power selected Kenetech Windpower, Inc. to build a 25 MW wind farm in 1993, placing it in operation in 1994. Also, in exchange for permitting dry cask storage at the Prairie Island nuclear plant, the Minnesota Legislature passed a law requiring NSP to have a total of 425 MW in wind power in operation or under contract by the end of 2002.

In addition to wind, the 1994 Minnesota law required NSP to develop 125 MW of closed-loop biomass generation by the end of 2002. At this time, NSP is negotiating with District Energy St. Paul Inc. and Lindroc Energy of Encinatas, Calif., to each supply 25 MW of biomass power (for a total of 50 MW) to NSP, beginning in summer 2002. Potential projects involve use of wood waste and plantation-grown trees to fuel generating facilities. NSP also has an agreement with Minnesota Valley Alfalfa Producers (MNVAP) of Granite Falls, Minn., to supply 75 MW of farm-grown, closed-loop biomass generation resources to the NSP system by early 2002. MNVAP will build a plant using integrated gasification combined cycle technology to be fueled with alfalfa stems primarily grown in Minnesota.[3]

Iowa

Alliant Corporation (as part of an agreement made between the former Interstate Power Company and FPL Energy Inc. of Florida) will purchase power produced from a new wind farm being installed in Cerro Gordo County. FPL Energy Inc. will erect 56 turbines on about 3,000 acres south of Clear Lake. The project is expected to be completed by the end of 1999. MidAmerican Energy and IES Utilities (also part of Alliant) are installing 250 turbines with 750 kW of capacity each in Cherokee and Buena Vista counties. A group of seven Iowa municipal utilities has been awarded $2.8 million by the Department of Energy and the Electric Power Research Institute to install three 750 kW turbines near Algona. The project will be operational by June 30, 1999.[4]

Texas

Central and South West Corporation (CSW) based in Dallas has a wind and solar generating facility located in the Davis Mountains of far West Texas. The project generates electricity using 12 550-kilowatt wind turbines. In February of 1998 CSW announced plans to procure renewable energy from a new 75-megawatt wind-generation facility that will be built near McCamey, Texas. Located at a 1,233-acre site five miles south of McCamey the wind-generation facility will be the largest in Texas, using 113 wind turbines, each generating 660 kilowatts. When completed, the facility will provide renewable energy to West Texas Utilities Company (WTU), Central Power and Light Company (CPL) and Southwestern Electric Power Company

[3] Northern States Power Company web site: http://www.nspco.com/.
[4] Iowa Energy Bureau web page: http://www.state.ia.us/dnr/energy/

(SWEPCO), all subsidiaries of CSW. The project is a result of Deliberative Polls™ in which CSW customers expressed a strong interest in renewable energy.[5]

Wisconsin

Wisconsin Electric (WE) issued a Request for Proposals (RFP) in early August of 1998 soliciting bids for contracts totaling up to 75 megaWatts (MW) of renewable energy generating capacity. The RFP was in response to the governor's electric reliability legislation signed into law in the spring of 1998. The legislation calls for the investor-owned utilities in the eastern part of the state to add a combined total of 50 MW of renewable energy generating capacity to their energy mix by the end of the year 2000. WE is responsible for 27 MW of this total, but elected to exceed the requirement.

United States

Several of the many electric industry restructuring bills introduced in the U. S. Congress incorporate some form of renewable energy set-aside (RPS) requirement. The Clinton administration’s proposal includes a requirement that 5.5% of retail electric sales must come from renewables by 2010 with transition levels between 2005 and 2009 set by the DOE Secretary. “Green pricing” programs, through which utility customers agree to pay more for renewable energy, have also begun to have some success. As electricity markets become more competitive retail customers interested in “green” electricity could elect to change their utility service provider if their current utility can not supply green energy.

Kansas

The Kansas Electric Utilities Research Program (KEURP) initiated a renewable energy research program in 1994 to address member concerns about the development of renewable energy. Biomass and wind are the two technically and economically most promising utility scale renewable energy sources of electricity for Kansas. This project was undertaken to determine which biomass resources (including “wastes”) and conversion technologies offer the most economically competitive and environmentally attractive option for generating electricity. At the outset biomass fueled generation was not expected to be economically competitive with coal, the primary generating fuel used in Kansas. Yet knowledge gained from this project should help KEURP members make more informed planning decisions in response to the rapidly changing utility market.

BioPower in Kansas

Each year over half a million Btus of solar energy fall on each square foot of Kansas (15 Kwh/M^2), representing the equivalent of 230 billion barrels of crude oil for the entire state. At an efficiency of 1%, photosynthesis[6] could yield the equivalent of some 2.3 billion barrels of oil per year, equal to 57 times 1997 Kansas oil production of around 40 million barrels. Kansas is a highly agricultural state with 85+% of its 52+ million acres dedicated to crops or pasture. While 1% may sound low, a not uncommon biomass yield of 4 dry tons per acre actually represents about 0.25% efficiency. At that yield converting one million acres to biofuel production would

[5] Central and South West press release at National Wind Coordinating Committee web site: http://www.nationalwind.org/announce/csw.htm

[6] See Vaclav Smil’s ***General Energetics-Energy in the Biosphere and Civilization*** for a detailed discussion of the theoretical and practical efficiency of photosynthesis.

produce the energy equivalent of roughly 24% of the 285 trillion Btus of coal consumed in Kansas in 1995 for electricity production. On September 30, 1998 a projected 2.53 million acres of Kansas farmland will be enrolled in the federal Conservation Reserve Program (CRP) across the state, about half of it in the eastern 74 counties investigated. In reality, the potential for biofuels is much more complex; however, these simple relationships provide a general perspective on the potential energy significance of biomass.

1.3 Existing Biomass Fueled Generation

Electricity may be produced from a variety of biomass resources, including woody and herbaceous energy crops grown in dedicated plantations, wood-, municipal-, and agricultural-wastes, and other bioprocessed gases and liquids. Direct combustion of biomass may be attractive, particularly if it can be co-fired with coal to reduce environmental emissions. Gaseous fuels derived from biomass by new gasifier technologies may be used in high efficiency gas turbines. In the future, gaseous and liquid fuels derived from biomass may be used as feedstocks for stationary fuel cells. With numerous research efforts underway by agricultural interests, national laboratories, utilities, utility R&D organizations, and private industry to maximize feedstock production and/or maximize conversion efficiencies, electric generating costs near $0.05/kWh are expected from certain biomass projects by the end of the decade.[7]

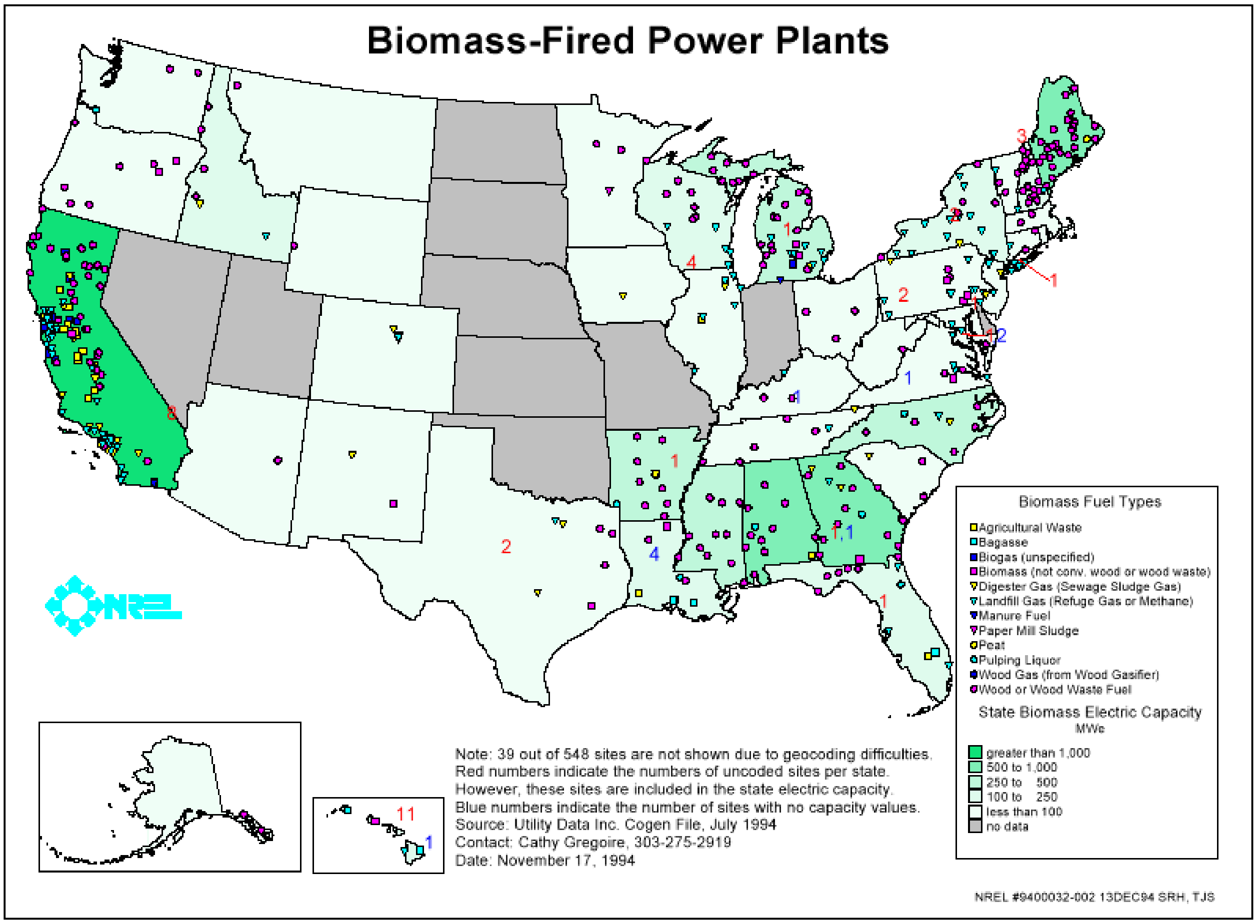

Figure 1.1 Biomass-Fired Power Plants in the United States

No biomass-fired electric generating plants exist today in Kansas. The business relationships, resource requirements, environmental impacts, and actual costs of utility-scale biomass power projects have not been assessed in Kansas for two decades. As a result, Kansas electric utilities have been reluctant to consider biomass as a power generation option.

When the Public Utilities Regulatory Policy Act (PURPA) requiring utilities to purchase power from and supply electricity at non-discriminatory rates to independent power producers was enacted in 1978, there was only about 200 MW of biomass generating capacity in the U.S.

The PURPA, along with the rising cost of oil in the early 1980s, caused biomass electric generating capacity to increase to over 6,000 MW by 1992. Wood accounted for 88 percent, landfill gas 8 percent, agricultural "waste" 3 percent, and anaerobic digesters 1 percent.[8] Although test burns of herbaceous energy crops (grasses) have been conducted, no power plants consistently burn this material. The number of wood fired power plants is estimated to be from 600 to almost 1,000, most in the 10-25 MWe range. Only a third of these plants offer electricity for sale. The rest are owned and operated by the paper and wood products industries for their own use.

The rate of introduction of wood electric plants peaked in the late 1980s, then fell dramatically with the decline in oil prices, reduced concern about future energy costs, and the end of federal tax incentives. Biomass generation can only be competitive with fossil fuel alternatives at very low prices and in an era in which electricity prices are expected to remain stable or even decline; thus increasing the use of biomass represents a major challenge.[9]

1.3 Overview of the Assessment

The Kansas Electric Utilities Research Program (KEURP) recently sponsored the development of the *Kansas Renewable Energy Research and Development Plan*, which articulated research activities that should be conducted for the benefit of its seven electric utility members.[10] The *Plan* included the following broad objectives related to biomass:

1) develop a detailed assessment of the quantity, quality, and spatial distribution of biomass resources;
2) determine the energy and capacity value of biomass-derived electrical production; and
3) familiarize Kansas utilities with the design, installation, grid-integration, and operational characteristics of biomass electric systems by installing and operating evaluation projects.
4) In response to the broad objectives outlined above, a statewide assessment of the most promising combinations of biomass energy crops and conversion technologies was outlined

---

[7]Before the inclusion of the federal $0.015/kWh credit applicable to closed-loop biomass systems.

[8] Overend, R. P., ***Production of Electricity from Biomass Crops - US Perspective,*** Industrial Technologies Division, National Renewable Energy Laboratory, Golden.

[9] Morris, D., ***The Economics of Plant Matter Derived Electricity***, Institute for Local Self-Reliance, Collegeville, Minnesota, 1994.

[10] The Kansas Electric Utilities Research Program (KEURP) is a joint venture between KPL, Topeka; KG&E, Wichita; Kansas City Power & Light, Kansas City; WestPlains Energy, Great Bend; The Empire District Company, Joplin; Midwest Energy, Inc., Hays; Sunflower Electric Power Corporation, Hays; to undertake applied research and development projects which may enhance reliability and minimize cost of electric service in Kansas.

in the *Plan*, with which this assessment is consistent.[11]

The assessment incorporates the following activities:

1) Assess likely yields and energy/economic balances (accounting for fertilizers, equipment, planting, harvesting, and transport) for switchgrass *(panicum virgatim)*, the most promising of the herbaceous energy crop (HEC) species considered; and black locust *(robinia pseudoacacia)*, the most promising of the short-rotation woody crops (SRWC) species considered;
2) Assess sensitivities of herbaceous and SRWC production to Kansas soil and moisture conditions, and the impacts of herbaceous crop development on soil erosion, water quality, biodiversity, and other environmental factors;
3) Assess CRP land availability and the suitability of herbaceous and short rotation woody crops on these lands;
4) Assess the type, location, volume/density, energy content, transportation requirements, and present use or disposal method of waste feedstocks, including wood wastes, agricultural crop residues, and municipal solid wastes; and
5) Assess the location and energy content of gas recoverable from municipal and county/regional landfills and wastewater/sewage treatment plants. [12]

The Assessment Team

This assessment was conducted by Coriolis, Heritage Technologies, and the Kansas Industrial Extension Service at Kansas State University, with funding support from KEURP, the Kansas Corporation Commission, and the U.S. Department of Energy's Western Regional Biomass Energy Program (via the Electric Power Research Institute). The U.S. Department of Agriculture's Blackland Research Center provided extensive and vital assistance on plant growth modeling and environmental impact assessment. Oak Ridge National Laboratory provided technical support to the project through collaboration with Kansas State University.

2.0 Plantation Biomass

2.1 The Plantation Biomass Concept

The U.S. Department of Energy began biomass energy crop research in 1978 at Oak Ridge National Laboratory with the goal of developing commercially viable fuel for electric generation and feedstocks for liquid transportation fuels. Over 150 hardwood species were evaluated for rapid growth potential[13] at over 100 locations in the U.S. By 1983 Geyer identified silver maple *(Acer saccharinum)*, black locust *(Robinia pseudoacacia)* and the Siberian Elm *(Ulmus pumila)* as the most promising species for the Great Plains.[14] By 1987 silver maple, sweetgum *(Liquidambar styraciflua)*, American sycamore *(Platanus occidentalis)*, black locust and the

---

[11]See Assessment Task #2: Statewide Assessment of Energy Crops and Conversion Systems, page 14 of the *Kansas Renewable Energy R&D Plan*.

[12]A planning process is underway in Kansas that will likely lead to an increase in the number and use of large regional landfills that are able to meet stricter environmental requirements for land fill operation.

[13] Tuskar, G. A., Downing, M. E., Wright, L. L., ***Current Status and Future Directions for the U. S. Department of Energy's Short-Roation Woody Crop Research***, Biofuels Feedstock Development Program, Mechanization in Short Rotation Intensive Culture Foerestry Conference, Mobile, AL, March 1994.

[14] Geyer, W. A., Melichar, M. W., ***Short-Rotation Forestry Research in the Unitied States***, Biomass, Elsevier, 1986.

genus Populus had been selected for additional research by DOE. Yields of 5.4 – 7.1 dry tons per acre (8 – 10 Mg) were deemed acceptable with a goal of achieving 9 dry tons per acre (20 Mg/ha).[15] By the mid 1990s Populus had become DOEs preferred SRWC with yields of 4.45 tons/acre (10 Mg/ha/yr) on measured sites and a productivity goal of 9.9 – 13.4 tons/acre (20 – 30 Mg/ha/yr). DOE hoped to achieve this goal with a variety of management methods, including fertilization and irrigation, and genetic improvements.

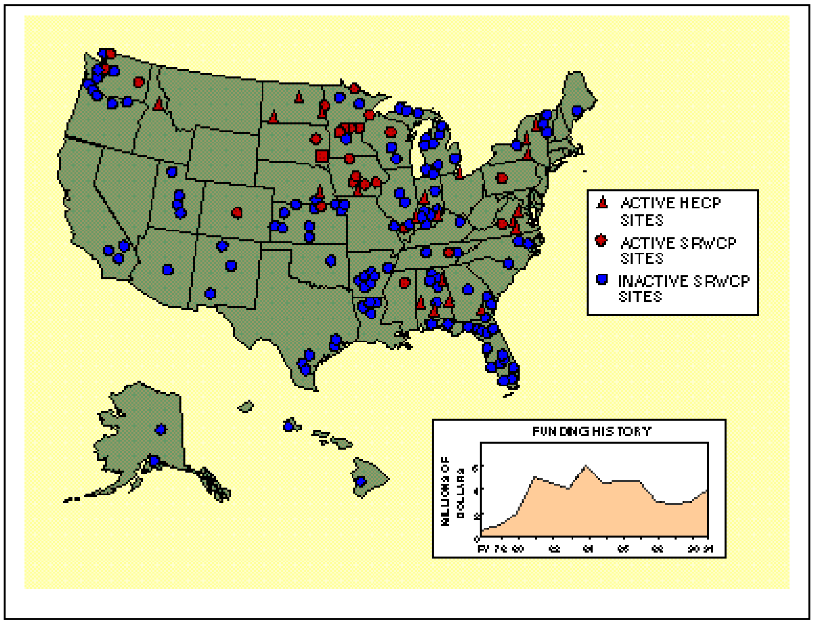

Figure 2.1 DOE Energy Crop Research Sites
Source: ORNL 1994

Many species of annual and perennial herbaceous energy crops have been evaluated under the DOE program. Perennial species with promising yields include big bluestem, reed canarygrass, and switchgrass. Switchgrass, a native warm season C4 bunch grass is the clear leader, with field trial yields as high as 15+ dry tons/acre [33.7 Mg/ha] (Bransby).

2.2 Factors Affecting Concept Viability

Ultimately, cost per unit of net boiler energy will be the determining factor in the acceptance of biomass as a generating fuel. Even if renewable energy mandates occur, cost will determine the preferred technology, and for biomass cost will determine the preferred crop and production strategy. Cost may or may not include externalities such as emissions credits or penalties. Biomass production cost is affected by many factors, the most important being yield, land rent, and the profit potential from production of conventional grain crops that compete for land use.

2.2.1 Biomass Fuel Cost

As electric utility markets evolve, becoming more open and competitive, fuel cost will become an ever more dominant factor for all types of electric power generators. Even if green pricing blossoms or federal mandates emerge, the lowest-cost renewable resource will dominate. A number of studies have attempted to estimate the yield and cost of biomass fuel from both SRWCs and HECs at the field edge in recent years, including:

[15] Ranney, J. W., Wright, L. L., Layton, P. A., ***Hardwood Energy Crops: The Technology of Intensive Culture***, Journal of Forestry, September 1987.

- Downing and Graham of Oak Ridge National Laboratory[16] estimated SRWC and HEC yields and cost for the TVA region covering portions of 11 southeastern states in 1995. SRWC yields were estimated to range from 2.4 – 4.3 dry tons per acre [5.4 – 9.7 dry Mg/ha] with costs ranging from $29 – 46 per dry ton [$32 – 51 per dry Mg] on former cropland and $44 – 63 per dry ton [$48 – 69 per dry Mg] on former pastureland. This represents a range of $1.72 – 3.73 per million Btu at the field edge. HEC yields ranged from 5.8 – 8.9 dry tons per acre [13 – 20 dry Mg/ha] with costs ranging from $28 – 64 per dry ton [$41 - $70 per dry Mg]. This represents a range of $ 1.77 – 4.04 per million Btu at the field edge. The wide range of estimated cost was primarily a result of yield variation resulting from differences in soil quality.

- At Oklahoma State University, Epplin estimated the cost to deliver switchgrass to a processing facility at $33/ton [$37/Mg]. This cost was broken down as 14% for establishment, 22% for land, 32% for maintenance and harvesting, and 32% for loading and transportation.[17]

- In 1993 at Virginia Polytechnic Mclaughlin remeasured switchgrass yields ranging from 2.5 – 6.5 ton/acre [5.6 – 14.6 Mg/ha] with a best site yield of 8.5 tons/acre [19 Mg/ha]. The full economic cost, including land rent of $42/acre [$104/ha] of producing large round switchgrass bales was estimated at $43.40/ton [$47.85/Mg] for yield of 4.0 tons/acre [9 Mg/ha] and $28.93/ton [$31.90/Mg] for yields of 10.0 tons/acre [22.4 Mg/ha].[18]

- Geyer used field trials to investigate the potential of black locust, box elder, sycamore, cottonwood, black alder, sandbar willow, silver maple, and catalpa in Kansas. Black locust had the highest annual yield (6.3 tons/acre) [14.2 Mg/ha], followed by cottonwood (5.3 tons/acre) [11.8 Mg/ha], and silver maple (4.3 tons/acre) [9.7 Mg/ha].[19]

These estimates are based on a wide variety of assumptions regarding yield, production cost, land rents, land access, and business structure. Many studies focus on estimating total potential biomass production by region or for the entire U.S. and the results are difficult to apply to specific projects; therefore, Kansas conditions may vary from those assumed in these analyses.

Yield is an important factor in production cost since many variable costs change little with changes in yield. Many factors affect yield, including the following:

- plant characteristics
- soil characteristics
- climate, including rainfall, frost free days, temperature extremes, and solar insolation
- fertilizer, herbicide, and pesticide use

---

[16] Downing, M. A., Graham, R. L., ***The Potential Supply and Cost of Biomass from Energy Crops in the Tennessee Valley Authority Region,*** Biofuels Feedstock Development Program, Oak Ridge National Laboratory, Biomass and Bioenergy Vol. II, Pergamon, 1996.
[17] Epplin, F. M., ***Cost to Produce and Deliver Switchgrass Biomass to an Ethanol-conversion Facility in the Southern Plains of the United States, Biomass and Bioenergy***, Vol. II, Elsevier Science, Ltd, 1996.
[18] McLaughlin, S. B., ***Switchgrass Variety Trials in the Upper Southeast of America***, http://194.178/register/data-re/ccr01834.htm
[19] Geyer, W. A., ***Biomass Yield Potential of Short-Roation Hardwooods in the Great Plains***, Biomass 20, Elsevier, 1989.

- management practices, including planting and harvesting schedules, tillage practices, harvesting methods, and for SRWCs the number of trees planted per acre, the number of years between harvests and the use of coppicing (regrowth from the stump instead of replanting).

The investigators gathered data from a wide range of field trials conducted in Kansas as well as elsewhere in the U.S. on promising biomass crops. Efforts to use the results of these trials to estimate potential yields for a range of Kansas climate and soil conditions proved problematic, leading to the use of a rigorous plant growth model. The goal was to identify the specific set of circumstances that offered the lowest plant gate biomass energy cost.

2.2.2 Land Requirements and Availability

Large scale production of biomass, sometimes referred to as plantation biomass to distinguish it from waste biomass or agricultural residue, requires a great deal of land. Table 2.2.1 below illustrates the land required for a 10 MW plant with an annual plant factor of 65%, two levels of conversion efficiency, and three levels of biomass yield. The conversion efficiencies are optimistic for biomass.

Table 2.2.1 Land Area Required to Support Biomass Electric Power

Plant Size (MW)	Conversion Efficiency (%)	Biomass Energy (Btu/lb)	Net Biomass Yield (dry tons/ acre/yr)	Annual Plant Factor (%)	Tons Required (per day)	Acres Required	Land Use Efficiency (%)	Square Miles Required
10	30%	8000	2	65%	171	20237	85%	37.2
10	50%	8000	2	65%	102	12142	85%	22.3
10	30%	8000	4	65%	171	10119	85%	18.6
10	50%	8000	4	65%	102	6071	85%	11.2
10	30%	8000	6	65%	171	6746	85%	12.4
10	50%	8000	6	65%	102	4047	85%	7.4

Table 2.2.2 shows the fraction of land area that would need to be dedicated to biomass energy production for power plants of 10, 50 and 100 MW (or a 10% co-firing rate for 100, 500, and 1,000 MW plants) with haul distances limited to an area enclosed by circles of 25 and 50 mile radii.

Table 2.2.2 Fraction of Land Area Required for Varying Plant Size and Haul Distance

Plant Size (MW)	Conversion Efficiency (%)	Net Biomass Yield (dry tons/ acre/yr)	Annual Plant Factor (%)	Acres Required	Land Use Efficiency (%)	Square Miles Required	Fraction of Land Area 25 Mile Max. Haul	Fraction of Land Area 50 Mile Max. Haul
10	30%	4	65%	10,119	85%	18.6	0.9%	0.2%
10	50%	4	65%	6,071	85%	11.2	0.6%	0.1%
50	30%	4	65%	50,594	85%	93.0	4.7%	1.2%
50	50%	4	65%	30,356	85%	55.8	2.8%	0.7%
100	30%	4	65%	101,187	85%	186.0	9.5%	2.4%
100	50%	4	65%	60,712	85%	111.6	5.7%	1.4%

The fraction of land area required ranges from 0.1 % (relatively insignificant) to 9.5%, which would likely have significant impact on agricultural land use patterns. Several strategies were identified for shifting land from current agricultural use to biomass energy crops, including:

- utility purchase and management,
- access to large areas of land in public or private ownership,
- long term production agreements or land leases with existing land owners with management either by the existing owners or custom contractors, and
- access to land currently in or eligible for the federal conservation reserve program (CRP) program, with either a USDA or Congressional waiver to allow harvesting of energy crops in exchange for paying a portion of the federal CRP "rent" payment and an incentive payment to the land owner.

Utility ownership is not an attractive option. Prevailing rents and CRP payments are well below the rate of return utilities would expect on any land investment made at current market prices. Large scale land acquisition would almost certainly force land prices higher and generate considerable local public resentment. Arguments that biomass energy production can benefit rural economies and individual farmers would also be at least partially negated.

The concept of using large contiguous public or single owner tracts of land mentioned in the original proposal proved untenable. With the possible exception of Indian reservations, large tracts of public land in Kansas are rare and generally held for other public uses.

Estimates of biomass energy crop costs are usually based on production costs, with assumptions regarding land rental rates often taken from the CRP program. However, only a portion of Kansas agricultural land qualifies for CRP, and such land is not necessarily the most productive. Investigating the feasibility of large scale biomass production also requires the evaluation of CRP eligible and non-eligible land. Long term production agreements or land leases on land not eligible for CRP would require that the land owner, whether a farmer or absentee landlord, could reasonably expect their profits, on average, would meet or exceed that from the most profitable alternative land use. While leases can be based on a fixed dollar per acre fee, leases in which the land owner gets a percentage of production are also common. CRP contracts specifically preclude harvest for any purpose without a waiver.

A biomass fueled power plant project would require a long term reliable fuel supply. This would mean that adequate areas of land would be committed under contract for a period of at least 15 years. To make such a commitment land owners would expect their profits to be, on average, equal to or greater than other land use options, principally grain production or CRP enrollment. Current grain prices are very low, as shown in Table 2.2.3 below.

Table 2.2.3 Kansas Grain Prices 1960 – 97, 1988 – 97 and Summer 1998

Grain Crop	**1960 – 97** **($ 1996)**	**1988 – 97** **($ 1996)**	**August 1998** **($ 1998)**
Corn	$4.72	$2.83	$1.78
Wheat	$6.24	$3.90	$2.35
Soybeans	$10.87	$6.91	$5.08
Grain Sorghum	$4.09	$2.49	$2.96

There is no assurance that current low grain prices will remain in place for the life of a biomass plant. A significant and persistent rise in grain prices could increase land rents sufficiently to draw land once converted to biomass, back into grain production (subject to contract limitations) and could even lead to reduction or termination of the CRP program. Many complex factors could affect future demand for grain and predicting future prices in the global market with confidence is unrealistic.

Population Growth

The United Nations predicts the 1997 global population of 5.8 billion will increase to 9.4 billion over the next 50 years. An esimated 60 percent of this gain will occur in Asia. China's population of 1.2 billion is projected to increase to 1.5 billion while India's 930 million will increase to 1.53 billion.[20] Lester Brown of the Worldwatch Institute believes China's rapid industrialization, low and declining arable land per person, water shortages and shifting dietary habits, will cause it to become a significant grain importer in the years ahead.[21]

Diet Changes

Economic growth, particularly in Asia, is permitting a shift away from traditional diets dominated by grains and vegetables toward greater consumption of animal protein and oils. This change generally requires more land per capita.

Buying Power

Many developing countries, once too poor to import significant quantities of food, are gaining rapidly in buying power as a result of industrialization. While the current economic slump in Asia is having a dramatic short term affect, economic expansion and increased demand for food is likely to return in the future.

Land Availability

Land dedicated to production of food crops is decreasing globally, both total and per capita. Global land area dedicated to grain production which represents over half of human intake (direct and indirect through animals) fell from a high of 732 million hectares in 1981 to around 695 million hectares in 1996. This represents about 0.12 hectare per person,[22] about half what it was in 1950. The decline can be attributed in part to land lost to erosion and urbanization, while some may have simply become unprofitable at the lower prices that prevailed, or shifted to production of other crops, including fruit and fiber crops. Declining per capita land area has been offset by yield increases, a pattern which some argue began to decline in 1985. Grain reserves average 81 days of global consumption during the 1982-1993 period, but fell to 48 days by 1995.[13] Declining water tables and increased competition from growing urban areas for water previously dedicated to irrigation is also threatening to reduce the total area of irrigated land, the most productive in many dry regions.

Government Subsidies and Land Use Policy

[20] Brown, L. R., Renner, M., Flavin, C., Vital Signs 1998: ***The Environmental Trends That are Shaping Our Future***, Worldwatch Institute, W. W. Norton & Company, New York, 1998.
[21] Brown, Lester R., ***Who Will Feed China?,*** Worldwatch Institute, W. W. Norton, New York, 1995.
[22] Gardner, G., ***Shrinking Fields: Cropland Loss in a World of Eight Billion***, Worldwatch Institute paper no. 131, 1996.

The impact of the decrease in federal farming regulation and support programs associated with the move toward "freedom to farm" is not yet clear, but initial indications suggest greater production and lower prices. There is also over 30 million acres of land, much of it prone to erosion when tilled, enrolled in the Conservation Reserve Program. Europe also has about 10% of its cropland in set-aside programs.[8] A persistent rise in grain prices, whether from reduced production or increased demand, might be arrested in the short term by placing all or a portion of these lands back in production.

Technology Limits

Gains in agricultural yields resulting from better plant varieties, synthetic fertilizers, herbicides and pesticides and improvements in general farming methods since World War II have been incredibly dramatic. Table 2.3.1 below summarizes changes in Kansas grain yields. If the improved dietary expectations of an increasing world population are to be met with existing tilled land this trend must continue unabated. Some argue that it can, while others believe technical and economics limits of increasing grain yields have been reached; however, the avaiability of grain does not always coincide with the ability to purchase.

Global Warming

Average global monthly temperatures for the first half of 1998 are the highest since detailed record keeping began over a century ago. Severe droughts have persisted through the summer of 1998 in much of the U.S. South and Southwest. Yet Kansas and U.S. grain prices are very depressed. It is inappropriate to associate local regional seasonal weather conditions with long term global climate shifts, and it is also unclear how global warming or regional weather conditions that may or may not be associated with it will affect short or long term grain harvests and consequent prices. There does appear to be a risk of greater regional weather variation ahead with the potential for instability in grain production and greater price variation.

The scope of this study did not include long term forecasting of global grain prices and their potential impact on the availability of land for biomass energy production at prices acceptable to market conditions. The issues briefly touched upon above serve only to point out that the recent trend toward cheaper grain might not continue and a significant and persistent change, regardless of the particular combination of events that might produce it, could jeopardize the fuel supply of a biomass generating facility if firm contracts are not secured for land use or fuel delivery.

2.2.3 Transportation

The edge of field cost of production is not an adequate indicator of the economic competitiveness of a biomass fuel. Biomass fueled power plants require relatively large areas of dedicated land and most strategies anticipate that hauling biomass as much as 50-75 miles may be required. In evaluating transportation costs of HEC for the Chariton Valley Project, Alan Teel of the Iowa State University Extension Service found careful planning was required to minimize costly handling steps, feedstock loss or feedstock quality degradation.[23] Recent studies of estimated biomass transportation costs, including:

- Graham and others at Oak Ridge National Laboratory evaluated the cost of delivering wood chips to plants of varying sizes across Tennessee. Transportation costs ranged from

[23] Personal conversation with Mr. Alan Teel, Atlantic, Iowa, July 1998.

$7 to $16 per dry ton ($8 - $18 per Mg), accounting for 18 to 29% of plant gate cost, with farmer participation rate and plant size which affect hauling distance having significant impact on cost. [24]
- Nelson informally surveyed Kansas custom haying contractors, concluding that typical costs are $4.00/ton to load and unload, plus $0.10 per mile from field to barn.

Based on the estimated production and transportation costs, the above studies suggest that plant gate prices for biomass fuels could range from $25.00 to $75.00 per ton.

2.2.4 Environmental Impacts

Shifting large areas of land from grain production to trees or grasses could have significant environmental impacts. Key impacts include:

- reduced water and wind produced soil erosion
- reduced surface and subsurface fertilizer and herbicide/pesticide migration, improving surface and ground water quality
- increased wildlife habitat
- reduced emissions of global warming gases and carbon sequestering in root systems that are more extensive than annual crops
- restoration of degraded soils
- Improve regional air quality by reducing SO_x and NO_x emissions.

It must be emphasized that large scale biomass plantations, even if scattered among other fields and managed with high edge plant diversity, do not represent a return to a complex diversified ecosystem. While biomass plantations have notable environmental benefits when compared with grain crops requiring some measure of annual tillage, they are another form of agriculture with large areas of a single crop.

Recent studies have estimated the environmental impact of dedicating large areas of land to biomass energy production, including the following:

- The Office of Technology Assessment (OTA) concluded that energy crops may be able to meet 10 to 30 percent of our energy needs. OTA also noted “Bioenergy crops have the potential to improve the environment, increase rural incomes, and reduce Federal budget deficits and the U.S. trade imbalance.” They also observed that “It will also be necessary to conduct some long-term and large-scale demonstration programs, and to address a variety of market barriers and distortions. Haphazardly implementing large-scale bioenergy programs without such a foundation could damage the environment and reduce potential economic benefits.”[25]

- Researchers at Oak Ridge National Laboratory have found that both switchgrass and SRWCs provided greater support for bird diversity than conventional row crops.

[24] Graham, R. L., Liu, W., Downing, M, et. al., The Effect of Location and Facility Demand on the Marginal Cost of Delverred Wood Chips from Energy Crops: A Case Study for the State of Tennessee, Oak Ridge National Laboratory , Biofuels Systems Division, U. S. Department of Energy.

[25] U.S. Congress, Office of Technology Assessment***, Potential Environmental Impacts of Bioenergy Crop Production – Background Paper***, OTA-BP-E-118 (Washington, DC: U.S. Government Printing Office), September 1993.

- Studies sponsored by DOE through ORNL have found significant augmentation of soil organic matter as well as a 70% to 200% reduciton in soil erosion (vs. corn) resulting from switchgrass. Reduction in surface runoff was also noticeable.

Improved Wildlife Habitat

Best and others compared the abundance and nesting success of birds in CRP fields during summer with row crops between 1991 and 1995 for Kansas and other Midwestern states. CRP fields were planted with a variety of introduced and native grasses and legumes, and experienced some disruption from mowing, burning and chemical applications. Birds were 1.4 to 10.5 times more abundant in CRP fields. Nests of 33 bird species were found in CRP fields compared with only ten for row crops, and the number of nests was 13.5 times greater in CRP fields.[26]

2.2.5 Embodied Energy

Except where existing biomass resources represent a waste disposal problem, such as in the lumber industry, the primary motivation for increasing biomass use is to substitute a renewable resource for combustion of fossil fuel with secondary benefits of reduced environmental benefits and increased rural income. However, production of biomass requires significant investments of fossil fuel, principally for fertilizer and equipment manufacturing and operation. The energy profit ratio, the useable energy content of net biomass production divided by the direct and indirect energy required to produce it, must be greater than one and ideally many time greater, if a biomass development project is to achieve its principal objective. Recent studies have estimated energy profit ratios for SRWCs and HECs.

- Borjesson investigated the energy yields, primary energy inputs, and net energy yields of a variety of crops, including reed canary grass and willow (Salix), concluding the energy output/input ratios (energy profit ratios) were 11 and 21 respectively.[27]

Each of the issues summarized above (biomass energy cost, land requirements, transportation, embodied energy, and environmental impact of large scale biomass energy production) have been investigated. The methodology employed and the results are discussed in greater detail in the following sections.

2.2.6 Federal Plantation Biomass Tax Credit

The Energy Policy Act of 1992 included a wind and biomass energy production tax credit. The biomass credit of 1.5 cents per kilowatt-hour applied only to electricity produced from a closed-loop or plantation biomass facility for the first ten years of the facility's existence. "Closed-loop" biomass refers to plants that are grown specifically for generating electricity. The credit applied to projects brought on-line after December 31, 1992, and before July 1, 1999. Rules for qualification are complex and no plantation biomass facilities have been placed in service that qualify, and none are expected prior to the current expiration date. Legislation has been

[26] Best, L., et. al., ***Wildlife Society Bulletin 1997***, 25 (4):864-877, as reported in ***Farmers & Wildlife***, Kansas Department of Wildlife and Parks and Kansas State University Agricultural Experiment Station, V 4, I 2, May 1998.

[27] Borjesson, P. I., ***Energy Analysis of Biomass Production and Transportation, Biomass and Bioenergy Vol. II***, Elsevier Sciences Ltd, 1996.

proposed that would extend the credit until July 1, 2004. Depending on how the tax credit were valued, it could offset a significant portion of the cost gap between biomass and coal.

2.3 Which Plants for Kansas

2.3.1 Maximizing Biomass Crop Yield

Table 2.3.1 below compares the average per acre yield of major Kansas grain crops for the ten year periods of 1937 to 1946 and 1987 to 1996, unadjusted for climatic differences.

Table 2.3.1 Changes in Kansas Grain Yield, 1937-46 vs. 1987-96

Grain Crop	1937-46 Yield (Bu/acre)	1987-96 Yield (Bu/acre)	Percent Increase
Wheat	14.5	33.0	218 %
Corn	19.2	131.4	685 %
Soybeans	10.6	29.1	275 %
Grain Sorghum	13.5	66.3	462 %

Source: Kansas Farm Facts

The enormous per acre yield increases were the result of numerous factors, but the most important were the dramatic increase in the use of artificial fertilizers and improved plant varieties, both hybrid and non-hybrid. It is tempting to infer that similar gains ought to be achievable with plants intended for for use as biofuels. DOE's Biofuels Development Program at Oak Ridge National Laboratory has a goal of increasing yields from significantly. While careful selection of individual plant cultivars best suited to particular local climate and soil conditions may offer improved yields, there are fundamental limits to the photosynthetic process. Smil assessed grain crop yield gains, noting,[28]

> *"High yields of modern cultivars have resulted above all from selection for a higher proportion of the harvested organ, mostly seeds. Traditional varieties produce no less phytomass than the modern cultivars but the partitioning of their photosynthates is much less desirable.*
>
> *Around 1900 the harvest index of unimproved cereals was just between 0.25 and 0.35 as the bulk of their phytomass was stored in long stalks and numerous leaves. Winter wheats now have typical harvest indices of 0.40 – 0.42, corn 0.47 – 0.50, barley 0.51 – 0.57, and rice around 0.5. These advances brought higher yields without any increases in the rate of the photosynthetic process itself."*

2.3.2 Herbaceous Energy Crops (HECs)

Herbaceous crops such as switchgrass, eastern gamagrass, and Indiangrass, are native warm season perennial grasses that are persistent and drought-resistant.[29] One estimate of annual production potential for switchgrass in Kansas is over 40 million dry tons, the largest potential for herbaceous energy crop production of any state in the Midwest.[30]

[28] Smil, V., ***General Energetics: Energy in the Bioshpere and Civilization***, John Wiley & Sons, 1991.
[29]Switchgrass is a plant species recommended as cover for land enrolled in the Conservation Reserve Program (CRP). Many Kansas farmers already have equipment needed to plant, tend, and harvest switchgrass.
[30]Union of Concerned Scientists, *Powering the Midwest,* 1993.

Switchgrass, a C4 plant, differs from other grasses considered, which are mostly C3. This helps explain its greater yield performance in particular climatic regions, based on the following specific points noted by Smil:[31]

- C3 plants reduce CO_2, producing a 3 carbon acid, using the Calvin photosynthetic cycle
- C4 plants reduce CO_2, producing a 4 carbon acid, sing the Hatch-Slack photosynthetic cycle
- C4 plants differ anatomically from C3 plants
- C4 plants have higher water use efficiency than C3 plants
- unlike C3 plants, C4 plants have no light saturation
- maximum C4 growth rates of 50-54 g/m^2 are roughly 40% higher than C3 growth rates of 34-39 g/m^2
- total growing season C4 growth rates of 22 g/m^2 are roughly 70% higher than C3 seasonal growth rates of 13 g/m^2.

Figure 2.2.1 Switchgrass
Source: ORNL

C4 grain crops include corn and grain sorghum. Among HECs and SRWCs species considered for biomass energy, C4 plants include switchgrass and big bluestem.

Table 2.3.2 Switchgrass Field Trial Yields

State/location/ Source	Soil	Variety	Nitrogen lb/ac	Nitrogen kg/ha	Year Meas-ured	Yield t/ac	Yield mg/ha	Comments
Kansas								
Manhattan (Fritz)		Pathfinder Clone	100		1992	8.06		Poorest variety
Manhattan (Fritz)		20 different	100		1992	9.42		Ave of 20 varieties
Manhattan (Fritz)		Pathfinder	100		1992	11.47		Best variety
Hutchinson(Fritz)		Nebraska 28	100		1992	6.55		Poorest variety
Hutchinson(Fritz)		20 different	100		1992	8.42		Ave of 20 varieties
Hutchinson(Fritz)		Kanlow	100		1992	10.02		Best variety
Kentucky								
Caldwell Co. (Parrish)	MLRA 120 or 122	Shelter	na	na	1994	3.4	7.60	Poorest variety
Caldwell Co. (Parrish)	MLRA 120 or 122	Six different	na	na	1994	3.8	8.50	Ave of 6 varieties
Caldwell Co. (Parrish)	MLRA 120 or 122	AlamoKanlow	na	na	1994	4.3	9.70	Best variety
Caldwell Co. (Parrish)	MLRA 120 or 122	Cave-in-Rock	na	na	1995	5.4	12.00	Poorest variety
Caldwell Co. (Parrish)	MLRA 120 or 122	Six different	na	na	1995	7.6	17.05	Ave of 6 varieties
Caldwell Co. (Parrish)	MLRA 120 or 122	Alamo	na	na	1995	9.2	20.60	Best variety
Indiana								
Tippecanoe Co.(Vogel)	MLRA 111	Kanlow	na	na	1991	4.4	9.90	Poorest variety
Tippecanoe Co.(Vogel)	MLRA 111	Many	na	na	1991	5.3	11.86	Ave of 20 plots
Tippecanoe Co.(Vogel)	MLRA 111	Trailblazer	na	na	1991	6.1	13.77	Best variety
Tippecanoe Co.(Vogel)	MLRA 111	NE 28	na	na	1992	4.1	9.15	Poorest variety
Tippecanoe Co.(Vogel)	MLRA 111	Many	na	na	1992	5.6	12.47	Ave of 20 plots
Tippecanoe Co.(Vogel)	MLRA 111	Cave-in-Rock	na	na	1992	7.3	16.28	Best variety
Iowa								
Clarke Co. (Teel)	Grundy Silty Clay Loam	Cave-in-Rock	0		1994	2.42		
Clarke Co. (Teel)	Grundy Silty Clay Loam	Cave-in-Rock	30		1994	2.52		
Clarke Co. (Teel)	Grundy Silty Clay Loam	Cave-in-Rock	60		1994	3.15		

[31] Smil, Vaclav, ***General Energetics: Energy in the Biosphere and Civilization***, J. Wiley & Sons, New York, 1991.

Table 2.3.2 Switchgrass Field Trial Yields (cont'd)

			Nitrogen		Year	Yield		
State/location/ Source	**Soil**	**Variety**	lb/ac	kg/ha	**Meas-ured**	t/ac	mg/ha	**Comments**
Clarke Co. (Teel)	Grundy Silty Clay Loam	Cave-in-Rock	90		1994	3.84		
Story Co. (Vogel)	MLRA 102	EyxFF High 3	na	na	1991	3.7	8.25	Poorest variety
Story Co. (Vogel)	MLRA 102	Many	na	na	1991	4.7	10.64	Average of 19 plots
Story Co. (Vogel)	MLRA 102	Cave-in-Rock	na	na	1991	5.6	12.51	Best variety
Story Co. (Vogel)	MLRA 102	Kanlow	na	na	1992	2.7	6.08	Poorest variety
Story Co. (Vogel)	MLRA 102	Many	na	na	1992	4.6	10.36	Average of 19 plots
Story Co. (Vogel)	MLRA 102	Cave-in-Rock	na	na	1992	7.2	16.04	Best variety
Nebraska								
Adams Co. (Vogel)	MLRA 75	Pathfinder	na	na	1991	4.8	10.76	Poorest variety
Adams Co. (Vogel)	MLRA 75	Many	na	na	1991	5.5	12.35	Average of 19 plots
Adams Co. (Vogel)	MLRA 75	Late syn C3	na	na	1991	6.3	14.12	Best variety
Adams Co. (Vogel)	MLRA 75	EyxFF High 3	na	na	1992	4.2	9.46	Poorest variety
Adams Co. (Vogel)	MLRA 75	Many	na	na	1992	5.7	12.74	Average of 19 plots
Adams Co. (Vogel)	MLRA 75	Late syn C3	na	na	1992	6.5	14.64	Best variety
Kentucky								
Fayette Co. (Collins)	MLRA 121	Carthage	0	0	1989	3.7	8.20	Poorest variety
Fayette Co. (Collins)	MLRA 121	Many	0-150		1989	5.5	12.30	Average of 11 plots
Fayette Co. (Collins)	MLRA 121	Kanlow	150		1989	8.2	18.30	Best variety
Fayette Co. (Collins)	MLRA 121	Carthage	0	0	1990	2.9	6.50	Poorest variety
Fayette Co. (Collins)	MLRA 121	Many	0-150		1990	3.9	8.70	Average of 15 plots
Fayette Co. (Collins)	MLRA 121	Kanlow	150		1990	6.6	14.70	Best variety
Fayette Co. (Collins)	MLRA 121	Carthage	0	0	1991	4.0	7.90	Poorest variety
Fayette Co. (Collins)	MLRA 121	Many	0-150		1991	5.4	12.21	Average of 15 plots
Fayette Co. (Collins)	MLRA 121	Carthage	150		1991	7.3	16.40	Best variety
Fayette Co. (Collins)	MLRA 121	Carthage	0	0	1992	2.3	5.10	Poorest variety
Fayette Co. (Collins)	MLRA 121	Many	0-150		1992	3.3	7.33	Average of 15 plots
Fayette Co. (Collins)	MLRA 121	Kanlow	150		1992	4.4	9.90	Best variety
Tennessee								
Madison Co. (Parrish)	MLRA 134	Shelter	na	na	1994	3.9	8.80	Poorest variety
Madison Co. (Parrish)	MLRA 134	Many	na	na	1994	4.6	10.37	Average of 12 plots
Madison Co. (Parrish)	MLRA 134	Kanlow	na	na	1994	5.4	12.00	Best variety
Madison Co. (Parrish)	MLRA 134	Cave-in-Rock	na	na	1995	4.1	9.30	Poorest variety
Madison Co. (Parrish)	MLRA 134	Many	na	na	1995	5.4	12.20	Average of 6 plots
Madison Co. (Parrish)	MLRA 134	Alamo, NC1	na	na	1995	6.2	13.80	Best variety
Texas								
Knox Co. (Sanderson)	MLRA 78	Cave-in-Rock	na	na	1994	0.6	1.32	Poorest variety
Knox Co. (Sanderson)	MLRA 78	8 varieties	na	na	1994	2.8	8.83	Average of 8 plots
Knox Co. (Sanderson)	MLRA 78	Alamo	na	na	1994	3.9	6.23	Best variety
Erath Co. (Sanderson)	MLRA 84b	Cave-in-Rock	na	na	1994	1.7	3.90	Poorest variety
Erath Co. (Sanderson)	MLRA 84b	Many	na	na	1994	6.1	13.70	Average of 8 plots
Erath Co. (Sanderson)	MLRA 84b	Alamo	na	na	1994	8.7	19.46	Best variety
Erath Co. (Sanderson)	MLRA 84b	Cave-in-Rock	na	na	1995	2.0	4.51	Poorest variety
Erath Co. (Sanderson)	MLRA 84b	Many	na	na	1995	6.2	13.96	Average of 16 plots
Erath Co. (Sanderson)	MLRA 84b	AlamoKanlow	na	na	1995	8.8	19.83	Best variety
Bell Co. (Sanderson)	MLRA 85 or 86	Cave-in-Rock	na	na	1994	2.9	6.39	Poorest variety
Bell Co. (Sanderson)	MLRA 85 or 86	8 varieties	na	na	1994	5.4	12.06	Average of 8 plots
Bell Co. (Sanderson)	MLRA 85 or 86	Alamo	na	na	1994	7.9	17.70	Best variety
DallasCo. (Sanderson)	MLRA 86	Cave-in-Rock	na	na	1994	3.8	8.46	Poorest variety
DallasCo. (Sanderson)	MLRA 86	8 varieties	na	na	1994	5.9	13.24	Average of 8 plots
DallasCo. (Sanderson)	MLRA 86	Alamo	na	na	1994	7.5	16.82	Best variety
DallasCo. (Sanderson)	MLRA 86	PMT-279	na	na	1995	2.4	5.47	Poorest variety
DallasCo. (Sanderson)	MLRA 86	8 varieties	na	na	1995	3.3	7.44	Average of 8 plots
DallasCo. (Sanderson)	MLRA 86	NCSU-1	na	na	1995	4.7	10.60	Best variety

Note: Except for Fritz and Teel data for Kansas and Iowa, The data in Table 2.3.2 is from the ORNL database provided by Anne Ehrenshaft. Failed stands not included. Only single annual harvest data shown above. Additional data is available from ORNL for the states listed in the table. Data for switchgrass field trials in Alabama, Virginia, West Virginia, North Carolina is also available but was not reported here due to the significant difference in climate. The highest yield reported in the ORNL database was 15.2 t/acre (34.6 Mg/ha) for a 1990 two cutting harvest of Alamo variety switchgrass in Tallapoosa Co. Alabama (Bransby).

Most of the data in Table 2.3.2 has likely been derived from relatively small and well managed field trial plots (Teel's data from Iowa is an exception). As such it may not represent the diversity of conditions that would occur with large scale biomass production. Analysis of available switchgrass field trial yield data was severely constrained by the infrequent reporting of nitrogen application levels and other management practices, the absence of detailed soil descriptions, and omission of precipitation data. Nonetheless the following observations appear warranted.

- Switchgrass yield can vary by more than one order of magnitude on plots considered appropriate for evaluation.
- Some switchgrass varieties are significantly more productive than others, with the preferred variety changing with latitude.
- Switchgrass is more productive on some soils than others.
- Switchgrass response to nitrogen fertilizer is significant.
- There is significant interannual variation in yield.

Switchgrass Varieties

Switchgrass (*panicum virgatum*) is a native warm season C4 grass. Varieties which have been isolated from native stock are listed below.

421138

Increased at SCS, Plant Materials Centers, Beltsville, MD, and Cape May Court House, NJ
Source - Single clone collected vegetatively by K. E. Graetz in 1957 near Carthage, NC
Description - Leafy, better than average spread, high nutrient value and early spring recovery

Alamo

Selected in 1975 at James E. "Bud" Smith Plant Materials Center, Knox City, TX
Source - Original seed collection made by Laramie McIntire of the SCS near George West, TX, in 1964
Description - Longer, wider leaves than Blackwell; taller and much greater forage producer

Blackwell

Selected at Plant Materials Center, SCS, Manhattan, KS
Source - Seed harvested in 1934 from single plant growing in native prairie near Blackwell, OK
Description - Upland-type switchgrass of medium height, with rather large stems. Ranked high in leafiness, total forage produced, and resistance to rust and other diseases

Caddo (Reg. No. 4)

Selected at Oklahoma AES, Stillwater, ARS cooperating - H.W. Staten, W.C. Elder, R.A. Chessmore, and J.R. Harlan
Source - Field collections from southern Great Plains, especially central Oklahoma
Description - Tall, robust, upland switchgrass generally characteristic of central Oklahoma, leafy, productive, considerable rust resistance, rather uniform when seeded in rows for seed production

Cave-In-Rock

Plant Materials Center, SCS in cooperation with the Missouri AES
Source - Selected from a native stand of grass at Cave-In-Rock, IL, in 1958 by Virgil B. Hawk and R.K. Lawson, Agronomist
Description - Greater seedling vigor, more resistance to dampening off or leaf spot, higher seed yields, resistance to lodging, lowland type of switchgrass. Tolerant to flooding, will withstand droughty soils but is better suited to moderately wet soils

Dacotah (Reg. No. CU-132)

Collected by the ARS, Northern Great Plains Research Laboratory, Mandan, ND, and Plant Materials Center, SCS, Bismarck, ND - George Rogler, Reed E. Barker, John McDermand, Erling T. Jacobson, and Russell J. Haas
Source - Original plants collected from a native stand near Breien, Morten County, ND
Description - Dacotah is 27 days earlier in anthesis than Forestburg and 45-50 days earlier than Blackwell, Summer Cave-in-Rock, Pathfinder, and Nebraska-28, tends to be shorter in mature height and have less rank growth than southern cultivars, appears to have increased drought tolerance for this species

Forestburg (Reg. No. 110)

Selected at the Plant Materials Center, SCS, Bismarck, ND, and ARS, Northern Great Plains Research Laboratory, Mandan, ND, cooperating - John McDermand, Erling T. Jacobson, Russell J. Haas, and Reed E. Barker
Source - Composite of four accessions collected from native stands in Sanborn County near Forestburg, SD
Description - Superior winter-hardiness and persistence, seed production ability, and earlier maturity than other accessions, forage production at northern latitudes exceeds that of Dacotah and is equal to/greater than Nebraska 28, Forestburg is similar in performance and adaptation to Sunburst

Grenville

Increased at former SCS Nursery, Albuquerque, NM
Source - Collection near Grenville, NM, at elevation of 1,800 m and annual precipitation of 400 mm
Description - Intermediate type between northern and southern geographic strains. Plants uniform, leafy, fine stemmed, and remain green well into fall, height at maturity 1-1.2 m. Medium maturity date, no rust or other diseases observed

Kanlow

Developed at Kansas AES, Manhattan, ARS cooperating - F.L. Barnett and K.L. Anderson
Source - SCS collection from lowland site near Wetumka, OK, in 1957
Description - Tall, coarse, productive, especially adapted to lowlands where flooding, high water table, or other excess water problems occur, but performs well on upland where soils are not too thin or droughty, not intended to replace upland varieties, such as Caddo and Blackwell, but to supplement them because of adaptation to wet locations

KY-1625 (Reg. No. GP-0057)

Selected at the SCS Plant Materials Center, Quicksand, KY - Donald S. Henry and Charles F. Gilbert
Source - Collected as KY-584 from Raleigh County, WV. Clonal selection of PI 431575 (KY-1625) made at the Quicksand Plant Materials Center in 1970
Description - A late maturing, leafy, fine stem, perennial rhizomatous native warm season grass, that responds well to small increments of nitrogen, it has a high leaf-stem ratio and has shown higher protein and digestibility when compared to other switchgrasses, poor seed quality and seedling vigor may be a limiting factor

Nebraska 28

Developed at Nebraska AES, Lincoln, ARS and SCS cooperating - L.C. Newell
Source - Native stand of switchgrass collected in Holt County, NE, in 1935
Description - Relatively early maturing strain of switchgrass, representative of Nebraska sandhill types, average plants semi-decumbent, with fine stems of moderate height, bluish green, and leafy; but considerable variation in plant type exists, well adapted to diverse soils and used successfully for pasturage and soil conservation purposes,

such as seeded waterways in pure stands or mixtures, matures seed in mid-August to early September, in areas with longer growing seasons is susceptible to rust, which is likely to be a serious factor in production

Pathfinder (Reg. No. 17)
Selected at Nebraska AES, Lincoln, ARS cooperating - L.C. Newell
Source - Domestic collections in 1953 from Nebraska and Kansas
Description - Winter-hardy, vigorous, leafy, late maturing, and rust resistant in region of adaptation, good stand establishment and forage production for late-spring and summer grazing, used in pure stands or in mixtures with other warm-season prairie grasses. Tests indicate its adaptation in Nebraska and adjacent areas, most favorable area for seed production is in eastern third of Nebraska south of Platte River

Shelter
Selected at Big Flats Plant Materials Center, SCS, Corning, NY
Source - Frank Glover collected switchgrass seed from a stand located south of St. Mary's, WV, in 1956
Description - Shelter has thicker stems and fewer leaves than other released varieties with the exception of Kanlow, it is 5-40 mm taller than Blackwell after the second growing season, but exhibits less seedling vigor during the establishment year

Summer
Selected at South Dakota AES, Brookings - J.G. Ross
Source - Native collection, PI 214759, made by W.L. Tolstead and L.C. Newell south of Nebraska City, NE, in 1953
Description - Tall, upright, with abundant, somewhat coarse leaves, starts growth after June 1 and matures seed in mid-September, produces high yield of forage and seed

Trailblazer
Developed by USDA-ARS (L.C. Newell) and Nebraska Agricultural Research Division, Dept. of Agronomy, Univ. of Nebraska
Source - Collections from natural grasslands in Nebraska and Kansas
Description - A 25-clone synthetic that is similar to Pathfinder in maturity, appearance, and area of adaptation, higher IVDMD than Pathfinder, twelve of the 25 clones are from the Nebraska strain ff, while the remainder are from the ey strain

Additional information of these varieties can be found in Appendix A.1.

Switchgrass Properties
Yield potential has moved switchgrass to the forefront among HECs, yet some have suggested the high alkali content and the presence of silicates that could cause slagging and formation of deposits on heat exchange surfaces made it unsuitable for use in utility scale boilers. This widely held view apparently originated with Miles, et.al., 1993, 1995. Later analysis suggest the samples used for these test were contaminated.[32] Researchers at Oak Ridge National Laboratory and other research institutions later reported that "more extensive analysis of ash and alkali content of switchgrass indicates that it typically has a relatively low alkali content and should have low slagging potential in coal-fired combustion systems."[33]

Harvesting timing and storage practices can affect the quality of fuel qualities of switchgrass. Harvesting switchgrass after fall frost (typically late October in Kansas) has several advantages, as well as limitation. Moisture content is reduced, and haying will not be competing with other

[32] McLaughlin, S. B., et. al, Evaluating Physical, Chemical, and Energetic Properties of Perennial Grasses as BioFuels, Oak Ridge National Laboratory.
[33] McLaughlin, S. B., et. al, Evaluating Physical, Chemical, and Energetic Properties of Perennial Grasses as BioFuels, Oak Ridge National Laboratory.

haying operations, however, wet weather and snow can cause the tall grass stems to fall and lodge, reducing fuel quality and making harvest more difficult and expensive.

Table 2.3.3 Physical and Chemical Properties of Switchgrass

Property	IP Units		SI Units	
	Value	Unit	Value	Unit
Energy content (dry)	15.84	MBtu/ton	17.4	MBtu/Mg
Moisture content (harvest)	15	%	15	%
Energy density (harvest)	15.84	Mbtu/ton	14.8	MBtu/Mg
Combustion ash	4.5 – 5.8	%	4.5 – 5.8	%
Sulfur content	0.12	%	0.12	%

Switchgrass Establishment Methods and Stand Management

Teel suggests the following switchgrass establishment and management methods based on extensive experience in south central Iowa:[34]

Year Prior to Planting

Test soil for P, K, and pH the year before seeding and bring P and K levels to minimum levels and pH to at least 6.5.

Seeding into a Tilled Seedbed

1) Till seedbed and pack very firm (footprints should be barely visible)
2) Between 15 April and 30 May seed five pounds pounds live seed (PLS) per acre of seed with a dormancy rate not great than 10% at maximum depth of ¼ to ½ inch.
3) Manage weeds with post emergence application of four ounces per acre of Pursuit in a two percent solution of ammonium sulfate solution. An alternative weed control is mowing the weed before the are six inches tall, several time if necessary.
4) Do not apply nitrogen fertilizer in the planting year.

No Till Establishment

If Planting into Grain Crop Residue

1) Just prior to seeding, control weeds with glypsophate (Round-up) at one to one and a half quarts per acre in a two percent ammonium sulfate solution. Go to step 4 below.

If Planting into Existing Pasture or Meadow, CRP Grass

1) Mow to 2 to 4 inches in mid-August the year prior to seeding and allow 4-6 inches of regrowth.
1) Kill existing sod with one quart glypsophate (Round-up) and one pint 2-4-D per acre in a 2% aluminum sulfate solution when plants are 4-6 inches tall, but prior to 15 September and before frost.
2) Inspect first two weeks of April and repeat prior step if sod is not dead.

[34] Teel, A., et. al., ***Management Guide for the Production of Switchgrass for Biomass Fuel in Southern Iowa***, Iowa State University Extension Service, Ames, February 1997.

3) Between 15 April and 30 May seed five pounds PLS per acre of seed with a dormancy rate not great than 10% at maximum depth of 1/4 to ½ inch. Insure drill packing wheels are working properly. A firm seed bed is essential.
4) Do not apply nitrogen fertilizer in the planting year.

Management in Production Years

1) Apply nitrogen annually.
2) Test soil for phosphorous and potassium every three years and adjust as required.
3) Harvest two to three weeks after hard freeze (minimum of four hours below 32^{o}F). Mow at 6 inch height to avoid root crown damage and provide wildlife cover. Expect moisture content of 15%.
4) Store indoors a soon as possible to minimize contamination and degradation.

Stand Renovation

1. If broadleaf weeds are a problem use four ounces of Pursuit per acre in a 2% ammonium sulfate solution applied in seven to ten gallons of water per acre. Properly practiced burning may also provide weed control. If yields are lower than anticipated, test soils and adjust phosphorous, potassium, lime, and nitrogen.

Teel also notes that due to its clump character, switchgrass may not control erosion in drainage pathways prone to form gullies. Fast running water moves around the clumps, eventually cutting into the soil. In areas of fields where gully prone drainage channels exist, erosion should be controlled with other grasses.[35]

2.3.3 Short Rotation Wood Crops (SRWC)

Suitable Species and Yield Potential

Short rotation woody crops (e.g. hybrid poplars, black locust, silver maple) may be planted and coppiced (harvested) every six to eight years, with the tree either chipped or burned as a whole tree. To achieve high yields, SRWC must be grown in quality soils with adequate rainfall, which would limit large scale production of SRWC to the eastern portions of the state. The U.S. Department of Energy initiated the Short Rotation Woody Crops Program in 1978. Coordinated by Oak Ridge National Laboratory, the program has built on earlier work on fiber production for the pulp and paper industries. The SWRC program has focused on determining minimum achieveable bioenergy cost using techniques that included the following:

- species selection and genetic improvement
- intensive planting – as dense as 4,000 trees/acre (9,900 trees/ha)
- short harvest cycles of 3 to 10 years
- optimum establishment practices, particularly weed control
- use of coppicing to eliminate replanting and improve yields
- specialized equipment to minimum harvesting cost.

[35] Personal conversation with Alan Teel, July 1998.

Suitable Species and Yield Potential

In conjunction with state specific research programs and over 20 research institutions across the U.S., the bioenergy potential of at least 150 tree species has been investigated extensively during the past 20 years. Species identified as having greatest promise for the eastern Great Plains (greater than 20 inches annual rainfall) include:

1) Black locust *(Robinia pseudoacacia)*
2) Siberian elm *(Ulmus pumila)*
3) Silver maple *(Acer Saccharinum)*
4) Eastern cottonwood *(Populus deltoides)*, the state tree.

Other species native to Kansas that have been evaluated include catalpa *(Catalpa speciosa)*, American sycamore *(Platanus occidentalis)* and honey locust *(Gleditsia triacanthos)*. Hybrid poplars have received a great deal of attention nationally; however, poplar may not be the most promising tree species for Kansas climate conditions.

Black Locust (Rhobinia pseudoacacia)

Black locust is native to southeastern North America, particularly the Ozark Mountains of Missouri and Arkansas and the Appalachians, and has been naturalized in Europe and Asia. It occurs naturally and is also widely planted in Kansas, growing in all but two counties along the Missouri border and in two along the Colorado border.[36] It grows rapidly in a range of soils (pH 4.6 – 8.2)[37], tolerating droughts and severe winters,[38] and has received wide consideration as a SRWC species. Mature specimens can reach a height of 30 - 40 feet [35 meters] with a diameter of 3+ feet [1 meter]. Properties of note include the following:

Figure 2.2.2 Black Locust Tree
source: http://www.oplin.lib.oh.us/OHS2/tree/factpages/locbla/locbla.html (Ohio Public Library)

- The plant is a nitrogen-fixing legume similar to alfalfa and soybeans
- The wood moisture content is very low compared with other tree species
- The heartwood contains flavinoids that impart exceptional decay resistance (a common use is fence posts where its longevity among native woods is exceeded only by osage orange *(Maclura pomifera)*
- It is widely used for erosion control and reforestation
- The tree is attacked by the locust stem borer, *Megacyllene robinae*, whose larvae bore through upper branches, often thinning the tree significantly, but can withstand periods of drought

---

[36] Stephens, H. A., ***Trees, Shrubs, and Woody Vines in Kansas***, University of Kansas Press, 1969.
[37] Hanover, J.W., Black Locust: An Excellent Fiber Crop, in New Crops, Janick, J. and Simon, J. E., (eds) Wiley, New York, 1993. www.hort.purdue.edu/newcrop/proceedings1993.
[38] Barrett, R. P., Mebrahtu, T., Hanover, J. W., ***Black Locust: A Multi-purpose Tree Species for Temperate Climates***, Advances in New Crops, J. Janick and J.E. Simons (eds), Timber Press, Portland, OR, www.hort.purdue.edu/newcrop/proceedings1990/V1-278.html.

- While the leaves are poisonous to some animals when young, they are widely used as fodder in Korea, Bulgaria, Nepal, and northern India
- Rapid canopy closure can reduce the need for weed control
- Exceptionally low moisture content at harvest reduces handling cost and improves net combustion efficiency

The ¾ inch long locust borer *(Mygacyllene robiniae)* is black with bright yellow bands. The black locust is the only host tree.[39] The inch long grub bores into the bark and later the heartwood, sometimes causing extensive damage. Trees grown on poor sites are more susceptable, while healthy trees are less affected.[9] The insect can be controlled with chlorpyrifos (Dursban, Pageant) or lindane, but good management practices reduce the risk. There has been some research to identify insect resistant strains, although their availability has not been confirmed as part of this project.

Figure 2.2.3 Mygacyllene robiniae – the Locust Borer
Source: USDA Forest Service, FIDL 71

Black locust is not widely used for lumber in the U.S. due to borers and often twisted trunks, but in Hungary where the borer does not occur, many improved cultivars have been developed for uses ranging from lumber to beekeeping. Research on improved cultivars has been conducted in the U.S. at Michigan State University (Barret, Mebrahtu, Hanover, Keathly) and the University of Georgia (Bongarten, Merkle).

Geyer reported that in field trials conducted on an alluvial site near Manhattan, Kansas during the 1980's "Black locust had the highest annual yield (6.3 t/ac) [14.2 Mg/ha], followed by cottonwood (5.3 tons/acre) [11.8 Mg/ha], with silver maple (4.3 tons/acre) [9.7 Mg/ha] being substantially lower. This trend between species was not altered by planting density or yearly differences."[40]

***Siberian elm** (Ulmus pumila)*

The Siberian elm is a fast growing non-native tree of rather weak brittle wood, causing significant branch dropping in older specimens. It is commonly incorrectly referred to as "Chinese Elm", a different species. It is been widely planted across Kansas as a drought tolerant source of quick shade. Uncrowded, it reaches a height of 65 feet [20 meters].

***Silver maple** (Acer saccharinum)*

The silver maple is a fast growing native moisture loving tree common to stream margins and bottomlands. It reaches a height of 60 to 80 feet with a diameter of three feet or more. The wood is relatively soft and weak, contributing to signifcant limb dropping and hollowing in larger specimens. It produces large numbers of seeds and is easily transplanted. Geyer found silver maple coppices extremely well, benefitting somewhat from higher cutting than other species. [41]

---

[39] Baker, J. R., Integrated Pest Management: Locust Borer, (Mygacyllene robiniae) North Carolina Cooperative Extension Service, www.ces.ncsu.edu/depts/ent/notes/Or…and_Turf/trees_contents.

[40] Geyer, W. A., ***Biomass Yield Potential of Short-Rotation Hardwoods in the Great Plains.***

[41] Geyer, W. A., Coppice ***Characteristics of Trees for Short Roation Forestry***, 4th E. C. Conf. Proceedings for Energy, Orleans, France, Elsevier Apppl. Sci., 1988.

Research plantations were established in central Kansas in 1991 as part of an effort to identify suitable clones for upland and lowland sites.

Cottonwood (Populus deltoides)

The eastern cottonwood, the state tree of Kansas, is fast growing with soft, brittle wood, reaching 49 feet [15 M] in shelter belts and 98 feet [30 M] in bottom lands. The tree, or the very similar western cottonwood (Populus sargentii) occur naturally in all but a few Kansas counties.[42]

Hybrid Poplar

Hybrid poplar is a cross of the eastern cottonwood *(Populus deltoides)* and one of several other *Populus* species, generally the black cottonwood *(Populus trichocarpa)*. Interest in hybrid poplar is fueled not only by its potential as a plantation biomass energy crop but also its use in fiber farms for the pulp and paper and building materials industries.[43] Development efforts have focused on the Pacific Northwest, the Great Lakes/North Central area, and the Southeastern U.S.

Table 2.3.4 Yields of Promising Short Rotation Woody Crops in Central and Eastern Kansas

Species/Location	Trees Planted (acre) [hectare]	Survival Rate	Harvest Year	Age	Coppice	Soil Type	Yield (dt/acre) [mG/ha]	Notes
Black Locust (Rhobinia pseudoacacia)								
Cheney		95%	1983	6	No	Silt loam	(3.2) [7.2]	1,2
Clinton		92%	1982	6	No	Silt loam	(3.7) [8.4]	1,2
Milford I		97%	1983	6	No	Silt loam	(4.6) [10.3]	1,2
Riley		98%	1983	4	No	Silty clay loam	(2.8) [6.3]	1,2
TeePee (Lawrence)		85%	1982	6	No	Sandy loam	(4.3) [9.6]	1,2
Tuttle Creek (Manhattan)		92%	1983	4	No	Silty clay loam	(6.5) [14.6]	1,2
Average (dry tons/acre)							**(4.2)**	
East. Cottonwood (Populus deltoides)								
Cheney (Km. Co.)	[3200]	na	1983	6	No	Shellabarger	(3.1) [6.9]	
Milford I	[3200]	na	1983	6	No	Cass	(3.1) [6.9]	
Milford II	[3200]	na	1983	5	No	Sarpy	(4.1) [9.2]	
Clinton (Dg. Co.)	[3200]	na	1982	6	No	Kennebec	(2.5) [5.6]	
TeePee (Dg. Co.)	[3200]	na	1982	6	No	Eudora-Kimo	(6.2) [13.9]	
Sunflower (Jo. Co.)	[3200]	na	1981	6	No		(3.1) [6.9]	
Average (dry tons/acre)							**(3.7)**	
Siberian Elm (Ulmus pumila)								
Milford II	[3200]	na	1983	5	No		(4.5) [10.1]	
Riley	[3200]	na	1983	4	No		(2.6) [5.8]	
Clinton (Dg. Co.)	[3200]	na	1982	6	No		(1.2) [2.7]	
TeePee (Cg. Co.)	[3200]	na	1982	6	No		(5.1) [11.4]	
Sunflower (Jo. Co)	[3200]	na	1981	6	No		(2.6) [5.8}	
Average (dry tons/acre)							**(3.3)**	
Silver Maple (Acer saccharinum)								
Sunflower (Jo. Co.)	(±1500)	na	na	6	No	Silty upland	(3.8)	
Clinton (Dg. Co.)	(±1500)	na	na	6	No	Silty alluvial	(3.6)	
TeePee (Dg. Co)	(±1500)	na	na	6	No	Sandy alluvial	(2.6)	
Average (dry tons/acre)							**(3.3)**	

[42] Stephens, H. A., ***Trees, Shrubs, and Woody Vines in Kansas***, University of Kansas Press, 1969.
[43] Kaiser, C. E., et. al., ***Stand Establishment and Culture of Hybrid Poplar***, James River Corporation, Mechaniization in Short Rotation, Intensive Culture Forestry Conference, Mobile, AL, 1994.

Table 2.3.5 Properties of Promising Short Rotation Woody Crops[44]

Property	Black Locust (Rhobinia Pseudoaccacia)	E. Cottonwood (populous deltoides)	Siberian Elm (Ulmus pumila)	Silver Maple (Acer Saccharinum)
Specific gravity (wood)	.57 - .68	.35	.40 - .57	.38 - .52
Ash content (% of dry tree mass)	2.0 – 2.2%	1.6%	.61 – 2.92	.31 - .51
Energy content (MBtu Btu/dry ton) [cal/g]	16.9 [4745]	17.0 [4777]	16.7 [4698]	16.7 – 19.4 [5077]
Moisture content (green)	32 – 38%	55%	45%	45%
Leaf area index (LAI) (leaf area:area of land)	4.4	5.5	4.4	4.4

Coppicing

SRWC plantations can be established by planting bare root nursery stock for most species. Some species can be established by planting bare cuttings. Others such as black locust, can be established by seeding, although this may require an additional year or two to reach harvest. The preferred strategy for a particular project depends on first cost and the impact on yield at harvest. Regardless of the initial method of establishment, allowing the stump remaining after harvest to send up new shoots, called coppicing, can avoid much of the cost of reestablishment and improve yields for some species. Weed control, and for some species fertilization, may be necessary the first post coppice season if maximum potential re-growth is to be achieved. Leaving the root system intact provides more rapid re-growth and reduces the risk of soil erosion. Species, season of harvest, spacing, age, and height of stump can all affect the success of coppicing. Geyer reported on the impact of coppicing on silver maple *(Acer saccharinum)*, Siberian elm *(Ulmus pumila)*, catalpa (*Catalpa speciosa*), and black locust *(Robinia pseudoacacia)*, observing the following:[45]

Figure 2.3.1 Coppiced Black Locust

- Cut stump height affected the maple and elm, but not the catalpa or locust
- Cutting during growing season reduced height of sprouts of all species 50%
- Neither dormant or growing season treatments affected survival

[44] Geyer, W. A., Bresnan, D. F., ***Characteristics and Uses of Black Locust for Energy***, Department of Foresty, Kansas State University, undated.

[45] Geyer, W. A., ***Coppice Characteristics of Trees for Short-rotation Forestry,*** 4th E.C. Conference Proceedings on Energy, 1987.

- Stump diameter has no relationship to sprout height
- Survival for all species exceeded 90% for all species, reaching 100% for all species when harvest occurred in the dormant season
- Coppice response for all four species was considered excellent.

Table 2.3.4 summarizes recorded SRWC yields for several studies of species that appear best suited to Kansas.

Black Locust Establishment and Stand Management

Field Preparation

Establishement of black locust would require chiseling and disking (within one month) after the harvest of one of the conventional commodity crops in the fall.

Planting

Plant seedlings by hand from a tractor pulled multi-station tree planting platform that cuts and closes the furrow.

Spacing

Tree spacing has a significant impact on establishment costs, required management practices, and yield. A variety of field trials have been conducted in an effort to determine what spacing strategy offers the best potential for achieving the lowest fuel cost.[46] Closely spaced plantings (some as close as 12 in. (.3 m) on center) - 43,500 trees/acre (107,500 trees/hectare)) are often referred to as short rotation intensive culture (SRIC) with harvest cycles as short as two years. Important factors in determining the preferred black locust spacing include the following:

- Closer spacing yields quicker canopy closure, reducing weed control problems
- Closer spacing increases the likelyhood of early insect infestation
- Closer spacing yields smaller trees altering harvest and handling methods
- Coppiced black locust also regrow from roots and closer spacing than original planting may lead to a greater loss of row definition, complicating subsequent harvest
- Closer spacing increases establishment cost.

A space of 4 x 10 feet [1.22 x 3.0 M], resulting in approximately 1,100 trees per acre [2,700 per Ha] was assumed for subsequent analysis.

Weed Control

Weed control is essential until tree canopy closure, which should occur by the third year for black locust. Mechanical tillage can be used in the first year, but herbicide control is generally recommended.

Insect Control

The locust borer is considered the greatest threat to decreased production from black locust plantings five years or older. Research on insect resistant strains has be done, but none were

[46] Geyer, W., ***Comparison of Biomass Yields of Several Hardwoods Grown in Short-rotation Plantations***, Southern Biomass Conference, Auburn, AL, 1988.

identified as commercially available. Suggested management practices to reduce insect damage include the following:

- Plant seedlings in wider spacing
- Plant only healthy seedling
- Carefully inspect for infestation and remove and destroy affected trees.

Harvest

Black locust trees would have a trunk diameter of 3.5 to 6 inches [8.9 to 15.2 cm] and a height of 24 to 36 feet [7.3 to 11 M] with an eight year harvest cycle. The most economical method of harvest would be a feller buncher. Felled trees would be skidded to the field edge where the entire tree would be chipped and blown into a chip truck for transportation to the generating plant for further processing. Details of harvesting energetics can be found in section 2.5. To maximize stump survival and coppice regrowth, harvesting should be performed during the dormant season, typically November – March.

Coppice Regrowth

Allowing the harvested tree to resprout from the stump essentially eliminates replanting costs and generally achieves greater yields in subsequent harvest since the tree is benefiting from an established root system. Risks of erosion are also substantially reduced. Geyer conducted research on coppice impact on black locust and other species in Kansas, observing the following:[47]

- First year height of coppice sprouts was significantly taller when cut during the dormant season, but after five years there was no difference
- Black locust survival was 79 – 89% during the dormant season, but dropped to 56% when cut during the growing season
- Heavier trees resulted from dormant season cuts of black locust.

Table 2.3.6 Physical and Chemical Properties of Black Locust[48]

Property	IP Units		SI Units	
	Value	Unit	Value	Unit
Energy content (dry)	16.87	MBtu/ton	15.34	MBtu/Mg
Moisture content (harvest)	15	%	15	%
Energy density (harvest)	14.34	Mbtu/ton	13.0	MBtu/Mg
Combustion ash	1.61	%	1.61	%
Sulfur content	0	%	0	%

[47] Geyer, W. A., ***Seasonal Cutting Response of Several Hardwood Tree Species***, 5th E. C. Conference on Biomass for Energy and Industry, Vol. I, Elsevier Applied Science, 1990.
[48] Geyer, W. A., ***Biomass Yield Potential of Short-Rotation Hardwoods in the Great Plains***, *Biomass*, 1989.

2.4 Predicting Crop Yields

More than any other single factor, cost will determine the potential for biomass energy. The cost of biofuels, as with any agricultural crop, is influenced by many factors, including yield, production costs, land value (rent), financing, and competitive profit from other agricultural options. Realistically estimating yield is essential for estimating cost. Yield is a function of many factors, including plant species and variety efficiency, climate, soil quality, fertilization and pest control (weeds and insects).

Seeking a viable method of extending ORNL field trial yields to a wide range of Kansas soil conditions, the regional office of the Natural Resource Conservation Service (NRCS) in Salina was contacted. NRCS's analysts suggested the newly developed Soil Rating for Plant Growth (SRPG) system would be suitable for such an analysis.

2.4.1 Soil Rating for Plant Growth (SRPG)

The Soil Rating for Plant Growth (SRPG) method developed by NRCS rates individual soil plant growth potential on a linear scale of 0 to 100. A soil with an SRPG rating of 100 is considered be approximately 10 times as productive as a soil with an SRPG rating of 10.

The SRPG was developed by NRCS soil scientists at Lincoln, Nebraska. It was designed to rate soils and soil map units based on soil properties related to plant growth. Soil properties are contained in the soil database, State Soil Survey Database (SSSD). SSSD is maintained at the NRCS State office in Salina, Kansas. The principal variables considered in calculating SRPG are listed below.[49]

1) ***Surface Structure and Nutrients***

- ***OM - Organic Matter -*** *percent is the weight of decomposed plant and animal residue and expressed as a weight percentage of the soil material less than 2 mm in diameter.*
- ***BD - Bulk Density -*** *of the surface layer is the oven dried weight of the less than 2 mm material per unit volume of soil at a water tension of 1/10 bar or 1/3 bar. Bulk density is an indicator of how well plant roots are able to extend into the soil.*
- ***Clay Content -*** *is the percent by weight of clay particles contained in the 2mm material of the soil.*
- ***$CaCO_3$ - Calcium Carbonate -*** *equivalent is the quantity of carbonate in the soil expressed as $CaCO_3$ and as a weight percentage of the less than 2mm size fraction. The availability of plant nutrients is influenced by the amount of carbonates in the soil.*
- ***Gypsum -*** *Gypsum is the percent by weight of hydrated calcium sulfates in the <20mm fraction of soil. Soils high in gypsum may collapse if the gypsum is removed by percolating water.*
- ***Depth to Root Zone -*** *rates soil using depth to beginning of first restriction.*
- ***Shrink-Swell -*** *potential of the surface layer is measured as linear extensibility percent, the linear expression of the volume difference of natural soil fabric at 1/3 bar and oven dryness.*
- ***Gravel and Stones -*** *rock framents are unattached pieces of rock 2mm in diameter or larger that are strongly cemented or are comparatively more resistant to rupture.*

[49] ***SRPG Calculation Summary***, NRCS.

2) ***Water Features***

- ***AWC - Available Water Capacity -*** *is the portion of water in a soil that can be absorbed by plant roots and is commonly estimated as the amount of water held between field capacity and wilting point.*
- ***Water table -*** *a seasonal water table is a zone of saturation at the highest average depth during the wettest season. It is at least 6 inches thick, persists in the soil for more than a few weeks, and is within 6 feet of the soil.*
- ***Permeability -*** *the quality of the soil that enables water or air to move through it.*

3) ***Toxixity***

- ***SAR- Sodium Adsorption Ration -*** *is a measure of the amount of sodium relative to calcium and magnesium in the water extract from saturated soil paste.*
- ***Salinity (electrical conductivity-EC):***
- ***Cation Exchange Capacity -*** *is the amount of exchangeable cations that a soil can absorb at a pH of 7.0 as estimated by the displacement of adsorbed ammonium ions in the ammonium acetate method for soils that have ph>=5.5. CEC is a measure of the ability of the soil to retain cations, some of which are plant nutrients.*

4) ***Soil Reaction pH***

- ***Reaction, Soil (pH) -*** *is the numerical expression of the relative acidity or alkalinity of a soil.*

5) ***Climate***

- ***Moisture Regime -*** *is based on the soil classification by great group, suborder, or order.*
- ***Temperature Regime –*** *is based on the number of frost free days.*

6) ***Physical Profile***

- ***Depth to Root Zone*** *- depth to beginning of first restriction.*
- ***Root Zone Available Water -*** *the root zone available water using all horizons above and including the root restrictive or bottom layer but not below 60 inches.*

7) ***Landscape***

- ***Slope*** *- is the percent slope. The standard SRPG method severely penalizes slope, appropriate for tilled land.*
- ***Other Variables*** *- Channeled/Gullied/Stony, NIRR Capability Class, Ponding, Erosion, Flooding.*

Values for many SRPG variables are specific to individual or groups of Major Land Resource Areas (MLRA).

SRPG was reportedly developed, at least in part, to serve as a simplified soil productivity rating tool for ad valorem tax equalization. The strategy of using it to predict biomass plant growth was not viable for the following reasons:

1) ORNL data. The ORNL switchgrass database did not contain detailed information on soil type or nitrogen application levels for many test plots. Efforts to acquire additional data from individual investigators were not successful.

2) Poor SRPG correlation with measured yields. When SRPG values and average pasture yields from the USDA Douglas County Soil Survey were compared for all soils in the county, the resulting R^2 value was less than 0.36 as shown in Figure 2.3.2. When average dryland wheat yields from Anderson, Jackson, Kingman, Saline, and Washington counties were evaluated the R^2 values were .35, .60, .71, .81, and .87 respectively. The SRPG did not appear to offer an acceptable prediction of either grass or grain yields.

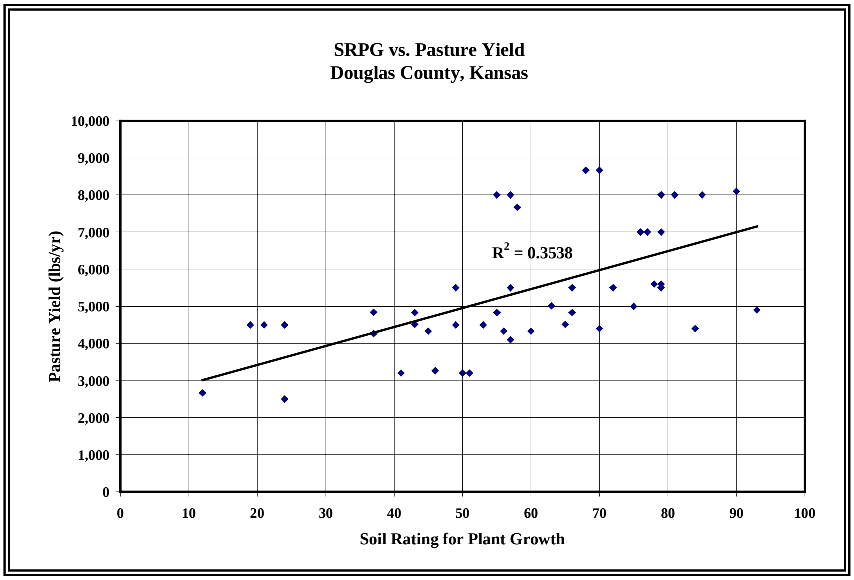

Figure 2.3.2 Soil Rating for Plant Growth vs. Pasture Yields

Absent a viable strategy for simplified but credible estimation of biomass energy crop yields under varying soil and climate conditions and recognizing the requirement to also evaluate competitiveness and embodied energy, a much more rigorous approach was pursued.

2.4.2 The Erosion Productivity Impact Calculator (EPIC)

The Erosion Productivity Impact Calculator (EPIC), also know as the Environmental Policy Integrated Climate, was developed by J. R. Williams and colleagues at the U.S. Department of Agriculture's (USDA) Blacklands Research Center in Temple, Texas, beginning in the early 1980s, to estimate soil productivity as affected by erosion. A detailed description of EPIC is presented in ***The EPIC Crop Growth Model*** by Williams, J. R., Jones, C. A., Kiniry, J. R., Spanel, D. A, published in *Transactions of the ASAE*, Vol. 32, No.2, pp. 497-511, 1989. EPIC has evolved into a robust plant growth model using a daily time step to simulate weather, hydrology, soil temperature, erosion-sedimentation, nutrient cycling, tillage, crop management and growth, and pesticide and nutrient movement for individually described plants. The EPIC Manual describes the following ten major program components:

Weather: Daily rain, snow, maximum and minimum temperatures, solar radiation, wind and relative humidity can be based on measured data and/or generated stochastically.

Hydrology: Runoff, percolation, lateral subsurface flow, and snow melt are simulated, as well as evapotraspiration.

Erosion: Soil erosion caused by wind and water are simulated. Sheet and rill erosion/sedimentation result from runoff from rainfall, snow melt, and irrigation. The model is capable of evaluating erosion of many years.

Nutrient Cycling: The model simulates nitrogen and phosphrous fertilization, transformations, crop uptake and nutrient movement. Nutrients can be applied as mineral fertilizers, in irrigation water, or as animal manures.

Pesticide Fate: The model simulates pesticide movement with water and sediment as well as degradation of foilage and in soil.

Soil Temperature: Soil temperature responds to weather, soil water content, and bulk density. It is computed daily in each soil layer.

Tillage: Tillage equipment affects soil hydrology and nutrient cycling. The user may change characteristics of simulated tillage equipment.

Crop Growth: A single crop growth model capable of simulating major agronomic crops, pastures, and trees is used. Crop specific parameters are available for most crops. The user may adjust or create new sets of parameters as needed. The model can also simulate crops grown in complex rotations and in some cases, mixtures. “The processes simulated include crop interception of solar radiation; conversion of intercepted light to biomass; division of biomass into roots, above-ground biomass, and economic yield; root growth; water use; and nutrient uptake. Potential plant growth is simulated daily and constrained by the minimum of five stress factors (water, nitrogen, phosphorous, temperature, and aeration). Root growth is constrained by a minimum of three stress factors (soil strength, temperature, and aluminum toxicity). EPIC is capable of simulating crop growth for both annual and perennial plants. Annual crops grow from planting to harvest date or until the accumulated heat units equal the potential heat units for the crop. Perennial crops (alfalfa, grasses, pine trees) maintain their root systems throughout the year, although the plant may become dormant after frost. They start growing when the average daily air temperature exceeds the base temperature of the plant.” (quoted from The EPIC Crop Growth Model)

Crop and Soil Management: The EPIC model is capable of simulating a variety of cropping variables, management practices and naturally occuring processes. These include different crop characteristics, plant populations, dates of planting and harvest, fertilization, irrigation, artificial drainage systems, tillage, runoff control with furrow dikes and other methods, liming, and pest control.

Economics: EPIC includes a costs of inputs and returns package, but the investigators developed an independent cost system in order to also calculate embodied energy.

EPIC has been tested throughout the U.S. and abroad for a variety of applications, including evaluation of crop yields, estimating soil erosion, evaluating the impact of different crop rotations and fertilizer application regimes, and evaluating the impact of different soils, climates and weather variations. While the complexity of the EPIC model was somewhat imtimidating, the range of capabilities it incorporated allowed the evaluation of key factors of interest for biomass crops, provided the essential plant description information could be located for switchgrass and black locust.

EPIC is a MS DOS based compiled Fortran program. A Windows interface is under development. The complete user's guide for EPIC can be found on the World Wide Web (WWW) at http://brcsun0.tamu.edu/epic/introduction/aboutmanual.html.

2.0 The Agricultural Land Management Alternatives with Numerical Assessment Criteria (ALMANAC)

The Agricultural Land Management Alternatives with Numerical Assessment Criteria (**ALMANAC**) model was developed by James R. Kiniry and collegues at the Blacklands Research Center in the early 1990s. Based on EPIC, ALMANAC provides added details for describing plant growth.

Kiniry reported on the use of ALMANAC to simulate the growth of Alamo switchgrass, the specific variety the investigators had identified as the most promising HEC for Kansas. In describing ALMANAC, Kiniry notes the following:[50]

- forage models require details for Leaf Area Index (LAI)
- the Radiation Use Efficiency (RUE) approach offers a useful technique for simulating crop biomass
- genotype differences in forage production are more closely related to total leaf area than productivity per unit of leaf area
- the ALMANAC model can describe forage production with different soils, rainfall, and temperatures.

Kiniry investigated ALMANAC's ability to predict switchgrass yields for a range of soil types and rainfall amounts. Plots were established in 1992 at six locations in Texas representing a range of rainfall and temperature regimes and soil types. Yields were measured in 1993 and 1994 and compared with ALMANAC simulations. ALMANAC overpredicted yields for 1993 by 0.2 t/acre (0.4 t/ha) and overpredicted 1994 yields by 0.4 t/acre (0.8t/ha). The mean error of prediction was 0.2 t/acre (0.5 t/ha).[51] ALMANAC was the only plant growth model identified that had been carefully evaluated for use in predicting switchgrass yields. The small difference between measured and predicted yields indicated it was well suited for evaluating switchgrass yields for a wide range of Kansas soil and climate conditions.

[50] Kiniry, J. R., Sanderson, M. A., Williams, J. R., Tischler, C. R., Hussey, M. A., Ocumpaugh,W. R., Read, J. R., Van Esbroeck, G, and Reed, R. L., ***Simulating Alamo Switchgrass with the ALMANAC Model***, Agronomy Journal, Vol. 88, No.4, 1996
[51] Kiniry, J. R., et. al., ***Simulating Alamo Switchgrass with the ALMANAC Model***, Agronomy Journal, 88:602-606, 1996.

2.4.3.1 The Blacklands Research Center (BRC)

A member of the project team was aware of the EPIC model and had begun suggesting its use be considered when it became apparent that the SRPG approach would not adequately meet project requirements. The ALMANAC model was identified while conducting a general web search for additional EPIC information. A series of phone conversations and email exchanges followed between project team members and Dr. Jim Kiniry and Dr. Verel Benson, staff scientists at the USDA's Blacklands Research Center (BRC) near Temple, Texas, to describe the KEURP project. Two project team members visited the BRC for two days in October 1997 with the goal of developing a strategy for BRC to assist in the use of the ALMANAC model for estimating switchgrass and black locust yields. Dr. Benson and other staff members provided an extensive briefing on the full set of agricultural and environmental models developed and maintained at BRC, including the following:

ALMANAC	—	Agricultural Land Management Alternatives with Numerical Assessment Criteria
APEX	—	Agricultural Policy/Environmental eXtender
CARE	—	Cost and Return Estimator
EPIC	—	Erosion Productivity Impact Calculator also known as the Environmental Policy Integrated Climate
GLEAMS	—	Groundwater Loading Effects of Agricultural Management Systems
HUMUS	—	Hydrologic Unit Model for the United States
SWAT	—	Soil and Water Assessment Tool
SWRRBWQ	—	Simulator for Water Resources in Rural Basins

Detailed discussions focused on ALMANAC. In addition to the work on switchgrass described above, Dr. Kiniry also conducted a limited field trial evaluation of the mesquite tree using ALMANAC.[52] The mesquite tree description was modified to describe black locust, including its leguminous character and canopy form, using leaf area index data from Europe.[53] Using soil characteristics and climate conditions for the sites at which Kansas black locust field trials were conducted (see Table 2.3.4), Dr. Kiniry used ALMANAC to estimate long term yield. The plant description parameters were then refined until the model predicted yields that approximated field trial yields. The ALMANAC model was then used with the refined black locust plant description to estimate yields for other Kansas soils for the six Kansas weather regions defined for the project (Figure 2.4.5). This strategy permitted use of the same model (with different plant descriptions) for both HEC (switchgrass) and a SRWC (black locust).

2.4.3.2 Analysis Strategy

Once confidence was gained in using ALMANAC to model for both switchgrass and black locust, the following strategy emerged:

1) Select soils and acquire data required by ALMANAC — Review Kansas soil series map,

[52] Personal conversation with Dr. Jim Kiniry at the Blacklands Reseach Center, October, 1997.

[53] Bencat, T., ***Leaf Biomass and Leaf Area Index (LAI) of Black Locust (Robeinia pseudoacacia L.) in Southwest Slovakia***, Ecology (CSFR), Vol. 9, No. 3, 1990.

- Identify soil series in the portion of Kansas to be analyzed (bounded on the west by the west side of Ellis County - Hays, roughly 24 in. of annual rainfall isoline)
- Determine which soils are already in the ALMANAC data set
- Acquire required data for other soils, coordinating format

2) Select six climate zones with representative weather data sites and identify soil series for each weather site.

   - Review rain isoline map
   - Review ALMANAC weather site list for Kansas
   - Match soil series with weather sites (some soils may require more than one weather site, but the zones will not necessarily follow county boundary lines).
   - Provide detailed list of soil series/data source and associated weather site(s)

3) Use ALMANAC to simulate switchgrass production for each soil/climate combination. (BRC staff)

   - Use Dr. Kiniry's Alamo Switchgrass plant description
   - Nitrogen application stress driven (maximum of two applications per year)
   - Standard establishment and management practices
   - 24 year analysis period
   - Annual single cutting post frost harvest
   - Output for each soil for each climate zone
     echo input
     estimated annual yield, dry Mg/Hectare
     fertilizer application (N)
     erosion and other environmental outputs

4) Use ALMANAC to simulate black locust production for each soil/climate combination, standard management practices. (BRC staff)

   - Use Dr. Kiniry's black locust plant description
   - Standard establishment and management practices
   - 24 year analysis period with three 8 year harvest/coppice regrowth cycles
   - Eight year post frost harvest cycle
   - Output —
     echo input
     estimated annual yield, dry Mg/Hectare
     erosion and other environmental factors

5) Use ALMANAC to simulate competing crops of corn, soybean, wheat, and grain sorghum production for each soil/climate combination. (BRC staff)

   - Use Dr. Benson's existing crop description and management files for grain crops in Kansas (do correlation check with ALMANAC to insure grass/trees and grains are evaluated essentially the same)

- Standard establishment and management practices
- 24 year analysis
- Output —
  echo input
  estimated annual yield, dry Mg/Hectare
  erosion and other environmental factors

6) Develop a custom EXCEL Workbook to estimate production cost and embodied energy

- Estimate net profit for each grain crop for each soil series/weather zone
- Determine edge of field energy price ($/million Btus) required for switchgrass and black locust to compete with highest profit grain crop (requires production cost of bioenergy crops)
- Repeat analysis for three different 24 year grain price scenarios

- Analyze three grain price scenarios
- Evaluate in energy cost increments of $0.50 from the level at which a "significant" volume of biomass is available through $5.00/million Btu edge of field cost
- Summarize by soil series and county

7) Use SSURGO and Landcover in ARCInfo or ARCView to determine production (land area x yield) for each land parcel of a soils series at incremental edge of field costs

- Identify land use exclusion categories (including but not limited to urban areas, highways, water, parks and public land, irrigated land, quarries)
- Filter out excluded land from SSURGO

Import data from previous step on cost at which biomass can compete for each soil series/climate zone into GIS and evaluate gross production available at varying energy cost increments. (This could also be done in Excel after gross areas per soil series are reduced for excluded land uses in GIS, then imported into GIS for transportation analysis.)

8) Identify potential biomass power generation sites (cofiring existing plants or new dedicated generation facilities) and use ARCView/Network/Spatial Analysis to calculate transportation cost of available biomass to potential sites.

- Review regional or state level maps of biomass energy crop availability at varying price levels
- Identify sites/regions of greater biomass energy crop availability
- Screen potential cofiring sites (existing facilities) for regional biomass energy crop availability
- Select potential biomass electric power generation sites
- Perform biomass energy crop transportation analysis from field (SSURGO parcel) to plant location (ton/miles) for each site and perform "inside the plant gate" analysis

9) Summarize quantified environmental impact of biomass energy crop production vs. conventional grain crops

- For each of the potential sites and each evaluated plant sizes, compare 24 year erosion impact of the lowest cost bioenergy crop and the competing grain crop
- Compare likely levels of herbicide use of the lowest cost bioenergy crop and the competing grain crop

10) Identify needs/opportunities for additional research beyond the scope of this study

2.4.3.3 Kansas Climate Regions

Growth of biomass energy crops varies daily in response to weather conditions, including precipitation, temperature, and solar radiation. Annual yield thus varies regionally from year to year in response to differences in these variables.

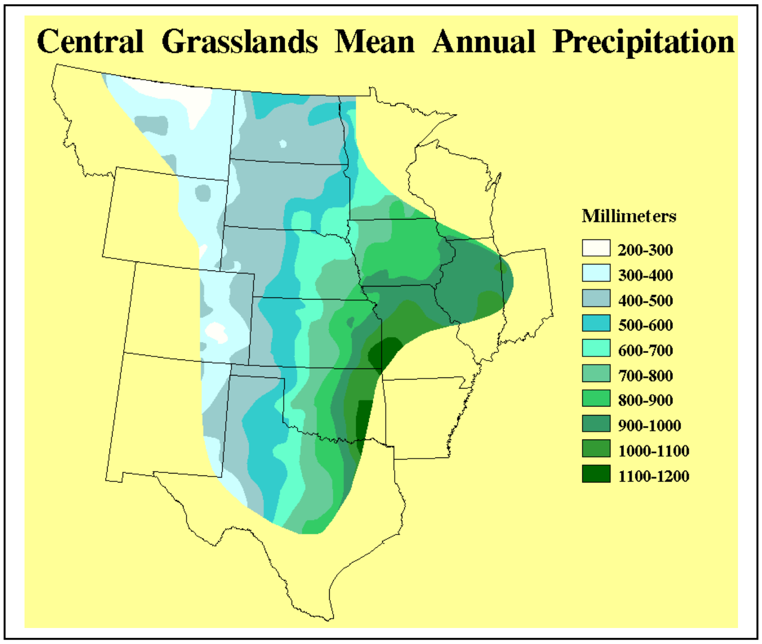

Figure 2.4.1 Precipitation in the Grasslands of the Great Plains
Source:
http://sgs.cnr.colostate.edu/atlas/

Kansas Climate Variation

The average annual rainfall for Kansas and the central Great Plains is shown in Figure 2.4.1. Not surprisingly, rainfall strongly influenced yield of both switchgrass and black locust. Growing season and solar radiation also affect yield, but the interaction among these variables was not analyzed.

United States: Average dates of last spring freeze (32 F)

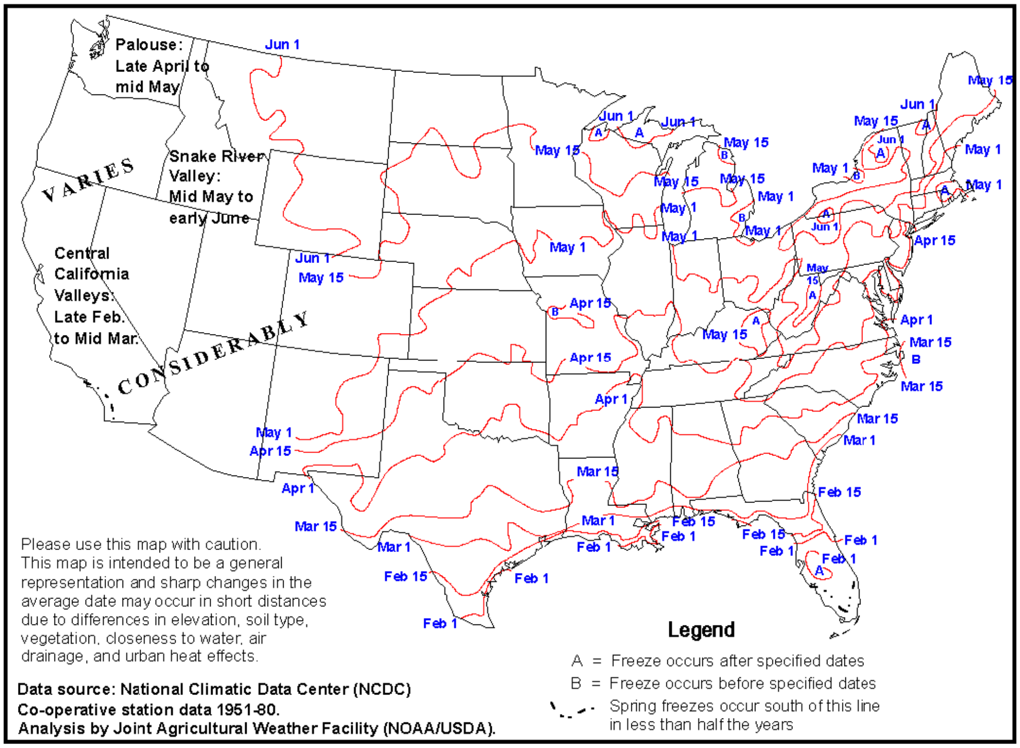

Figure 2.4.2 Date of Last Spring Freeze

United States: Average dates of first autumn freeze (32 F)

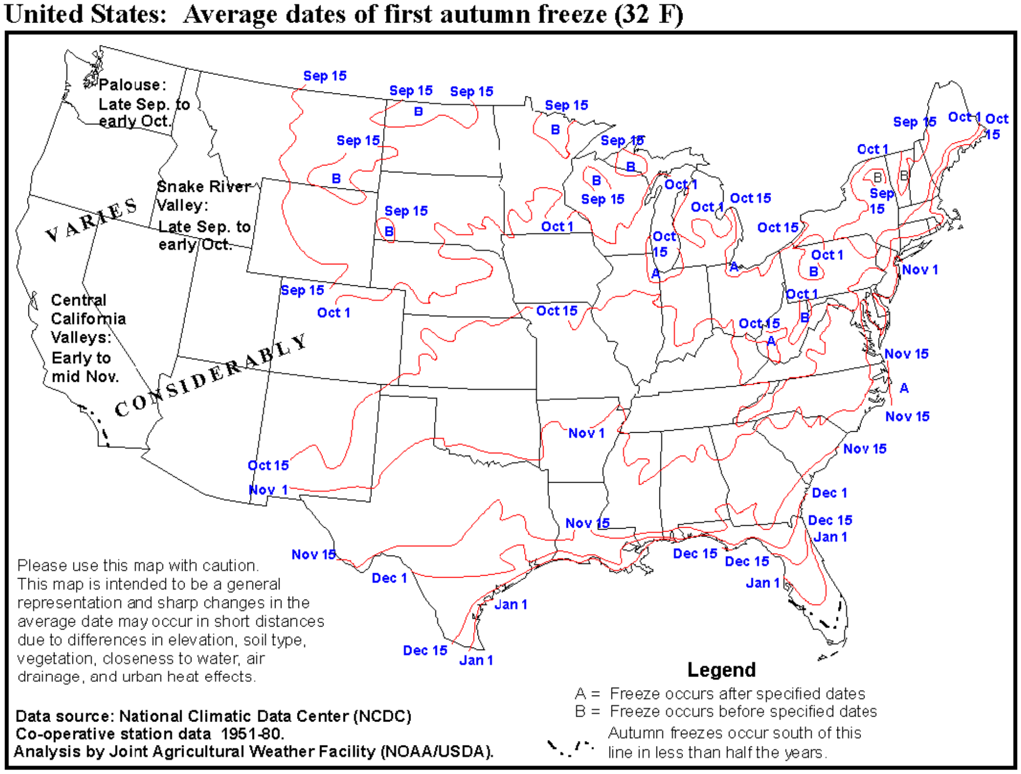

Figure 2.4.3 Date of First Autumn Freeze

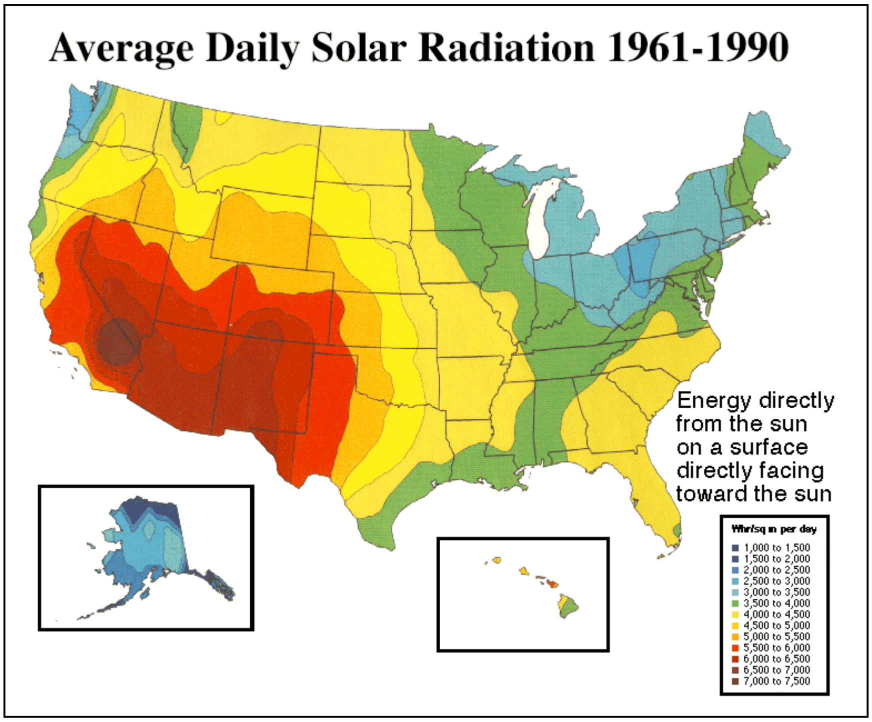

Figure 2.4.4 Average Daily Solar Radiation
Source: NREL, Solar Electric Systems, Inc.

Kansas lines of equal precipitation and solar radiation, shown in Figure 2.4.4, generally run vertically while lines of equal numbers of frost free days, characterized in Figures 2.4.2 and 2.4.3, generally run horizontally. The western third of the state, that portion receiving less than 22 inches in average annual precipitation, was considered too dry for economic production of biomass energy crops. The eastern two-thirds was divided vertically into three zones, reflecting gradations in precipitation and solar radiation, and then horizontally into two zones reflecting gradations in growing season. Climate station sites for each of the resulting six regions were selected based on available weather data files in a format readable by ALMANAC and location within the climate region. Where possible climate stations further north and west in the zone were selected to allow the analysis to be somewhat more conservative. Climate regions and data station cities are shown below in Figure 2.4.5.

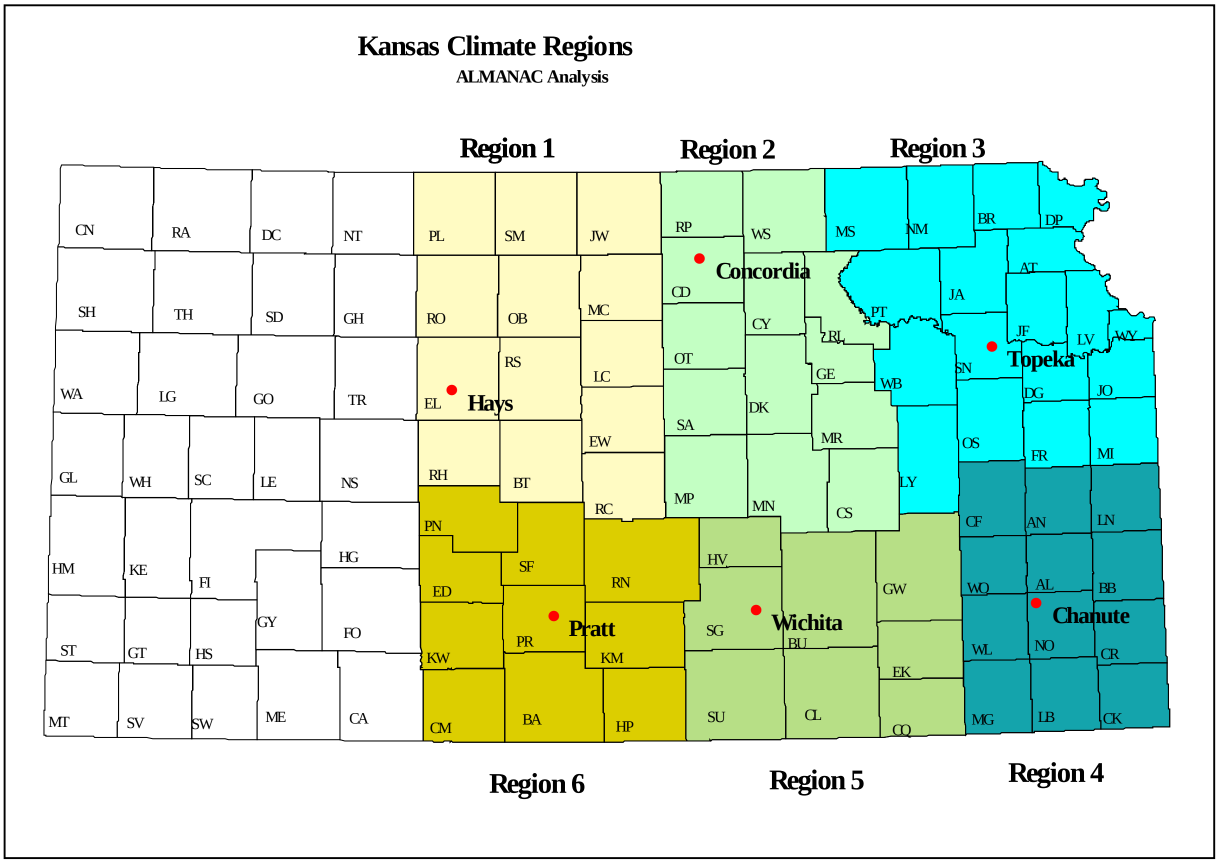

Figure 2.4.5 Kansas Climate Regions for ALMANAC Analysis

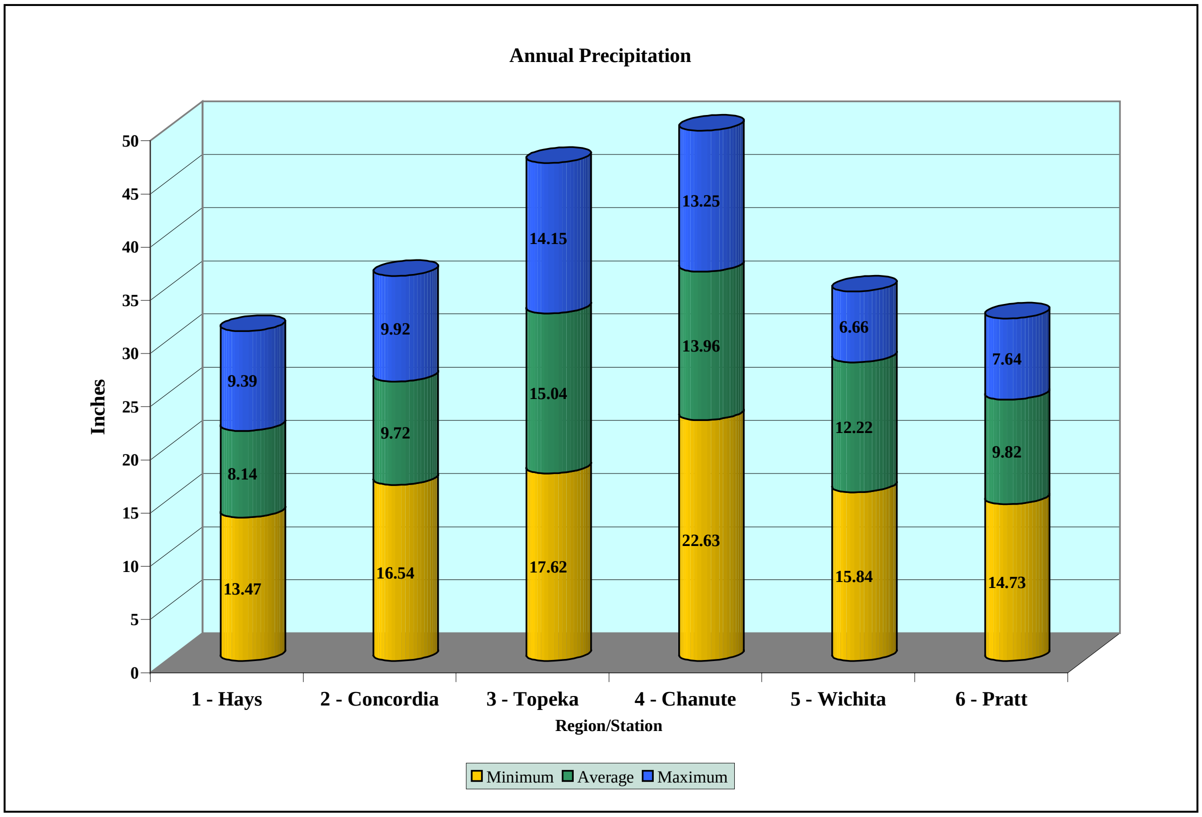

Figure 2.4.6 Annual Precipitation for Six ALMANAC Climate Regions

ALMANAC weather files for each climate station contain monthly or daily values for rain, snow, maximum and minimum temperatures, solar radiation, wind and relative humidity. For each year of the 24 year analysis period the model adjusts stochastically each of these values within statistically normal bounds to create a representative climate with associated "good" years and "bad" years for plant growth.

2.4.3.4 Kansas Soils

Soils are classified in a variety of ways, depending on what soil properties are being described, several of which are described elsewhere in this report. Kansas has around 3900 individually named soils in the 74 counties being analyzed. These soils are grouped into about 300 soil series. Figure 2.4.6 illustrates the regional diversity of soils across the area being evaluated. Significant differences in soil quality have a direct impact on plant growth and crop yield. Analyzing production for six crops for each individual soil would have generated an enormous amount of data, and the range for individual soils within a series was expected to be quite small. The ALMANAC analysis was therefore performed for the dominant soil within each series.

Figure 2.4.7 The STATSGO Soil Map of Kansas

This is the STATSGO general soil association map for Kansas developed by the National Cooperative Soil Survey. Soil associations are broader and more generalized classifications than the soil series used in this project which are to detailed to show on a statewide level at a small scale. Soil quality strongly influences yield of biomass energy crops.

2.5 Biomass Energy Production Cost and Embodied Energy (BEPCEE. XLS)

(an Excel Workbook)

Realistically estimating the cost per million Btus of biomass fuel combusted by a utility boiler is a key factor in evaluating the feasibility of biomass for electric power generation. Many factors directly or indirectly affect the cost of producing, delivering, and processing biomass fuel. Identifying which set of conditions offer the potential for achieving an acceptable volume of energy with sufficient geographic concentration at the lowest possible cost is required if biomass is to be given a fair and objective opportunity to compete, not only with fossil and nuclear fuels, but other renewables as well. A major goal of this project has been to develop a set of analytical tools that will permit rigorous evaluation of biomass energy feasibility for electric power generation. While biomass is not expected to compete on a cost of fuel basis with current low costs fuels, including coal and nuclear, future policy changes may shift this balance. The tools developed as part of this project should permit a rapid reassessment should circumstances change. In the mean time this analysis can help identify research opportunities that may help reduce the future cost of biomass crops.

In addition to cost, the Energy Profit Ratio (EPR) is an important consideration. EPR is the ratio of all fossil energy inputs required to produce the biomass to its effective energy value. It gives an indication of just how much renewable energy is actually gained from using biomass to displace fossil fuels. The ability to evaluate EPR parallel to the evaluation of cost was a major objective of the analysis.

BIOCOST, a spreadsheet program developed by Oak Ridge National Laboratory, is designed for estimating the cost of producing switchgrass and hybrid poplar bioenergy crops in 1995 dollars. BIOCOST provides output on quantities of fertilizers, chemicals, and fuels, permitting the evaluation of the embodied energy of direct inputs.[54] BIOCOST was seriously considered, but the need to evaluate indirect embodied energy and to use the production cost model as a bridge between ALAMANAC yield estimates and GIS analysis lead us to a different approach.

The Cost And Return Estimator (CARE) program developed by USDA's Natural Resource Conservation Service was considered for analysis of biomass energy and competing crop production cost analysis. The program is intended for use by NRCS personnel in providing assistance to farmers on planning, program assistance and loan analysis, and did not offer a means of evaluating embodied energy.

The requirement to analyze embodied energy parallel to the analysis of production cost and the need to structure data output in a format useable by PC ArcInfo and ArcView for spatial analysis lead to the development of an extensive Excel workbook named Biomass Energy Production Cost and Embodied Energy (BEPCEE.XLS).

Biomass crops, unlike annual grains, are perennials. If land owners, whether farmers or absentee landlords, are to convert their land to a perennial crop they will normally expect to achieve, over time, a financial return equal to or greater than what they would have earned from other land use

[54] Walsh, M. E., Becker, D. A., ***BIOCOST Documentation***, Oak Ridge National Laboratory, September, 1996.

options. The two principal options available today are grain production and enrollment in the federal Conservation Reserve Program (CRP). It could be argued that they should expect more since returning the land from biomass to conventional grain production will add significant cost, particularly for SRWCs where established stumps would need to be removed. Investment in a biomass fueled power plant would require confidence in a long term fuel supply and converting land to a perennial crop would require confidence in a long term market. The BEPCEE model is therefore based on a twenty-five year cycle. The cycle would begin with an establishment year, followed by annual harvest for HECs and three harvests eight years apart for SRWCs. The BEPCEE model estimates the production cost of biomass fuels at the edge of field in the following two distinct ways:

1. The yearly profit for four conventional grain crops; corn, wheat, soybeans, and grain sorghum is estimated for each soil for each of six Kansas climates zones (see Figure 2.4.5). The required price for switchgrass and black locust, based on the estimated yield for that soil and climate region, to achieve a total gross profit equal to that from the most profitable grain crop, is then determined. This analysis requires that the farmer always plants the best crop, even though it may vary from year to year and will not be known in advance. Since SRWC are harvested only every eight years, the grain crop profit, less income tax, is compounded with interest (as well as rent and other expenses) until the year of harvest.

2. The land is assumed to be enrolled in the CRP program and a waiver has been acquired from the U.S. Department of Agriculture permitting the biomass energy crops to be harvested from the land in exchange for a payment to USDA equal to 20% of the CRP rent (see further discussion of CRP in Section 2.7). The land owner, in exchange for a fee of the exact same amount, agrees to allow the land to be converted to a biomass energy crop and harvested for a period equal to the CRP enrollment. The cost of biomass is then the actual cost of production, including land rent payments equal to a total of 40% of the CRP rent, plus a profit of 10 percent.

The individual worksheets within BEPCEE and the calculations performed within the worksheets are reviewed below. A copy of the entire Workbook is on the KRD-9513 CD disk in the BEPCEE directory. Note that the full Worksheet extends the analysis for a period of 25 years (first year startup plus 24 years of production), not the seven to eight shown below. The additional years are reflected in all reported summary data in later sections. The data here is only to review the structure and methods of the Workbook and individual Worksheets and should not be considered part of the final analysis.

2.5.1 Data Import Worksheet

The ALMANAC output file for each crop, for each soil, for each climate region evaluated appears in Table 2.5.1 below.

```
                                    YLD    FN   USLE    YW    RAIN       Q  YON    YP  YAP YNO3   SSFN   PRKN     TMX   TMN     RAD
 1  x:\idp\ks3\ak3sg10.dat SWCH,   .00, 47.00,  .06, .00, 732.25,    .02, .00, .00, .00, .00,  7.16, 22.38,  18.47, 5.62,  15.00,
 2  x:\idp\ks3\ak3sg10.dat SWCH, 15.37, 61.27,  .03, .00, 740.80,   2.60, .01, .00, .00, .02,  1.27,  2.28,  17.95, 5.11,  15.64,
 3  x:\idp\ks3\ak3sg10.dat SWCH,  1.46, 70.50,  .04, .00, 795.42,  15.05, .04, .01, .01, .12,   .49,   .02,  18.42, 5.06,  15.93,
 4  x:\idp\ks3\ak3sg10.dat SWCH,  8.73, 85.37,  .02, .00, 648.86,   7.94, .00, .00, .00, .22,   .82,   .00,  18.85, 5.80,  15.90,
 5  x:\idp\ks3\ak3sg10.dat SWCH, 11.62, 61.80,  .05, .00, 945.57,  27.72, .08, .01, .01, .23,   .82,  1.32,  19.13, 6.10,  15.35,
 6  x:\idp\ks3\ak3sg10.dat SWCH, 11.93, 91.09,  .03, .00,1017.27,  14.47, .02, .00, .00, .29,   .67,  1.17,  18.52, 5.06,  15.37,
 7  x:\idp\ks3\ak3sg10.dat SWCH,   .09, 70.50,  .02, .00, 593.02,  22.37, .04, .01, .00, .32,  1.36,  2.97,  19.39, 5.95,  16.31,
 8  x:\idp\ks3\ak3sg10.dat SWCH,  7.71, 66.49,  .03, .00, 861.13,  46.11, .03, .00, .02, .67,  1.48,  3.56,  17.98, 5.41,  15.46,
 9  x:\idp\ks3\ak3sg10.dat SWCH,   .00, 44.67,  .03, .00, 799.64,  14.48, .04, .01, .01, .13,  1.30,  4.37,  19.06, 5.31,  15.76,
10  x:\idp\ks3\ak3sg10.dat SWCH,  3.82, 47.00,  .03, .00, 918.37,  25.44, .03, .00, .01, .28,   .72,  1.08,  18.26, 4.75,  15.89,
11  x:\idp\ks3\ak3sg10.dat SWCH, 19.19, 91.38,  .04, .00,1075.75,  63.88, .07, .01, .02, .78,   .86,  2.56,  17.75, 4.97,  15.49,
12  x:\idp\ks3\ak3sg10.dat SWCH,   .44,113.44,  .02, .00, 633.29,   5.88, .01, .00, .00, .05,   .60,   .55,  19.66, 6.55,  15.90,
13  x:\idp\ks3\ak3sg10.dat SWCH, 14.58, 92.04,  .02, .00, 685.29,    .72, .00, .00, .00, .01,   .37,   .35,  18.28, 5.78,  14.91,
14  x:\idp\ks3\ak3sg10.dat SWCH,   .36, 70.50,  .01, .00, 447.60,   6.23, .00, .00, .00, .14,   .40,  1.13,  18.72, 5.59,  15.71,
15  x:\idp\ks3\ak3sg10.dat SWCH,  3.62, 70.50,  .02, .00, 857.14,   7.97, .02, .00, .01, .07,  1.59,  1.54,  18.32, 5.44,  14.96,
16  x:\idp\ks3\ak3sg10.dat SWCH,  4.06, 47.00,  .05, .00,1024.68,  67.85, .15, .02, .04, .78,  1.82,  1.66,  17.76, 4.35,  15.45,
17  x:\idp\ks3\ak3sg10.dat SWCH,   .00, 40.62,  .02, .00, 656.63,   8.53, .01, .00, .00, .30,   .76,  1.88,  18.49, 5.84,  15.38,
18  x:\idp\ks3\ak3sg10.dat SWCH, 14.37, 67.76,  .02, .00, 716.35,  21.59, .02, .00, .01, .41,   .45,   .86,  18.59, 6.15,  15.58,
19  x:\idp\ks3\ak3sg10.dat SWCH,   .60, 70.50,  .06, .00,1188.94,  67.81, .15, .02, .02, .75,   .91,  1.63,  17.26, 4.40,  14.90,
20  x:\idp\ks3\ak3sg10.dat SWCH,  1.89, 70.50,  .03, .00, 757.36,  11.40, .02, .00, .01, .21,   .61,  1.78,  16.69, 3.85,  15.45,
21  x:\idp\ks3\ak3sg10.dat SWCH, 14.48, 67.90,  .03, .00, 939.36,  40.06, .02, .00, .01, .65,   .52,  1.14,  18.52, 5.52,  15.69,
22  x:\idp\ks3\ak3sg10.dat SWCH,  4.85, 92.10,  .03, .00, 842.94,  10.32, .01, .00, .00, .18,   .34,   .19,  17.72, 5.38,  14.92,
23  x:\idp\ks3\ak3sg10.dat SWCH, 16.66, 91.03,  .04, .00,1048.93,  25.54, .05, .01, .00, .42,   .78,   .31,  18.75, 5.68,  15.37,
24  x:\idp\ks3\ak3sg10.dat SWCH,   .32, 91.86,  .05, .00, 981.74,  47.21, .10, .01, .01, .41,  1.40,  3.74,  18.87, 6.03,  15.61,
```

Table 2.5.1 ALMANAC Output File: One Climate, One Crop, One Soil. 24 Years

Each row represents one year. A macro[55] concatenates all six files (switchgrass, black locust, wheat, corn, soybeans, and grain sorghum) for each soil and climate region into a single file. Another macro pastes the combined file into the Data Import worksheet. This worksheet converts the metric values into IP units, and changes yield from dry tons to bushels with standard moisture content for grain crops. Other worksheets within BEPCEE address cells within the Data Import worksheet and analyze the cost of production and embodied energy for each crop for that particular soil and climate region. These worksheets are discussed in greater detail below. Other macros discussed later execute batch processing of all soils within a climate region. Copies of all ALMANAC input and output files are on the KRD-9513 CD drive in the ALMANAC directory, compressed in Zip format.

2.5.2 Unit Costs Worksheet

The Unit Costs worksheet contains unit cost information obtained from a wide variety of sources for all major material and labor inputs for conventional grain and biomass crop establishment, management, harvest, and placement in the truck used for transportation away from the field edge. Unit costs are ultimately reduced to cost per production unit (dry ton for biomass, bushel or cwt for grain), typically by converting unit costs to cost per acre and dividing by yield for each land parcel being evaluated. Maximum, minimum, and average values are retained in output data. Data for individual years can be evaluated by loading the ALMANAC output file for a specific climate region and soil of interest.

Planting rates, shown in Table 2.5.2 below, were derived from conversations with KSU Department of Agronomy (grains), Dr. Wayne Geyer (black locust), and Alan Teel (switchgrass).

[55] Macros are custom programs that run within another larger program. A single macro can execute many steps. Once written they allow the process to be repeated, typically with dramatic time savings. The Excel macros for BEPCEE were written in Visual Basic.

Table 2.5.2 Planting Rates and Unit Costs

Seeds/Seedlings	Unit	Cost/ Unit	Seed/ Seedlings/ Unit	Seeds/Seedlings/acre by Climate Region 1	2	3	4	5	6
Switchgrass	lb	$10.00	360000	1800000	1800000	1800000	1800000	1800000	1800000
Black Locust	lot	$250.00	1000	1089	1089	1089	1089	1089	1089
Wheat	lb	$0.20	15000	975000	975000	1350000	1350000	975000	975000
Corn	lb	$2.00	1600	22800	22800	22800	22800	22800	22800
Soybeans	lb	$0.35	3000	145000	145000	145000	145000	145000	145000
Grain Sorghum	lb	$1.00	15000	50000	50000	70000	70000	50000	50000

These planting rates and unit prices resulted in the seed/seedlings cost per acre shown in Table 2.5.3.

Table 2.5.3 Seed/Seedling Cost per Acre by Climate Region

	Seeds/Seedlings, $/acre by Climate Region					
Crop	**1**	**2**	**3**	**4**	**5**	**6**
Switchgrass	$50.00	$50.00	$50.00	$50.00	$50.00	$50.00
Black Locust	$272.25	$272.25	$272.25	$272.25	$272.25	$272.25
Wheat	$13.00	$13.00	$18.00	$18.00	$13.00	$13.00
Corn	$28.50	$28.50	$28.50	$28.50	$28.50	$28.50
Soybeans	$16.92	$16.92	$16.92	$16.92	$16.92	$16.92
Grain Sorghum	$3.33	$3.33	$4.67	$4.67	$3.33	$3.33

Annual phosphorous (P), potassium (K), and lime (L) application rates shown in Table 2.5.4 below were derived from Kansas State University Farm Management Guides. Nitrogen applications rates were calculated by the ALMANAC model based on plant stress and vary for each crop by climate region, soil, and year.

Table 2.5.4 Annual Fertilizer and Lime Application Rates (lbs/acre)

	Pounds/acre by Climate Region																	
Crop	**1**			**2**			**3**			**4**			**5**			**6**		
	P	**K**	**L**	**P**	**K**	**L**	**P**	**K**	**L**	**P**	**K**	**L**	**P**	**K**	**L**	**P**	**K**	**L**
Switchgrass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Black Locust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wheat	20	15	0	20	15	0	25	10	400	30	20	500	20	0	500	20	0	500
Corn	30	15	0	30	15	0	30	10	400	30	20	500	20	20	500	20	20	500
Soybeans	25	15	0	25	15	0	30	30	400	20	20	500	25	25	500	25	25	500
Grain Sorghum	25	15	0	25	15	0	30	10	400	20	20	500	25	0	500	25	0	500

First year costs for fertilizers and lime, not including application:

Nitrogen (N)	$0.31/lb	Phosphorous	$0.28/lb
Potassium (K)	$0.13/lb	Lime	$0.005/lb

Fertilizer prices were escalated at the general inflation rate, although the Money Worksheet permits differential escalation.

Herbicide and Pesticide Costs

Herbicides, and usually to a much lesser extent pesticides, are a significant cost. The regional costs for each biomass and grain crop being evaluated were derived from Kansas State University Farm Management Guides.

Table 2.5.5 Herbicide and Pesticide Costs

Crop	Herbicide and Pesticide Cost by Region ($/acre, not including application)					
	1	2	3	4	5	6
Switchgrass	$2.30	$2.30	$2.30	$2.30	$2.30	$2.30
Black locust	$0.38	$0.38	$0.38	$0.38	$0.38	$0.38
Winter wheat	$9.24	$9.24	$5.33	$4.93	$9.19	$9.19
Corn	$34.30	$34.30	$34.85	$34.45	$34.25	$34.25
Soybeans	$28.96	$28.96	$29.51	$29.51	$28.91	$28.91
Grain Sorghum	$14.04	$14.04	$27.23	$20.30	$13.99	$13.99

Energy Costs

Current global crude oil prices are exceptionally low, leading to low retail prices for refined petroleum products. Energy costs used in the base case analysis are shown in Table 2.5.6 below. As with other inputs, costs were escalated at the inflation rate although the Money Worksheet permits differential escalation for energy costs permitting sensitivity analysis.

Table 2.5.6 Energy Costs

Liquid Fuels	Unit	Cost/ Unit	Tax/ Unit	Total Cost/ Unit	Electricity	Unit	Cost/ Unit
Diesel (off road)	gal.	$0.75	$0.00	$0.75	Energy	kWh	$0.04
Diesel (on road)	gal.	$0.75	$0.30	$1.05	Demand	kW/ mo.	$3.50
Gasoline	gal.	$0.80	$0.32	$1.12	Average	kWh	$0.08
Engine Oil	gal.	$4.00	$0.50	$4.50			
Propane	gal.	$0.85	$0.05	$0.90			

Field Operations: Planting, Tilling, Chemical Application, Harvesting, Move to Field Edge

All field operations for biomass and grain crops, including seedbed preparation, planting, cultivating, applying fertilizer and chemicals, harvest, and post harvest tilling are based on conventional agricultural and forestry practices. While specialized machinery for both HECs and SRWCs might improve efficiency and reduce cost they are generally not currently available, save for isolated prototypes, and were therefore not considered. In order to develop consistent estimates of field operations costs and related embodied energy, parallel equipment profiles were developed. Equipment purchase, O & M, and operating costs for equipment used for all crops are described in Table 2.5.7 below.

Table 2.5.7 Field Operations Equipment Purchase and Operating Costs

Equipment	Purchase & Maint. Cost	Life	Salvage	Annual Use	Labor	Motor Fuel Use	Fuel Cost (incl. Eng. oil)	Equip. Cost	Equip., Labor & Fuel Cost
	($ + tax)	(Hrs)	(% of 1st cost)	(Hrs)	($/hr)	(gal/hr)	($/hr)	($/hr)	($/acre)
Tractors						Max PTO HP			
60 HP	$64,697.	12,000	30%	800	labor	60		$6.82	(see
140 HP	$134,186.	12,000	30%	800	labor	140		$14.14	Specific use
220 HP	$245,943.	12,000	30%	800	labor	220		$25.91	below)
Field Equipment									(includes tractor)
16 ft Chisel Plow 220 HP	$23,382.	2000	20%	200	$13.94	9.68	$7.49	$14.25	$6.98
32 ft Disk Harrow 220 HP	$42,414.	2000	20%	120	$13.94	9.68	$7.49	$32.34	$5.14
42 ft Field Cultivator 220HP	$35,684.	2000	20%	120	$13.94	9.68	$7.49	$27.21	$3.66
12 Row Cultivator 140 HP	$22,812.	2000	20%	120	$13.94	6.16	$4.78	$17.39	$5.56
20 ft Grain Drill 220 HP	$67,473.	1500	20%	120	$13.94	9.68	$7.49	$59.81	$12.88
15 ft Grass Drill 140 HP	$23,044.	1500	20%	120	$13.94	6.16	$4.78	$20.43	$7.78
12 Row NT Planter 140 HP	$69,938.	1500	20%	120	$13.94	6.16	$4.78	$61.99	$8.62
Tree Planter 140 HP	$8,027.	3000	20%	120	$41.82	2.64	$2.14	$5.23	$50.07
Fertilizer 140 HP	$6,863.	3000	15%	120	$13.94	6.16	$4.78	$4.75	$3.15
42 ft Sprayer 140 HP	$27,451.	3000	15%	120	$13.94	6.16	$4.78	$19.00	$3.07
Lime 140 HP	$6,863.	3000	15%	120	$13.94	6.16	$4.78	$4.75	$2.77
Harvesting									
HECs									
Swather 60 HP	$66,851.	3000	20%	300	$13.94	2.64	$2.06	$33.96	$9.76
Baler 60 HP	$38,253.	1500	20%	300	$13.94	2.64	$2.06	$32.36	$18.68
Hay Hauler 60 HP	$22,888.	2500	20%	300	$13.94	2.64	$2.06	$13.15	$3.14
SRWCs									
Feller/buncher 165 HP	$161,658.	6000	20%	1040	$13.94	4.34	$3.44	$35.20	$9.33
Skidder 130 HP	$150,661.	6000	20%	1040	$13.94	3.64	$2.88	$32.80	$11.09
Chipper 400 HP	$288,029.	6000	20%	1040	$13.94	9.17	$7.28	$62.71	$14.26
Grain Combines/pickers									
Wheat	$185,298.	3000	30%	350	$13.94	6.36	$5.01	$89.46	$17.03
Corn	$194,132.	3000	30%	350	$13.94	8.15	$6.34	$93.72	$22.39
Soybeans	$185,298.	3000	30%	350	$13.94	7.00	$5.48	$89.46	$17.11
Grain Sorghum	$185,298.	3000	30%	350	$13.94	6.36	$5.01	$89.46	$17.03

Transportation equipment cost for equipment used for loading at the field edge (if not part of other operations listed above) and for transport to the plant gate are summarized in Table 2.5.8 below.

Table 2.5.8 Transportation Equipment Costs

Equipment	Purchase & Maint. Cost	Life	Salvage	Annual Use	Labor	Fuel	Fuel	Equip. Cost	Equip., Labor & Fuel Cost
	($ + tax)	(Hours)	(% of 1st cost)	(Hours)	($/hr)	(gal/hr)	($/hr)	($/hr)	
HECs									($/ton)
Fork lift	$64,697.	6000	0.3	800	$13.94	2.64	$2.06	$15.02	$1.03
									($/ton/mile)
Bale truck	$227,127.	6000	0.2	600	$20.91	7.00	$7.35	$57.69	$0.11
SRWCs									
Chip truck	$238,389.	6000	0.2	600	$20.91	7.00	$7.35	$60.55	$0.09
Grain truck	$238,389.	6000	0.2	600	$27.88	7.00	$7.35	$60.55	$0.09
Manager									($/mile)
Pick-up	$27,728.	4000	0.2	500	$27.88	3.00	$3.36	$9.83	$1.03

Key factors in developing the equipment costs in Tables 2.5.7 and 2.5.8 above, include:

- The purchase and maintenance costs are based on list price less 10 percent, plus sales tax, plus the full lifetime maintenance cost, less salvage value. This is comparable to purchasing a new implement with a lifetime full service warranty with no deductible.

- Labor rates were $8.00/hr for general labor, $12.00 per hour for equipment operators, $16.00/hr for field managers plus benefits equal to 15% of salary, indirect costs totaling 27% of salary, and a labor field efficiency of 85%.

- Diesel fuel use was based on 0.044 x maximum PTO horsepower. While speed and field efficiency for individual implements (see Table 2.5.16 below) provided some opportunity to tune estimated fuel use for the intensity of individual tasks, the lack of a more comprehensive method of estimating fuel use is a limiting factor in the accuracy of the model. This is particularly true where variations in yield affect harvest cost and energy intensity.

- Equipment cost per hour is based on 100% financing of the full capital cost for the life of the equipment at short term interest rates shown in the Money Worksheet. The annual cost was escalated at the rate of inflation in subsequent analysis, representing a case in which the entire operation was large enough to generate a persistent acquisition of new equipment.

The cost per acre shown in Table 2.5.7 for individual field operations are generally slightly higher than custom rates published in 1997 Kansas Agricultural Statistics. The difference is even greater when one considers the above rates do not yet include profit and overhead. Table 2.5.7 values could have easily been adjusted to those in custom rate, but were not for several reasons: 1) labor rates for the biomass plantation field workers are likely higher than many custom field workers, 2) equipment purchase costs are based on all new equipment in a start-up operation and 3) the need for a realistic but conservative estimate of costs.

Land cost is a significant portion of production cost. While in many cases the farmer may own the land, the rent it could have garnered in the open market is a reasonable indication of the return the farmer should expect. The Kansas Agricultural Statistics service tracks the average sale price of crop (irrigated and non-irrigated) and pasture land in Kansas, as well as average rent as a percent of land value. Land sale price and rent information is summarized in Table 2.5.9 below.

Many factors affect the value of a particular parcel of agricultural land, such as Its location, financial condition of area farmers, potential for commercial development, field shape, slope and ease of farming, and soil productivity. Soil productivity is perhaps somewhat less of an issue today than a few decades ago since it can be amended to some degree with fertilizers. The average regional values below do not provide a means of adjusting estimated rent as a function of soil quality or other factors that might affect yield and production cost. Where 1997 county level CRP rents were available for a particular soil (areas of which might qualify for CRP), the larger of the following values was used for estimating rent:

- the CRP land rent value ($/acre)
- average crop land sale price x the average crop land rental rate.

This will overestimate the real rental value of some grasslands and underestimate the real rental value of highly productive tilled land.

Table 2.5.9 Land Rental Rates by Statistical District

	NW	WC	SW	NC	C	SC	NE	EC	SE
Sale $/acre									
Crop (Non-Irr.)	$540	$440	$420	$595	$595	$675	$900	$910	$740
Pasture	$225	$240	$210	$340	$370	$315	$610	$565	$445
Annual Rent $/acre									
Crop (Non-Irr.)	$29.00	$26.00	$24.00	$37.00	$34.00	$33.00	$50.00	$36.00	$35.00
Pasture	$10.00	$8.40	$8.80	$13.00	$12.00	$9.70	$14.70	$15.10	$14.90
Rent as a Percent of Land Value									
Crop (Non-Irr.)	5.4%	5.9%	5.7%	6.2%	5.7%	4.9%	5.6%	4.0%	4.7%
Pasture	4.4%	3.5%	4.2%	3.8%	3.2%	3.1%	2.4%	2.7%	3.3%

Note: Agricultural Statistical Districts and the climate regions used for this project do not align exactly. Land rent values that represented the highest degree of overlap were used.

2.5.3 Grain Prices Worksheet

The Grain Prices worksheet contains data on nominal average grain prices from 1960 thru 1997 for wheat, corn, soybeans, grain sorghum and hay (includes alfalfa). Price values for 1996 dollars are also shown. Maximum, minimum, average, 75th percentile, and 95th percentile grain prices are calculated for each crop for 1960-1997 and 1988-1987. The summary data is present in Table 2.5.10 below.

Table 2.5.10 Kansas Grain Prices 1960-1997

1960-97 (1996 = 1)										
	Year	**Wheat**	**Year**	**Corn**	**Year**	**Soybeans**	**Year**	**Sorghum**	**Year**	**Hay**
Maximum	1973	$13.25	1974	$9.59	1974	$20.19	1974	$8.57	1974	$146.50
Minimum	1990	$3.02	1986	$2.29	1994	$5.64	1986	$1.91	1986	$61.60
Average		$6.24		$4.72		$10.87		$4.09		$98.33
75th Percentile		$7.19		$5.73		$12.88		$4.96		$110.56
95th Percentile		$10.96		$7.50		$18.31		$6.75		$140.91
1988-97 (1996 = 1)										
	Year	**Wheat**	**Year**	**Corn**	**Year**	**Soybeans**	**Year**	**Sorghum**	**Year**	**Hay**
Maximum	1988	$4.75	1988	$3.45	1988	$9.63	1995	$3.19	1988	$102.12
Minimum	1990	$3.02	1992	$2.40	1994	$5.64	1992	$2.01	1991	$73.16
Average		$3.90		$2.83		$6.91		$2.49		$80.89
75th Percentile		$4.72		$2.88		$6.95		$2.56		$83.35
95th Percentile		$4.74		$3.40		$8.51		$3.07		$97.18

Adjusted for inflation, recent grain prices have been low compared to historic levels. Even the higher 95^{th} percentile prices for the 1988-97 period are below the average for the 1960-97 period. The lower price trend reflects higher yields, larger farms, stiff competition, and lower margins.

Future Grain Prices

See Section 2.2.2 for a discussion of future grain prices.

2.5.4 CRP Rates Worksheet

Criteria for federal CRP rates paid to land owners for removing their land from grain production and placing it in a cover crop have changed somewhat during the life of the program (see Section 2.7). The new CRP program based on 1996 legislation places greater emphasis on cost, and acceptance of proposals for CRP participation is based in part on the price the farmer proposes. The rent rates shown in the CRP Rates worksheet are the maximum that were accepted in round 16 for soil types potentially eligible, by county. The CRP Rates worksheet is summarized in Table 2.5.11 below. A complete copy is in the CRP directory on the CD Disk labeled KRD-9573. When evaluating production cost BEPCEE uses the greater of the CRP rate or conventional rental rates based on a percent of average regional non-irrigated farmland price for the scenario in which biomass crops are competing with conventional grain crops. CRP rates only are used in the CRP waiver case.

Table 2.5.11 Summary of CRP Rates Worksheet Values

	Region 1	**Region 2**	**Region 3**	**Region 4**	**Region 5**	**Region 6**	**All Regions**
Maximum	$51	$73	$82	$66	$55	$48	$82
Minimum	$21	$25	$30	$27	$24	$19	$19
Average	**$33.57**	**$43.59**	**$55.77**	**$42.99**	**$34.76**	**$30.46**	**$40.19**

2.5.5 Land Prices Worksheet

Statewide average land prices for non-irrigated crop land and pasture are shown for 1962 thru 1997 in nominal and 1996 dollars. In an attempt to assess the sensitivity of land prices to changing grain prices, the trend between average land price and the ratio between crop land and wheat price, crop land and corn price, and pasture and hay were evaluated for the 1962 – 1997 period. The R^2 values ranged from 0.10 to 0.48 suggesting the relationship is much more complex. The worksheet and data have been retained to permit additional future analysis. Table 2.5.12 provides a summary of the data.

Table 2.5.12 Kansas Land Prices 1962-1997

Year	CPI		Crop Land	Land/Wheat	Land/Corn	Pasture		Pasture/hay
	1996		(non-Irr., $/acre)	($/acre)/($/Bu)	($/acre)/($/Bu)	($/acre)		($/acre)/($/Bu)
1962-97								
Average			$797	144.7	185.1		$469.50	4.80
Maximum		1977	$1,274	204.4	287.5	1977	$752.38	7.20
Minimum		1990	$561	57.5	89.6	1990	$321.74	3.23
Standard Deviation				44.1	54.6			1.11
1988-97								
Average			$595	156.8	212.7		$340.33	4.25
Maximum		1995	$613	199.6	242.7	1996	$361.00	4.57
Minimum		1993	$561	126.5	177.7	1993	$321.74	3.31
Standard Deviation				26.1	22.6			0.41

2.5.6 Money Worksheet

Interest rates, inflation, and real cost changes of key components are important factors in evaluating production cost, as well as tax rates and non-crop specific overhead. This is particularly true for short rotation wood crops where up-front establishment costs and annual land rent payments, as well other direct costs, must be carried with compounding interest for 5-10 years (8 as modeled) until recovered at harvest. Table 2.5.13 shows a portion of the Money worksheet from BEPCEE, indicating the variables that can be adjusted individually for each year of the 25 year analysis period (values shown were used for all 25 years).

Table 2.5.13 Money: Interest, Inflation, Taxes

BIOMASS ENERGY PRODUCTION COST AND EMBODIED ENERGY									**UNIT COSTS**
									Unit Costs of Money, Inflation, Taxes
Money									
	Base Year								
Value	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Inflation/Escalation									
General	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%
Compounded	1.00	1.03	1.05	1.08	1.10	1.13	1.16	1.19	1.22
Grain Prices	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%
Compounded	1.00	1.03	1.05	1.08	1.10	1.13	1.16	1.19	1.22
Fertilizers	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%
Compounded	1.00	1.03	1.05	1.08	1.10	1.13	1.16	1.19	1.22
Pesticides	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%
Compounded	1.00	1.03	1.05	1.08	1.10	1.13	1.16	1.19	1.22
Petroleum	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%
Compounded	1.00	1.03	1.05	1.08	1.10	1.13	1.16	1.19	1.22
Electricity	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%
Compounded	1.00	1.03	1.05	1.08	1.10	1.13	1.16	1.19	1.22
Interest									
Short term	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%
Mortgage	7.00%	7.00%	7.00%	7.00%	7.00%	7.00%	7.00%	7.00%	7.00%

Discount rate	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%
Overhead, Profit, and Taxes									
	Base Year								
Tax	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Ad Valorem	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%
Sales	6.50%	6.50%	6.50%	6.50%	6.50%	6.50%	6.50%	6.50%	6.50%
Income	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%
Capital Gains	21.00%	21.00%	21.00%	21.00%	21.00%	21.00%	21.00%	21.00%	21.00%
Overhead	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%
Profit	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
(profit set by market conditions, not mark-up)									

2.5.7 Embodied Energy Worksheet

A principal reason for considering biomass as an energy source is the potential for replacing fossil fuel use with solar derived energy. Yet producing biomass requires significant fossil fuel energy inputs to manufacture equipment and fertilizer and to perform field operations and fuel processing. Energy inputs associated with the production of switchgrass and black locust as well as the four conventional commodity crops considered in this analysis were divided into direct and embodied energies. Direct energy inputs include energy derived from the consumption of gasoline, diesel fuel, natural gas, lubricating oils, and LP-gas. Embodied energy inputs are defined as the energy required to produce machinery and chemicals (fertilizers and herbicides/ pesticides) needed to perform various crop production operations and maintain crops.

Direct Energy Use

Direct energy inputs of all operations associated with field preparation, planting, maintenance, and harvesting of switchgrass and the four conventional commodity crops include diesel fuel and lubricating oil consumption. For each field operation, the diesel fuel consumption per hour was calculated as the product of the rated horsepower of the required tractor engine, the rate of diesel fuel consumed per hour per maximum PTO horsepower for a diesel engine (0.044 gallons/hp-hr), and the heating value of diesel fuel (Bowers, 1992). Energy allocated to lubricating oil use was calculated in a similar manner using a consumption equation (gallons of lubricating oil consumed per hp-hour) developed by the American Society for Agricultural Engineers (ASAE, 1993). The heating values for diesel fuel and lubricating oil are 140,000 Btu per gallon and 186,732 Btu per gallon respectively (Fluck, 1992).

The amount of energy expended on a per acre basis (MMBtu/acre) for a particular field operation (chiseling, planting, herbicide application, etc.) was calculated as the energy expended on an hourly basis by the tractor required for that field operation (60, 140, or 220 hp), divided by the field capacity associated with that field operation. Field capacity was based on implement width, tractor speed appropriate for each implement, and field efficiency.

This analysis also applies to machinery used for black locust field preparation and production. Diesel fuel and lubricating oil consumption for black locust harvesting operations (felling, bunching, and skidding) were obtained from the USDA Forest Service (Klepac, 1998) and are presented in Table 2.5.14.

Table 2.5.14 Embodied Energy of SRWC Harvesting Equipment Operation

	Gallons of diesel fuel per HP-hr	HP rating	**Fuel consumption** (gallons/hour)	**Oil consumption** (gallons/hour)
Feller buncher	**0.02633**	165	4.34	0.04038
Skidder	0.028	130	3.64	0.03303
Chipper	0.02292	400	9.17	0.08973

Direct energy inputs associated with all field operations for corn, wheat, grain sorghum, and soybean production were calculated in the same manner. Direct energy expenditures of transportation vehicles such as bale and grain trucks were developed in a similar manner for use in the field to plant gate transportation analysis.

Embodied Energy Inputs

The quantity of energy embodied in tractors, field equipment (implements for field preparation and maintenance), switchgrass and black locust harvesting equipment, conventional grain crop harvesting, and transportation vehicles as well as energy embodied in fertilizers and herbicides/pesticides was estimated.

Embodied Energy in Agricultural and Transportation Equipment

The amount of energy embodied in agricultural and transportation equipment was calculated as the total amount of energy used to manufacture, repair, and transport one ton of that equipment multiplied by the total tonnage of that piece of equipment. The amount of energy used to manufacture one ton of agricultural and transportation equipment has been estimated as 74,544,000 Btu (Bowers, 1992). This value is assumed to apply to all agricultural machinery considered in this study. In addition, the amount of energy allocated to repairs and transportation to the dealer over the lifetime of each piece of machinery was added to this value. Repair energies are based on a repair rate multiplier which varies by individual piece of equipment. Energy consumed in the transportation of agricultural machinery to the dealer has been estimated to be 7.56 MBtu/ton (Bowers, 1992).

Energy embodied in each piece of agricultural field equipment was allocated on a per acre basis to permit an energy-profit ratio calculation. Total embodied energy of each piece of equipment was divided by its useful life to obtain energy in MBtu/hour and then divided by the field capacity (acres per hour) associated with each field operation. These values are presented in Table 2.5.16.

Direct (diesel fuel and lubrication use) and embodied energy of the vehicles used to transport baled switchgrass and black locust chips was determined on a Btu/ton-mile basis. Direct and embodied energies of the tractor (fork lift) used to load baled switchgrass was determined on a Btu/dry ton basis. Direct and embodied energy values for all three transportation vehicles are presented in table 2.5.15. Direct energy values of the bale and chip truck were determined as the heating value of diesel divided by the product of the expected miles per gallon and the total transported load in dry tons. Direct energy associated with the tractor loading operation is the quotient of the hourly fuel and oil consumption usage and an average hourly loading rate (1 bale every 6 minutes).

Energy embodied in each transport vehicle was estimated as the total energy required to manufacture, repair, and deliver each vehicle divided by its useful life. Btu/dry ton-mile values for both the bale and chip truck were obtained by dividing this hourly embodied energy allocation by the average expected transport speed (miles per hour) and the total transported load (dry tons). The embodied energy allocation for the tractor was determined in the same manner except the divisor is its average hourly loading rate. Total direct and embodied energy values are 1,726 and 2,716 Btu per dry ton-mile for the switchgrass bale truck and the black locust chip truck repectively. The total energy allocation for the tractor is 41,752 Btu per dry ton loaded.

Table 2.5.15 below contains data on embodied energy of equipment used in all phases of biomass energy production and conventional commodity crop production through delivery to the field edge. Embodied energy of conventional grain crops was not investigated in conjunction with this project, although BEPCEE is configured to do so with the exception of irrigation. Methods for analyzing irrigation were not developed. Irrigation would significantly increase the embodied energy of biomass production and irrigated land was therefore excluded from the analysis. The energy of human labor, although quite small, was also estimated.

Table 2.5.15 Embodied Energy of Equipment

Farm Equipment		**Weight**	**Energy Input**	**Repairs**	**Delivery** (transport to dealer)	**Total Embodied Energy**		
Tractors	HP	(pounds)	(Btu)	(Btu)	(Btu)	(MBtu)		
60 HP	60	9,000	335,450,422	164,370,707	34,020,557	534		
140 HP	140	18,200	678,355,298	332,394,096	68,797,126	1,080		
220 HP	220	28,600	1,065,986,898	522,333,580	108,109,769	1,696		
Field Equipment	HP					Tractor (MBtu)	Implement (MBtu)	Total (MBtu)
16 ft Chisel Plow [220 HP]	220	8,000	298,178,153	289,232,809	30,240,495	1,696	618	2,314
32 ft Disk Harrow [220 HP]	220	18,000	670,900,845	368,995,465	68,041,114	1,696	1,108	2,804
42 ft Field Cultivator [220 HP]	220	18,000	670,900,845	409,249,515	68,041,114	1,696	1,148	2,845
12 Row Cultivator [140 HP]	140	7,000	260,905,884	159,152,589	26,460,433	1,080	447	1,526
20 ft Grain Drill [220 HP]	140	3,000	111,816,807	61,499,244	11,340,186	1,080	185	1,264
15 ft Grass Drill [140 HP]	140	2,500	93,180,673	51,249,370	9,450,155	1,080	154	1,233
12 Row NT Planter [140 HP]	140	6,000	223,633,615	96,162,454	22,680,371	1,080	342	1,422
Tree Planter [60 HP]	60	1,200	44,726,723	24,599,698	4,536,074	534	74	608
Fertilizer [140 HP]	140	2,000	74,544,538	40,999,496	7,560,124	1,080	123	1,203
42 ft Sprayer [140 HP]	140	1,500	55,908,404	20,686,109	5,670,093	1,080	82	1,162
Lime [140 HP]	140	2,000	74,544,538	40,999,496	7,560,124	1,080	123	1,203
Harvesting								
HECs								
Swather [60 HP]	60	5,850	218,042,774	126,464,809	22,113,362	534	367	900

Baler 60 HP	60	4,350	162,134,371	94,037,935	16,443,269	534	273	806
Hay Hauler 60 HP	60	7,000	260,905,884	151,325,413	26,460,433	534	439	973
SRWCs								
Feller/buncher	na	25,000	931,806,729	540,447,903	94,501,547	na	1,567	1,567
Skidder	na	32,000	1,192,712,613	691,773,315	120,961,980	na	2,005	2,005
Chipper	na	83,000	3,093,598,339	1,794,287,037	313,745,135	na	5,202	5,202
Grain Combines/pickers								
Wheat	250	25,000	931,806,729	540,447,903	94,501,547	na	1,567	1,567
Corn	250	25,000	931,806,729	540,447,903	94,501,547	na	1,567	1,567
Soybeans	250	25,000	931,806,729	540,447,903	94,501,547	na	1,567	1,567
Grain Sorghum	250	25,000	931,806,729	540,447,903	94,501,547	na	1,567	1,567
Transportation from Edge of Field to Plant Gate								
Equipment								
HECs								
Fork lift		9,000	335,450,422	164,370,707	34,020,557	na	534	534
Bale truck (flat bed)		7,500	1,024,987,401	512,493,701	103,951,701	na	1,641	1,641
SRWCs								
Chip truck		32,000	1,192,712,613	596,356,306	120,961,980	na	1,910	1,910
Grain truck		32,000	1,192,712,613	596,356,306	120,961,980	na	1,910	1,910
Manager								
Pick-up		4,000	149,089,077	74,544,538	15,120,247	na	239	239

Embodied Energy in Fertilizers and Chemicals

Energy required to produce nitrogen, potassium, and phosphate fertilizers, lime, and herbicides/pesticides were obtained from Helsel (1992). Energy embodied in fertilizers included energy for fertilizer manufacture, packaging, and transport and were 32,973, 5,510 and 6,887 Btu per pound for nitrogen, potassium, and phosphate fertilizers, respectively. Energy sequestered in herbicides/pesticides included energy content of raw materials, diesel fuel, electricity, and/or natural gas used to manufacture and formulate the herbicide/pesticide, as well as energy associated with packaging, transport, and distribution. These totaled 122,931 Btu per pound for both Ally/Escort (switchgrass) and Oust (black locust).

A wide array of herbicides accompanies grain production, varying not only by region, but field to field. Data on herbicide application rates were acquired from Kansas State University Cooperative Extension Service (1991 and 1992). Based on the frequency of use, levels of application, and embodied energy, a weighted embodied energy value was calculated for each crop for each of three agricultural regions. The value for the regions that had the greatest overlap with the climate region was then assigned to that climate region. Table 2.5.20 details energy content of herbicides and pesticides by climate region. Additional information on herbicides and pesticides can be found in Appendix A5.

Energy-Profit Ratio Analysis

Energy-profit ratios (EPR's) associated with the production of switchgrass and black locust at the edge-of-field were estimated. Energy-profit ratios are defined as the amount of energy derived from switchgrass or black locust at the edge-of-field, divided by the total amount of direct and embodied energy used to produce these crops. Direct energy inputs include energy derived from the consumption of gasoline, diesel natural gas, lubricating oils, and LP-gas. Embodied energy inputs are defined as the energy required to produce machinery and chemicals (fertilizers and herbicides/ pesticides) needed to perform various crop production operations. The energy required to produce the conventional commodity crops of corn, wheat, grain sorghum, and soybeans was also evaluated (see Switchgrass Worksheet later in this section). The energy of human labor, although quite small, was also estimated.

2.5.8 Unit Energy Worksheet

The Unit Energy Worksheet combines the equipment embodied energy from the Embodied Energy Worksheet with equipment fuel consumption, and human labor and equipment field efficiency, to estimate the embodied energy per acre for each field operation for each crop. Fixed field efficiencies are assumed for each operation (energy consumption proportional to yield might improve accuracy). Information on equipment embodied energy and the energy intensity of field operations is present in Table 2.5.16 below. Similar information on energy intensity of transportation from edge of field to plant gate is presented in Table 2.5.17. Table 2.5.18 summarizes energy intensity of labor for field operations and Table 2.5.19 details energy content of fuels. The energy content of fuels was not adjusted to reflect the energy required for their production, processing, and delivery.

Table 2.5.16 Embodied Energy and Energy Intensity of Field Operations

Equipment	**Manufacture Transport & Repair**	**Life**	**Speed**	**Width**	**Efficiency**	**Field Capacity**	**Energy Labor**	**Energy Equipment**	**Energy Fuel**
	(million Btu)	(hours)	(mph)	(feet)		(acres/hr)	(MBtu/ acre)	(MBtu/acre)	(MBtu/ acre)
Tractors								(MBtu/hour)	(MBtu/ hour)
60 HP	534	12,000						0.0445	0.37302
140 HP	1,080	12,000						0.0900	0.86896
220 HP	1,696	12,000						0.1414	1.36490
Field Equipment	(MBtu, implement)							(MBtu/ac) (implement + tractor)	(MBtu/ acre) (impl. + tractor)
16 ft Chisel Plow $^{\text{220 HP}}$	618	2,000	5	16.0	91%	8.82	0.00010	0.0510	0.15
32 ft Disk Harrow $^{\text{220 HP}}$	1,108	2,000	5	32	80%	15.52	0.00006	0.0448	0.09
42 ft Field Cultivator $^{\text{220 HP}}$	1,148	2,000	5	42	80%	20.36	0.00005	0.0351	0.07
12 Row Cultivator $^{\text{140 HP}}$	447	2,000	3	42	73%	11.15	0.00008	0.0281	0.08
20 ft Grain Drill $^{\text{220 HP}}$	185	1,500	5	15	92%	8.32	0.00011	0.0318	0.16
15 ft Grass Drill $^{\text{140 HP}}$	154	1,500	5	15	92%	8.36	0.00011	0.0230	0.10
12 Row NT Planter $^{\text{140 HP}}$	342	1,500	3	42	81%	12.37	0.00007	0.0257	0.07
Tree Planter $^{\text{140 HP}}$	74	3,000	1.65	10	75%	1.50	0.00061	0.0764	0.58
Fertilizer $^{\text{140 HP}}$	123	3,000	5	42	62%	15.65	0.00006	0.0084	0.06
42 ft Sprayer $^{\text{140 HP}}$	82	3,000	5	42	82%	20.75	0.00004	0.0057	0.04
Lime $^{\text{140 HP}}$	123	3,000	5	42	70%	17.82	0.00005	0.0074	0.05
Harvesting									
HECs									
Swather $^{\text{60 HP}}$	367	2,000	4	15	80%	5.82	0.00016	0.0392	0.06
Baler $^{\text{60 HP}}$	273	1,500	2.5	15	65%	2.95	0.00031	0.0766	0.13

Hay Hauler 60 HP	439	3,000	7	15	90%	11.45	0.00008	0.0166	0.03
SRWCs									
Feller/buncher	1,017	10,000	na	na	na	0.38	0.00242	0.2677	1.62
Skidder	1,661	10,000	na	na	na	0.84	0.00110	0.1977	0.61
Chipper	1,880	10,000	na	na	na	0.69	0.00133	0.2725	1.88
Grain Combines/pickers									
Wheat	1,567	2,000	3	25	70%	6.36	0.00014	0.1231	0.142
Corn	1,567	2,000	3	20	70%	5.09	0.00018	0.1539	0.141
Soybeans	1,567	2,000	3	25	70%	6.36	0.00014	0.1231	0.141
Grain Sorghum	1,567	2,000	3	25	70%	6.36	0.00014	0.1231	0.142

Table 2.5.17 Energy Intensity of Transportation from Edge of Field to Plant Gate

Equipment	Mfr, Repair, & Delivery	Life	Speed	Load-ing	Miles per Gallon	Hauling Capacity	Energy Labor	Energy Equipment	Energy Fuel
	(million Btu)	(Hours)	(ave mph)	(tons/hr)		(dry tons)		(Btu/ton/mi)	(Btu/ton/mi)
HECs							(MMBtu/ acre)	(MMBtu/dry fork ton lift)	
Fork lift	534	12000	na	10	na	1.0	0.00092	0.0044	0.0373
Bale truck	1,641	10000	40	na	3.75	24	0.00004	0.0002	0.0016
SRWCs									
Chip truck	1,910	10000	40	na	3.75	15.5	0.00006	0.0003	0.0024
Grain truck	1,910	10000	40		3.75	20	0.00005	0.0002	0.0019
Manager									
Pick-up	239	4000	40	na	na	na		na	na

Table 2.5.18 Energy Intensity of Labor for Field Operations

Labor	Base Metabolism	Maximum Work Metabolism	Work Intensity	Energy Overhead	Total
	(Btu/hr)	(Btu/hr)			(Btu/hr)
General labor	200	1200	65%	15%	1127
Equipment operator	200	1200	50%	15%	920
Operations Manager	200	1200	35%	15%	713

Table 2.5.19 Energy Content of Fuels

Liquid Fuels	Unit	Btu/ Unit		Electricity	Unit	Btu/ Unit
Diesel (off road)	gal.	140,000		Energy	kWh	3,413
Diesel (on road)	gal.	140,000		Demand	kW/month	na
Engine Oil	gal.	186,732		Average	kWh	3,413
Gasoline	gal.	125,000				
Propane	gal.	91,000				

Table 2.5.20 Energy Content of Herbicides and Pesticides by Climate Region

	Btu/Acre By Climate Region					
Chemical/Crop	**1**	**2**	**3**	**4**	**5**	**6**
Herbicides						
Switchgrass	811	811	811	811	811	811
Black locust	4,057	4,057	4,057	4,057	4,057	4,057

Winter wheat	1,340	1,340	352	352	1,340	1,340
Corn	381,667	381,667	331,278	331,278	381,667	381,667
Soybeans	122,847	122,847	51,895	51,895	122,847	122,847
Grain Sorghum	136,128	136,128	262,112	262,112	136,128	136,128
Pesticides						
Switchgrass	0	0	0	0	0	0
Black locust	0	0	0	0	0	0
Winter wheat	1,462	1,462	0	0	1,462	1,462
Corn	48,730	48,730	0		48,730	48,730
Soybeans	0	0	0	0	0	0
Grain Sorghum	16,078	16,078	28,437	28,437	16,078	16,078

2.5.9 BRC Name Codes Worksheet

Soils are are described and named in many ways. The method used in this project is based on USDA county level soil surveys. Individual soils are grouped into soil series of several similar soils. The eastern 74 counties in Kansas evaluated for this project contain individual soils that are grouped into about 315 soil series. While a major goal of the analysis approach developed for this project has been a high degree of rigor, analysis at the individual soil level would have created an unmanageable volume of data and the change between individual soils within a series were expected to be quite small. The soil series was therefore selected as the appropriate analysis level.

The SSURGO soils database (see Section 2.6.1 below) used for spatial analysis contains records at the individual soil level. Within the database soils are referenced by MUID, a five character code consisting of thee numbers and two characters, such as 001BA. Soils 001BA, 001BB, and 001BC are all part of the Bates series. The two letter code BA is often used to identify a particular soil. In a few cases a two letter code may be the same for two totally different soils, creating the risk of accidentally attributing data for a particular soil to another with a similar name. To avoid name confusion and assign crop growth data for a soil series to all soils within that series, the Blacklands Research Center developed a unique two letter code for each soil series. The full set of soil codes can be found in the BRC Name Code worksheet. A sample is shown in Table 2.5.21.

Table 2.5.21 BRC Name Codes

MUID	SERIES NAME	TX_CODE
001BA	BATES	Ak
001BB	BATES	Ak
001BC	BATES	Ak
001CA	CATOOSA	Bn
001CB	CATOOSA	Bn
001CC	COLLINSVILLE	By
001CC	BATES	Ak
001DA	DENNIS	Ck
001DB	DENNIS	Ck
001DC	DENNIS	Ck
001DC	KENOMA	Eu
001EA	ERAM	Da
001EB	ERAM	Da
001EC	ERAM	Da

2.5.10 Switchgrass Worksheet

Three base management practice levels for nitrogen application were evaluated for switchgrass, coded levels 10, 20, and 30, with each level further modified annually by soil conditions and plant stress. Table 2.5.22 below summarizes the yield, nitrogen application levels, energy profit ratios, and some of the environmental impacts for varying nitrogen applications scenarios for Collinsville and Kenoma soils in Neosho County, Region 4, for all three management practices. Collinsville had a 24 year average switchgrass yield of 2.15 tons/acre (4.83 Mg/ha) under management practice 10 and was considered a poor prospect. Kenoma, on the other hand, had an average 24 year yield of 6.80 tons/acre (Mg/ha), the highest yield in Neosho County for a soil with an erosion index greater than 8.0. In all three cases for both soils, starting from a higher base level of nitrogen increased yield. The EPR was highest for the middle level. Nitrogen movement from all pathways changed, sometimes increasing or decreasing in unanticipated ways. Optimizing yield and energy profit ratio while minimizing the environmental impact of nitrogen application in actual large scale production would likely require careful planning and frequent measurement of soil conditions. The middle level (20) was used in this project.

The additional output files for levels 10 and 30 are included with the others in the ALMANAC directory of the CD disk.

Table 2.5.22 Impact of Varying Nitrogen Levels on Switchgrass Performance

Region 4, Neosho County						
Soil Series	**Kenoma (high yield)**			**Collinsville (low yield)**		
Management Practice	**10**	**20**	**30**	**10**	**20**	**30**
Yield (Mg/ha)						
Maximum	22.97	25.36	28.01	11.94	12.33	13.51
EPR at max yield	22.17	24.25	20.30	44.58	36.70	30.24
Minimum	6.98	7.74	9.53	0.11	0.16	0.28
EPR at min yield	14.23	14.41	14.53	0.64	0.86	1.11
24 Yr. Average	16.05	17.84	20.23	5.07	6.14	7.80
EPR at average yield	20.10	21.94	21.22	21.73	23.52	22.18
Nitrogen (Kg/ha)						
Maximum yield						
Applied N	293.72	296.52	391.27	75.94	95.26	126.67
organic N loss w/ sediment	0.15	0.16	0.16	0.24	0.23	0.25
NO3 loss in subsurface flow	4.79	3.00	3.53	2.25	1.95	2.19
mineral N loss in subsurface flow	3.07	3.30	4.00	14.52	15.53	17.2
mineral N loss with percolate	0.00	0.00	0.00	12.72	12.79	12.91
Minimum yield						
Applied N	121.80	152.25	185.99	42.46	52.69	71.34
organic N loss w/ sediment	0.02	0.01	0.01	0.06	0.06	0.04
NO3 loss in subsurface flow	0.24	0.20	0.21	0.39	0.37	0.23
mineral N loss in subsurface flow	0.33	0.37	0.33	0.91	0.70	1.03
mineral N loss with percolate	0.00	0.00	0.00	0.04	0.04	0.04
Average yield						
Applied N	198.34	230.50	270.25	57.93	74.00	99.74
organic N loss w/ sediment	0.09	0.08	0.09	0.14	0.14	0.14
NO3 loss in subsurface flow	1.45	1.40	1.53	1.19	1.11	1.15
mineral N loss in subsurface flow	0.97	1.17	1.32	3.62	3.22	4.21
mineral N loss with percolate	0.00	0.00	0.00	1.24	0.89	1.12
Percent Change						
Maximum yield	base	10.40%	21.94%	base	3.27%	13.15%
Applied N	base	0.95%	33.21%	base	25.44%	66.80%
organic N loss w/ sediment	base	6.67%	6.67%	base	-4.17%	4.17%
NO3 loss in subsurface flow	base	-37.37%	-26.30%	base	-13.33%	-2.67%
mineral N loss in subsurface flow	base	7.49%	30.29%	base	6.96%	18.46%
mineral N loss with percolate	base	na	na	base	na	na

Minimum yield	base			base		
Applied N	base	25.00%	52.70%	base	24.09%	68.02%
organic N loss w/ sediment	base	-50.00%	-50.00%	base	0.00%	-33.33%
NO3 loss in subsurface flow	base	-16.67%	-12.50%	base	-5.13%	-41.03%
mineral N loss in subsurface flow	base	12.12%	0.00%	base	-23.08%	13.19%
mineral N loss with percolate	base	na	na	base	na	na
Average yield	base			base		
Applied N	base	16.21%	36.26%	base	27.75%	72.18%
organic N loss w/ sediment	base	-1.96%	0.49%	base	-2.59%	-6.05%
NO3 loss in subsurface flow	base	-3.02%	5.44%	base	-7.12%	-3.98%
mineral N loss in subsurface flow	base	21.19%	36.91%	base	-11.04%	16.34%
mineral N loss with percolate	base	na	na	base	na	na

Table 2.5.23 Crop Climate and Soil Information
Crop Production Cost and Embodied Energy Analysis

Switchgrass

Material inputs and equipment operation

BLUE means enter value

Climate Zone:	**6**	**BRC Name Code**	**FE**	**MUID**	**025KR**
Two Letter Soil Code	**KR**	**Soil Series Name**	**503**		**KRIER**

Green cells include real time value of money but not inflation

Crop Code (1=switchgrass, 2= black locust, 3= wheat, 4= corn, 5= soybeans, 6= grain sorghum) **1**

Table 2.5.24 Switchgrass Annual Fertilizer, Herbicide, Pesticide Applications

Schedule of Operations and Rates of Application									
	Establishment								
	Prepare	Year							
	1998	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Fertilizer (lbs/acre)									
Fertilizer (lbs/acre)	(copy these values from the BRC data file for each region and soil series)								
Nitrogen (1st application)	0.00	144.60	116.14	81.40	114.95	115.84	116.33	114.72	115.33
Potassium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phosphate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Herbicides (see unit cost and unit energy for regional Cost and Btu per acre)									
(# = number of times, blank or 0=none)									
Number of Applications	0	1	1	0	0	0	0	0	0
Pesticides (see unit cost and unit energy for regional Cost and Btu per acre)									
(# = number of times, blank or 0=none)									
Number of Applications	0	0	0	0	0	0	0	0	0

Switchgrass

Date	
Year 1	
Fall	Commodity crop harvest from corn, grain sorghum, soybeans
7-10 days after harvest	Chisel
1-2 weeks after chisel	Tandem disk
3/25 - 4/10	Field cultivate
4/1 - 4/15	Plant with grass drill

4/1 - 4/15	Pre-emerge herbicide (Ally or Escort *metsulfuron-methyl*)
Years 2-25	
10/31	Begin harvest - swath
Nov-Dec	Bale in large-round bale (800-1000 pounds)
Nov – Dec	Haul to field edge
Nov - Feb	Transport to covered storage at plant

Table 2.5.25 Switchgrass Annual Field Operations Schedule

Switchgrass Field Operations									
Field Operations Schedule (# = number of times, blank or 0=none)									
Field preparation (tilling)	1	0	0	0	0	0	0	0	0
16 ft Chisel Plow 220 HP	1	0	0	0	0	0	0	0	0
32 ft Disk Harrow 220 HP	0	1	0	0	0	0	0	0	0
42 ft Field Cultivator 220 HP									
Planting	0	0	0	0	0	0	0	0	0
20 ft Grain Drill 220 HP	0	1	0	0	0	0	0	0	0
15 ft Grass Drill 140 HP	0	0	0	0	0	0	0	0	0
12 Row NT Planter 140 HP	0	0	0	0	0	0	0	0	0
Tree Planter 140 HP									
Cultivation and Chemicals	0	0	0	0	0	0	0	0	0
12 Row Cultivator 140 HP	0	0	1	1	1	1	1	1	1
Fertilizer 140 HP (1st Application)	0	1	1	1	1	1	1	1	1
Fertilizer 140 HP (2nd Application)	0	1	0	0	0	0	0	0	0
42 ft Sprayer 140 HP	0	0	0	0	0	0	0	0	0
Lime 140 HP									

Table 2.5.25 continued

Harvest									
Switchgrass									
Swathing (cuttings/yr)	0	0	1	1	1	1	1	1	1
Baling	0	0	1	1	1	1	1	1	1
Move to field edge	0	0	1	1	1	1	1	1	1
Load on bale truck	0	0	1	1	1	1	1	1	1
Black Locust									
Feller buncher	0	0	0	0	0	0	0	0	0
Skidder	0	0	0	0	0	0	0	0	0
Chipper	0	0	0	0	0	0	0	0	0
Combine Grain									
Wheat	0	0	0	0	0	0	0	0	0
Corn	0	0	0	0	0	0	0	0	0
Soybeans	0	0	0	0	0	0	0	0	0
Grain Sorghum	0	0	0	0	0	0	0	0	0

Table 2.5.26 Switchgrass Material Costs: Eight Years, One Soil, One Climate Region

		Establishment							
	Prepare	Year							
Costs ($/acre)	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Yield									
Gross yield (dt or bu/acre)		4.8	7.4	1.9	5.2	5.0	6.2	3.8	4.3
Harvest loss rate		0%	5%	5%	5%	5%	5%	5%	5%
Net yield (dt or bu/acre)		4.7736	6.98	1.76	4.93	4.77	5.88	3.60	4.05
Material Costs ($/acre)									
Seed & Fertilizer	**Plant year?>>**	Y	N	N	N	N	N	N	N
Seed ($/acre)		$41.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
($1998 base)		$40.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fertilizer ($/acre)									
Nitrogen (all applications)	$ -	$45.80	$37.70	$27.09	$ 39.21	$40.50	$ 41.69	$ 42.14	$43.42
Potassium	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Phosphate	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Lime	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
SubTotal Fertilizer	$ -	$45.80	$37.70	$27.09	$ 39.21	$40.50	$ 41.69	$ 42.14	$43.42
($1998 base)	$ -	$44.68	$35.89	$ 25.15	$35.52	$35.79	$35.95	$35.45	$35.64
Herbicides and Pesticides ($/ acre)									
Herbicide(s) and Pesticide(s)	$0.00	$2.36	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
($1998 base)	$0.00	$2.30	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Twine ($/acre)		$4.89	$7.34	$1.90	$5.44	$5.40	$6.82	$4.27	$4.94
Polywrap ($/acre)		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
($1998 base)		$4.77	$6.98	$1.76	$4.93	$4.77	$5.88	$3.60	$4.05
SubTotal, Materials ($/acre)	**$0.00**	**$94.05**	**$45.04**	**$28.98**	**$44.65**	**$45.90**	**$48.50**	**$46.41**	**$48.36**
($1998 base)	**$0.00**	**$91.76**	**$42.87**	**$26.91**	**$40.45**	**$40.57**	**$41.83**	**$39.04**	**$39.69**

Table 2.5.27 Switchgrass Annual Cost of Field Operations, ($/acre)

	Prepare	Start Year							
Costs ($/acre)	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Field preparation ($/acre)									
16 ft Chisel Plow 220 HP									
Equipment & maintenance	$1.62	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel and oil	$0.85	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Labor	$1.58	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
32 ft Disk Harrow 220 HP									
Equipment & maintenance	$2.08	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel and oil	$0.48	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Labor	$0.90	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
42 ft Field Cultivator 220 HP									
Equipment & maintenance	$0.00	$1.37	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel and oil	$0.00	$0.38	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Labor	$0.00	$0.70	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Planting									
20 ft Grain Drill 220 HP									
Equipment & maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel and oil	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Labor	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
15 ft Grass Drill 140 HP									
Equipment & maintenance	$0.00	$2.50	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel and oil	$0.00	$0.59	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Labor	$0.00	$1.71	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
12 Row NT Planter 140 HP									
Equipment & maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel and oil	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Labor	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Tree Planter 140 HP									
Equipment & maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel and oil	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Labor	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Cultivation and Chemicals									
12 Row Cultivator 140 HP									
Equipment & maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel and oil	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Labor	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fertilizer 140 HP (1st Application)									
Equipment & maintenance	$0.00	$0.00	$0.32	$0.33	$0.33	$0.34	$0.35	$0.36	$0.37
Fuel and oil	$0.00	$0.00	$0.32	$0.33	$0.34	$0.35	$0.35	$0.36	$0.37
Labor	$0.00	$0.00	$0.94	$0.96	$0.98	$1.01	$1.03	$1.06	$1.09
Fertilizer 140 HP (2nd Application)									
Equipment & maintenance	$0.00	$0.31	$0.32	$0.33	$0.33	$0.34	$0.35	$0.36	$0.37
Fuel and oil	$0.00	$0.31	$0.32	$0.33	$0.34	$0.35	$0.35	$0.36	$0.37
Labor	$0.00	$0.91	$0.94	$0.96	$0.98	$1.01	$1.03	$1.06	$1.09
42 ft Sprayer 140 HP									
Equipment & maintenance	$0.00	$0.94	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel and oil	$0.00	$0.24	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Labor	$0.00	$0.69	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Lime 140 HP									
Equipment & maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel and oil	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Labor	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00

Table 2.5.27 continued

Harvest									
Switchgrass									
Swathing									
Equipment & maintenance	$0.00	$0.00	$6.13	$6.29	$6.44	$6.60	$6.77	$6.94	$7.11
Fuel and oil	$0.00	$0.00	$0.37	$0.38	$0.39	$0.40	$0.41	$0.42	$0.43
Labor	$0.00	$0.00	$2.52	$2.58	$2.64	$2.71	$2.78	$2.85	$2.92
Baling									
Equipment & maintenance	$0.00	$0.00	$11.51	$11.79	$12.09	$12.39	$12.70	$13.02	$13.34
Fuel and oil	$0.00	$0.00	$0.73	$0.75	$0.77	$0.79	$0.81	$0.83	$0.85
Labor	$0.00	$0.00	$4.96	$5.08	$5.21	$5.34	$5.47	$5.61	$5.75
Hay Hauler (move to field edge)									
Equipment & maintenance	$0.00	$0.00	$1.21	$1.24	$1.27	$1.30	$1.33	$1.36	$1.40
Fuel and oil	$0.00	$0.00	$0.19	$0.19	$0.20	$0.20	$0.21	$0.21	$0.22
Labor	$0.00	$0.00	$1.28	$1.31	$1.34	$1.38	$1.41	$1.45	$1.48
Load on Bale Truck									
Equipment & maintenance	$0.00	$0.00	$3.67	$0.95	$2.72	$2.70	$3.41	$2.14	$2.47
Fuel and oil	$0.00	$0.00	$0.50	$0.13	$0.37	$0.37	$0.47	$0.29	$0.34
Labor	$0.00	$0.00	$3.41	$0.88	$2.53	$2.51	$3.17	$1.99	$2.29
Black Locust									
Feller buncher									
Equipment & maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel and oil	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Labor	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Skid to edge of field									
Equipment & maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel and oil	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Labor	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Chipping									
Equipment & maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel and oil	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Labor	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Grain Crops									
Combining									
Equipment & maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel and oil	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Labor	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00

Table 2.5.28 Switchgrass Annual Production Cost Summary

	Prepare	Start Year							
Costs ($/acre)	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
SubTotal, Field Costs ($/acre)									
Equipment & maintenance	$3.70	$5.12	$23.16	$20.92	$23.19	$23.68	$24.92	$24.18	$25.07
Fuel and oil	$1.33	$1.51	$2.44	$2.12	$2.41	$2.46	$2.61	$2.48	$2.59
Labor	$2.48	$4.01	$14.03	$11.77	$13.69	$13.95	$14.90	$14.01	$14.62
SubTotal ($/acre)	$7.51	$10.65	$39.63	$34.80	$39.29	$40.09	$42.42	$40.67	$42.27
Materials & Equipment ($/acre)	$7.51	$104.70	$84.67	$63.78	$83.94	$85.99	$90.93	$87.09	$90.62
(material, equipment, labor, not including land)									
($1998 base) SubTotal, Field Costs ($/acre)									
Equipment & maintenance	$3.70	$5.00	$22.04	$19.42	$21.01	$20.93	$21.49	$20.34	$20.57
Fuel and oil	$1.33	$1.47	$2.32	$1.96	$2.18	$2.17	$2.25	$2.09	$2.12
Labor	$2.48	$3.91	$13.36	$10.93	$12.40	$12.33	$12.85	$11.78	$12.00
SubTotal ($/acre)	$7.51	$10.39	$37.72	$32.32	$35.60	$35.43	$36.58	$34.22	$34.69
Materials & Equipment ($/acre)	$7.51	$102.14	$80.59	$59.23	$76.04	$76.00	$78.41	$73.26	$74.38
Other Costs									
Interest (on 1/2 of field costs)	$0.32	$4.45	$3.60	$2.71	$3.57	$3.65	$3.86	$3.70	$3.85
Land Value									
Conventional Rent	$35.00	$35.88	$36.77	$37.69	$38.63	$39.60	$40.59	$41.60	$42.64
Estimated Land Value	$715.91	$733.81	$752.15	$770.96	$790.23	$809.99	$830.24	$850.99	$872.27
Tax rate	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%
Ad valorem taxes per acre	$3.58	$3.67	$3.76	$3.85	$3.95	$4.05	$4.15	$4.25	$4.36
Other Operating Expenses									
Insurance rate	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%
General overhead rate	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%
Profit (set by market)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Overhead, Profit, and Insurance	$0.83	$11.52	$9.31	$7.02	$9.23	$9.46	$10.00	$9.58	$9.97
SubTotal, Including Interest	$4.72	$19.64	$16.67	$13.58	$16.75	$17.16	$18.02	$17.54	$18.18
SubTotal, Including Interest	*$4.72*	*$19.16*	*$15.87*	*$12.61*	*$15.18*	*$15.17*	*$15.54*	*$14.75*	*$14.92*
TOTAL COST ($/acre)	$12.23	$137.61	$101.35	$77.37	$100.69	$103.15	$108.94	$104.62	$108.81
TOTAL ($/acre)	$12.23	$124.33	$101.35	$77.37	$100.69	$103.15	$108.94	$104.62	$108.81
TOTAL COST ($/acre)	$12.23	$121.30	$96.46	$71.84	$91.22	$91.17	$93.94	$88.01	$89.30
(material, equipment, labor, not including land)									
Land Cost									
Conventional Rent	na	$33.00	$34.67	$35.54	$36.43	$37.34	$38.27	$39.23	$40.21
CRP "Rent"	na	$9.73	$10.23	$10.48	$10.74	$11.01	$11.29	$11.57	$11.86
TOTAL ($/yield unit)									
Conventional Rent	na	$35.74	$19.47	$64.16	$27.82	$29.44	$25.04	$40.00	$36.77
CRP "Rent"	na	$30.87	$15.97	$49.92	$22.61	$23.92	$20.45	$32.31	$29.77
Land Cost									
Conventional Rent	na	$33.00	$33.00	$33.00	$33.00	$33.00	$33.00	$33.00	$33.00
CRP "Rent"	na	$9.73	$9.73	$9.73	$9.73	$9.73	$9.73	$9.73	$9.73
TOTAL ($/yield unit)									
Conventional Rent ($1998)	*na*	*$32.32*	*$18.54*	*$59.58*	*$25.21*	*$26.02*	*$21.59*	*$33.65*	*$30.18*
CRP "Rent" (1998)	*na*	*$27.45*	*$15.21*	*$46.35*	*$20.48*	*$21.15*	*$17.63*	*$27.18*	*$24.44*

Note: 1998 dollars shown in italics

2.5.11 Energy-Profit Ratio Analysis of Herbaceous and Short-Rotation Woody Crops

Energy-profit ratios (EPR's) associated with the production of switchgrass and black locust at the edge-of-field were estimated. Energy-profit ratios are dimensionless and are defined as the amount of energy derived from switchgrass or black locust (MMBtu) at the field edge divided by the total amount of direct and embodied energy (MMBtu) used to produce these crops. Energy-profit ratios were not developed for the four commodity crops because their end purpose is food and fiber related and not energy.

Table 2.5.29 –2.5.33 shown below documents both direct and embodied energy inputs in terms of MMBtu/acre for all material inputs and field operations, and energy-profit ratios for switchgrass for the first nine years.

Values are calculated for the startup year and 24 additional production years. Maximum, minimum, and average values are calculated for key variables and written to the Summary Data Temp File Worksheet.

Table 2.5.29 Switchgrass Embodied Energy of Materials (MBtu/acre)

	Establishment								
	Prepare	Year							
Material Inputs	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Seed	0	0.006	0	0	0	0	0	0	0
Fertilizer									
Nitrogen	0.000	4.768	3.830	2.684	3.790	3.820	3.836	3.783	3.803
Potassium	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Phosphate	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lime	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Herbicides									
Herbicides	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Pesticides									
Pesticides	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Twine	0.000	0.005	0.007	0.002	0.005	0.005	0.006	0.004	0.004
Polywrap	0.000	0.005	0.007	0.002	0.005	0.005	0.006	0.004	0.004
SubTotal, Embodied Energy of Material Inputs									
Materials	**0.001**	**4.784**	**3.844**	**2.688**	**3.801**	**3.830**	**3.848**	**3.791**	**3.812**

Table 2.5.30 Switchgrass Field Operations Embodied Energy (MBtu/acre)

	Prepare	Start Year							
Field Operations	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
16 ft Chisel Plow 220 HP									
Equipment & maintenance	0.051	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel and oil	0.155	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
32 ft Disk Harrow 220 HP									
Equipment & maintenance	0.045	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel and oil	0.088	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
42 ft Field Cultivator 220 HP									
Equipment & maintenance	0.000	0.035	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel and oil	0.000	0.067	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Planting									
20 ft Grain Drill 220 HP									
Equipment & maintenance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel and oil	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15 ft Grass Drill 140 HP									
Equipment & maintenance	0.000	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel and oil	0.000	0.104	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12 Row NT Planter 140 HP									
Equipment & maintenance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel and oil	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tree Planter 140 HP									
Equipment & maintenance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel and oil	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 2.5.31 Switchgrass Cultivation and Chemicals Embodied Energy (MBtu/acre)

	Prepare	Start Year							
Field Operations	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Equipment & maint.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel and oil	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fertilizer 140 HP (1st Application)									
Equipment & maint.	0.000	0.000	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Fuel and oil	0.000	0.000	0.056	0.056	0.056	0.056	0.056	0.056	0.056
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fertilizer 140 HP (2nd Application)									
Equipment & maint.	0.000	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Fuel and oil	0.000	0.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
42 ft Sprayer 140 HP									
Equipment & maint.	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel and oil	0.000	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lime 140 HP									
Equipment & maint.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel and oil	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 2.5.32 Harvest Embodied Energy (MBtu/acre)

	Prepare	Start Year							
	1998	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Switchgrass									
Swathing									
Equipment & maintenance	0.000	0.000	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Fuel and oil	0.000	0.000	0.064	0.064	0.064	0.064	0.064	0.064	0.064
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Baling									
Equipment & maintenance	0.000	0.000	0.077	0.077	0.077	0.077	0.077	0.077	0.077
Fuel and oil	0.000	0.000	0.126	0.126	0.126	0.126	0.126	0.126	0.126
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Move to Field Edge (hay hauler)									
Equipment & maintenance	0.000	0.000	0.017	0.017	0.017	0.017	0.017	0.017	0.017
Fuel and oil	0.000	0.000	0.033	0.033	0.033	0.033	0.033	0.033	0.033
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Load on Bale Truck (Fork Lift)									
Equipment & maintenance	0.000	0.000	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Fuel and oil	0.000	0.000	0.990	0.990	0.990	0.990	0.990	0.990	0.990
Labor	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Black Locust									
Feller buncher									
Equipment & maintenance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel and oil	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Skid to edge of field									
Equipment & maint.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel and oil	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Chipping									
Equipment & maint.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel and oil	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Grain Crops									
Combining									
Equipment & maintenance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel and oil	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SubTotal, Embodied Energy of Field Operations (million Btus per acre)									
Equipment & maintenance	0.096	0.072	0.161	0.161	0.161	0.161	0.161	0.161	0.161
Fuel and oil	0.243	0.268	1.268	1.268	1.268	1.268	1.268	1.268	1.268
Labor	0.000	0.000	0.002	0.002	0.002	0.002	0.002	0.002	0.002
SubTotal	**0.339**	**0.341**	**1.431**	**1.431**	**1.431**	**1.431**	**1.431**	**1.431**	**1.431**

Table 2.5.33 Switchgrass Total Embodied Energy (MBtu), Energy Profit Ratios (EPR)

	Prepare	Start Year							
	1998	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
TOTAL MMBtu									
Fertilizers	0.000	4.768	3.830	2.684	3.790	3.820	3.836	3.783	3.803
Herbicides and pesticides	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Materials	0.000	0.016	0.014	0.004	0.010	0.010	0.012	0.007	0.008
Equipment & maintenance	0.096	0.072	0.161	0.161	0.161	0.161	0.161	0.161	0.161
Fuel and oil	0.243	0.268	1.268	1.268	1.268	1.268	1.268	1.268	1.268
Labor	0.000	0.000	0.002	0.002	0.002	0.002	0.002	0.002	0.002
SubTotal	0.339	5.125	5.275	4.119	5.232	5.261	5.279	5.222	5.243
Cumulative (if 0 harvest)	0.339	5.464	5.275	4.119	5.232	5.261	5.279	5.222	5.243
MMBtu/dry ton (energy crop)	**na**	**1.14**	**0.76**	**2.34**	**1.06**	**1.10**	**0.90**	**1.45**	**1.29**
MMBtu/bu or cwt (grain)	na	na	na	na	na	na	na	na	na
BioFuel Energy Profit Ratio									
(edge of field)	**na**	**13.84**	**20.97**	**6.77**	**14.92**	**14.37**	**17.64**	**10.91**	**12.24**

Values are calculated for the startup year and 24 additional production years. Maximum, minimum, and average values are calculated for key variables and written to the Summary Data Temp File Worksheet.

2.5.12 Black Locust Worksheet

The Black Locust Worksheet is identical to the Switchgrass Worksheet, except that it evaluates black locust data from the Data Import Worksheet. Black locust is harvested on an eight year cycle. Seedlings are used to establish the stand with the second and third cycles started from coppice re-growth. The schedule for black locust field operations for establishment and harvest is described in the box to the right.

Black Locust	(Wayne Geyer, 1998)
Year/Season/Date	
Preparation Year	
Fall	commodity crop harvest
7-10 days after harvest	chisel plow
1-2 weeks after chisel	offset disk
3/25 - 5/1	plant trees
1 week after planting	herbicide – Oust, ½ oz/ac
1st growing season	no operations
2nd growing season	
3/25 - 4/15	row cultivate
1 week later	herbicide – Oust, ½ oz/ac
3rd growing season	
3/25 - 4/15	row cultivate
1 week later	herbicide – Oust, ½ oz/ac
4th growing season	no operations
5th growing season	no operations
6th growing season	no operations
7th growing season	no operations
8th growing season	
Harvest during dormant	felling and bunching
season to maximize	Skidding
Coppice regrowth	Chipping

2.5.13 Wheat Worksheet

The Wheat Worksheet is identical to the Switchgrass Worksheet, except that it evaluates winter wheat data from the Data Import Worksheet, using the using ALMANAC conservation tillage management practices for this particular grain crop in box to the right.

Winter Wheat		
Almanac code	**Field Operation**	**Almanac description**
	tillage/field operation	
	herbicide application	
7	harvest	harv1.95
	truck sgl-axle-diesel 2 ton	
2	tandem disk	tan disk
	anhydrous ammonia application	
	fertilizer adjustment	
	phosphorus application	
6	field cultivate	fld cult
18	plant (drill)	plant dr
	glean DF	

2.5.14 Corn Worksheet

The Corn Worksheet is also identical to the Switchgrass Worksheet, except that it evaluates corn data from the Data Import Worksheet, using the ALMANAC conservation tillage management practices for the particular grain crop listed in the box to the right.

Corn		
Almanac		**Almanac**
code	**Field Operation**	**description**
	tillage/field operation	
2	tandem disk	tan disk
6	field cultivate	fld cult
	anhydrous ammonia application	
	fertilizer adjustment	
4	plant	plant
	phosphorus application	
	herbicide application	
5	row cultivate	row cult
	2,4-D application	
7	harvest	harv1.95
	truck sgl-axle-diesel 2 ton	

2.5.15 Soybeans Worksheet

The Soybeans Worksheet is also identical to the Switchgrass Worksheet, except that it evaluates soybean data from the Data Import Worksheet, using the following ALMANAC conservation tillage management practices for the particular grain crop listed in the box to the right.

Soybeans		
Almanac		**Almanac**
code	**Field Operations**	**description**
	tillage/field operation	
	phosphorus application	
2	tandem disk	tan disk
	truck pickup 3/4 ton	
6	field cultivate	fld cult
	herbicide application	
4	plant	plant
	nitrogen application	
	nitrogen application	
7	harvest	harv1.95
	truck sgl-axle-diesel 2 ton	

2.5.16 Grain Sorghum Worksheet

The Grain Sorghum Worksheet is identical to the Switchgrass Worksheet, except that it evaluates grain sorghum data from the Data Import Worksheet, using the following ALMANAC conservation management practices for this particular grain crop listed in the box at right.

Grain Sorghum		
Almanac code	**Field Operations**	**Almanac description**
	tillage/field operation	
	anhydrous ammonia application	
	fertilizer adjustment	
	phosphorus application	
2	tandem disk	tan disk
6	field cultivate	fld cult
4	plant	plant
	atrazine application	
5	row cultivate	
7	harvest	harv1.95
	truck sgl-axle-diesel 2 ton	

2.5.17 BioEnergy Cost Worksheet

The BioEnergy Cost Worksheet estimates the price of biomass energy that would yield a profit equal to that from the most profitable grain crop for each soil, climate year and region, and yield, by year. This assumes that the farmer always makes the correct decision regarding which crop to plant for that particular year. Biomass costs are generated for the inflation adjusted 10 year average grain price (1987-1996), as well as 75th and 95th percentile prices for that period.

Table 2.5.34 BioEnergy Cost Soil and Climate

Bioenergy Cost to Equal Grain Profit (edge of field)

Grain prices, production cost, profit, bioenergy cost per ton and MMBtu

BioEnergy Cost

(note: climate and soil values set in Switchgrass sheet)

Climate Zone:	**6**	**BRC Soil Code**	**Ih**	**MUID**	**007ZE**
		Soil Series Name:	**ZENDA**		

Green cells include real time value of money but not inflation

Table 2.5.35 Projected Future Grain Prices Based on 1987-97 Average

Price/Cost/Profit	Establishment Year	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
With Inflation Described in 'Money' Sheet									
Grain Prices ($/bu)	**1987-97**								
10 Year Average									
Wheat	$3.90	$3.90	$4.00	$4.10	$4.20	$4.30	$4.41	$4.52	$4.64
Corn	$2.83	$2.83	$2.90	$2.97	$3.05	$3.12	$3.20	$3.28	$3.36

Soybeans	$6.91	$6.91	$7.08	$7.26	$7.44	$7.63	$7.82	$8.01	$8.21
Grain Sorghum	$2.49	$2.49	$2.55	$2.61	$2.68	$2.74	$2.81	$2.88	$2.96
75th Percentile, 10 yr									
Wheat	$4.72	$4.72	$4.84	$4.96	$5.08	$5.21	$5.34	$5.47	$5.61
Corn	$2.88	$2.88	$2.95	$3.02	$3.10	$3.18	$3.26	$3.34	$3.42
Soybeans	$6.95	$6.95	$7.12	$7.30	$7.48	$7.67	$7.86	$8.06	$8.26
Grain Sorghum	$2.56	$2.56	$2.62	$2.69	$2.76	$2.83	$2.90	$2.97	$3.04
95th Percentile, 10 yr									
Wheat	$4.74	$4.74	$4.86	$4.98	$5.11	$5.23	$5.36	$5.50	$5.64
Corn	$3.40	$3.40	$3.48	$3.57	$3.66	$3.75	$3.84	$3.94	$4.04
Soybeans	$8.51	$8.51	$8.72	$8.94	$9.17	$9.39	$9.63	$9.87	$10.12
Grain Sorghum	$3.07	$3.07	$3.15	$3.23	$3.31	$3.39	$3.48	$3.57	$3.66

Table 2.5.36 Future Grain Production, Profit, and Most Profitable Crop

		1999	2000	2001	2002	2003	2004	2005	2006
Production Cost ($/acre) (With Conventional Land Rent)									
Wheat		$ 116.80	$ 185.69	$ 160.93	$ 120.86	$ 144.38	$ 182.26	$ 173.22	$ 133.40
Corn		$ 178.58	$ 211.02	$ 216.13	$ 186.39	$ 218.38	$ 223.84	$ 229.44	$ 205.74
Soybeans		$ 153.05	$ 163.28	$ 157.66	$ 166.38	$ 169.93	$ 176.96	$ 176.68	$ 182.63
Grain Sorghum		$ 111.92	$ 128.96	$ 137.47	$ 115.49	$ 138.87	$ 142.34	$ 145.90	$ 127.48
Yield (average $/acre)									
Wheat (bu)	Wheat	0.00	48.22	44.61	17.88	31.16	57.73	40.18	32.64
Corn (bu)	Corn	45.67	107.68	39.17	44.09	61.13	68.16	49.01	50.41
Soybeans (bu)	Soybeans	23.72	35.12	15.81	21.70	31.81	31.26	23.17	25.56
G. Sorghum (100 lb - cwt)	Grain Sorghum	22.09	52.93	16.59	22.09	35.62	30.23	23.92	22.80
Profit, Grain Crops ($/acre)									
Wheat									
10 Year Average	Wheat	$(116.80)	$ 7.05	$ 21.85	$ (45.78)	$ (10.24)	$ 72.45	$ 8.50	$ 17.89
75th Percentile, 10 yr	Wheat	$(116.80)	$ 47.62	$ 60.32	$ (29.98)	$ 17.99	$ 126.07	$ 46.75	$ 49.73
95th Percentile, 10 yr	Wheat	$(116.80)	$ 48.68	$ 61.32	$ (29.57)	$ 18.73	$ 127.47	$ 47.75	$ 50.57
Corn									
10 Year Average	Corn	$ (49.44)	$ 101.07	$ (99.76)	$ (52.13)	$ (27.59)	$ (5.80)	$ (68.73)	$ (36.29)
75th Percentile, 10 yr	Corn	$ (47.18)	$ 106.53	$ (97.72)	$ (49.79)	$ (24.25)	$ (1.98)	$ (65.92)	$ (33.33)
95th Percentile, 10 yr	Corn	$ (23.38)	$ 164.04	$ (76.28)	$ (25.05)	$ 10.91	$ 38.19	$ (36.30)	$ (2.10)
Soybeans									
10 Year Average	Soybeans	$ 10.80	$ 85.40	$ (42.89)	$ (4.97)	$ 72.63	$ 67.35	$ 8.93	$ 27.25
75th Percentile, 10 yr	Soybeans	$ 11.79	$ 86.89	$ (42.20)	$ (4.01)	$ 74.09	$ 68.82	$ 10.04	$ 28.51
95th Percentile, 10 yr	Soybeans	$ 48.81	$ 143.08	$ (16.26)	$ 32.47	$ 128.90	$ 124.02	$ 51.98	$ 75.93
Grain Sorghum									
10 Year Average	Grain Sorghum	$ (57.01)	$ 5.92	$ (94.13)	$ (56.35)	$ (41.11)	$ (57.31)	$ (76.94)	$ (60.10)
75th Percentile, 10 yr	Grain Sorghum	$ (55.38)	$ 9.91	$ (92.85)	$ (54.60)	$ (38.22)	$ (54.80)	$ (74.90)	$ (58.10)
95th Percentile, 10 yr	Grain Sorghum	$ (44.01)	$ 37.86	$ (83.87)	$ (42.35)	$ (17.96)	$ (37.18)	$ (60.61)	$ (44.14)
Maximum Profit Grain Crop									
10 Year Average		Soybeans	Corn	Wheat	Soybeans	Soybeans	Wheat	Soybeans	Soybeans
75th Percentile, 10 yr		Soybeans	Corn	Wheat	Soybeans	Soybeans	Wheat	Wheat	Wheat
95th Percentile, 10 yr		Soybeans	Corn	Wheat	Soybeans	Soybeans	Wheat	Soybeans	Soybeans
Maximum Grain Profit/Acre (Before Tax)									
10 Year Average		$ 10.80	$ 101.07	$ 21.85	$ (4.97)	$ 72.63	$ 72.45	$ 8.93	$ 27.25
75th Percentile, 10 yr		$ 11.79	$ 106.53	$ 60.32	$ (4.01)	$ 74.09	$ 126.07	$ 46.75	$ 49.73
95th Percentile, 10 yr		$ 48.81	$ 164.04	$ 61.32	$ 32.47	$ 128.90	$ 127.47	$ 51.98	$ 75.93

Maximum Grain Profit/Acre (After Tax)									
10 Year Average		$ 7.56	$ 70.75	$ 15.29	$ (4.97)	$ 50.84	$ 50.72	$ 6.25	$ 19.07
75th Percentile, 10 yr		$ 8.25	$ 74.57	$ 42.22	$ (4.01)	$ 51.86	$ 88.25	$ 32.72	$ 34.81
95th Percentile, 10 yr		$ 34.17	$ 114.83	$ 42.93	$ 22.73	$ 90.23	$ 89.23	$ 36.39	$ 53.15

Table 2.5.37 Switchgrass and Black Locust Cost per Ton to Equal Grain Profit with Conventional Land Rent

Bioenergy Cost to Equal Grain Profit (edge of field)									**BioEnergy Cost**
With Inflation Described in 'Money' Sheet									
	1998	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Conventional Land Rent		$33.00	$33.83	$34.67	$35.54	$36.43	$37.34	$38.27	$39.23
Switchgrass Cost ($/ton)									
Yield	0	4.3	6.5	1.6	4.9	4.9	6.2	4.0	4.8
Production Cost per Acre	$12.23	$144.92	$132.52	$111.65	$133.86	$138.29	$145.63	$159.31	$147.92
Cumulative Production Cost	$12.23	$158.19	$132.52	$111.65	$133.86	$138.29	$145.63	$159.31	$147.92
(carry forward with interest if no yield)									
Production Cost per Ton		$36.88	$20.29	$69.46	$27.59	$28.50	$23.68	$40.15	$30.94
Cumulative Maximum Grain Profit/Acre for Highest Profit Crop									
10 Year Average		$7.56	$70.75	$15.29	-$4.97	$50.84	$50.72	$6.25	$19.07
75th Percentile, 10 yr		$8.25	$74.57	$42.22	-$4.01	$51.86	$88.25	$32.72	$34.81
95th Percentile, 10 yr		$34.17	$114.83	$42.93	$22.73	$90.23	$89.23	$36.39	$53.15
Switchgrass Cost for Equal Profit ($/ton)									
10 Year Average		$38.64	$31.12	$78.97	$26.56	$38.98	$31.92	$41.72	$34.93
75th Percentile, 10 yr		$38.80	$31.71	$95.72	$26.76	$39.19	$38.02	$48.39	$38.23
95th Percentile, 10 yr		$44.84	$37.87	$96.16	$32.27	$47.10	$38.18	$49.32	$42.06
Black Locust Cost ($/ton)									
Yield	0	0	0	0	0	0	0	0	14.24
Production Cost	$12.23	$403.45	$40.25	$41.26	$39.49	$40.48	$41.49	$42.52	$545.69
Cumulative Production Cost	$12.23	$416.72	$492.40	$575.51	$663.92	$760.82	$866.98	$983.20	$1,612.46
(carry forward with interest if no yield)									
Production Cost per Ton		na	na	na	na	na	na	na	$113.21
Cumulative Maximum Grain Profit/Acre for Highest Profit Crop									
10 Year Average		$7.56	$78.96	$100.96	$104.57	$164.30	$228.98	$254.70	$295.42
75th Percentile, 10 yr		$8.25	$83.52	$132.85	$140.13	$203.91	$309.48	$368.52	$434.65
95th Percentile, 10 yr		$34.17	$123.78	$133.55	$166.86	$242.27	$310.47	$372.18	$452.99
Black Locust Cost for Equal Profit ($/ton)									
10 Year Average		na	na	na	na	na	na	na	$133.95
75th Percentile, 10 yr		na	na	na	na	na	na	na	$143.72
95th Percentile, 10 yr		na	na	na	na	na	na	na	$145.01
Constant Dollar Cost *(includes "real" cost of money, not inflation, not discounted)*									
Switchgrass Cost *($/ton edge of field)*									
10 Year Average		*$37.70*	*$29.62*	*$73.33*	*$24.06*	*$34.45*	*$27.53*	*$35.10*	*$28.67*
75th Percentile, 10 yr		*$37.86*	*$30.18*	*$88.89*	*$24.24*	*$34.64*	*$32.79*	*$40.71*	*$31.37*
95th Percentile, 10 yr		*$43.75*	*$36.04*	*$89.29*	*$29.24*	*$41.63*	*$32.93*	*$41.49*	*$34.52*
Black Locust Cost *($/ton edge of field)*									
10 Year Average		*na*	*na*	*na*	*na*	*na*	*na*	*na*	*$109.94*
75th Percentile, 10 yr		*na*	*na*	*na*	*na*	*na*	*na*	*na*	*$117.96*
95th Percentile, 10 yr		*na*	*na*	*na*	*na*	*na*	*na*	*na*	*$119.02*

Table 2.5.38 Switchgrass and Black Locust Production Cost on CRP Land at 40% Rent

Bioenergy Cost on CRP Land (production cost - not in competition w/ grain or hay)									**BioEnergy Cost**
With Inflation Described in 'Money' Sheet									
	1998	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
CRP Rate ($/acre)		$27.25	$27.93	$28.63	$29.35	$30.08	$30.83	$31.60	$32.39
BioEnergy incentive rate (paid land owner)		20%	20%	20%	20%	20%	20%	20%	20%
CRP cost share rate (paid land government)		20%	20%	20%	20%	20%	20%	20%	20%
Target Land "Rent Rate" ($/acre)		$10.90	$11.17	$11.45	$11.74	$12.03	$12.33	$12.64	$12.96
Switchgrass Cost ($/ton)									
Yield	0	4.3	6.5	1.6	4.9	4.9	6.2	4.0	4.8
Production Cost (rent adjusted)	$12.23	$122.82	$109.87	$88.43	$110.06	$113.90	$120.63	$133.68	$121.65
Cumulative Production Cost	$12.23	$136.09	$109.87	$88.43	$110.06	$113.90	$120.63	$133.68	$121.65
Switchgrass Cost ($/MBtu edge of field)		$2.00	$1.06	$3.47	$1.43	$1.48	$1.24	$2.13	$1.61
Black Locust Cost ($/ton)									
Yield	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.2
Production Cost	$12.23	$381.35	$17.60	$18.04	$15.69	$16.08	$16.48	$16.90	$519.42
Cumulative Production Cost	$12.23	$394.62	$445.77	$501.70	$560.03	$623.71	$693.21	$769.03	$1,353.82
Black Locust Cost ($/MBtu edge of field)		na	na	na	na	na	na	na	$5.63
Constant Dollar Cost (cost unadjusted for general inflation, not discouted)									
Switchgrass Cost ($/MBtu edge of field)		$1.95	$1.01	$3.23	$1.30	$1.31	$1.07	$1.79	$1.32
Black Locust Cost ($/MBtu edge of field)		na	na	na	na	na	na	na	$4.62

2.5.18 Environmental Impact Worksheet

The ALMANAC is capable of providing estimates of a very wide range of environmental impact data. To limit the total volume of analysis data reported by ALMANAC for the six climate regions to a manageable 70 MB the number of variables reported were limited. The Environmental Impact Worksheet in BEPCEE was used to collect and organize environmental data from the Data Import Worksheet. Table 2.5.39 below provides a sample for switchgrass for a period of eight years. The full 25 years (startup plus 24 years of harvest) was analyzed for all six crops. Only the maximum, minimum, and cumulative values for each variable and each crop were carried forward for further analysis and reporting.

Table 2.5.39 Annual Environmental Variables Reported

Crop/Variable	**Variable Description**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Switchgrass									
Erosion									
USLE	(water erosion)	0.000	0.004	0.004	0.004	0.004	0.004	0.000	0.004
YW	(wind erosion)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PRCP	(precipitation)	21.557	26.665	17.791	20.336	23.770	32.181	25.611	26.488
Q	(surface runoff)	0.002	1.030	0.857	0.853	0.449	2.560	1.272	0.665
Nutrient Migration									
YON	(organic N loss w/ sediment)	0.000	0.011	0.011	0.000	0.000	0.022	0.000	0.000
YP	(P loss w/ sediment)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

YAP	(soluble P loss in runoff)	0.000	0.000	0.000	0.000	0.000	0.011	0.000	0.000
YNO3	(NO3 loss in surface runoff)	0.000	0.258	0.202	0.202	0.112	0.627	0.325	0.168
SSFN	(mineral N loss in subsurface flow)	5.300	0.762	1.524	0.627	0.560	1.210	1.882	0.986
PRKN	(mineral N loss in percolate)	1.087	0.471	0.168	0.134	0.146	1.199	0.549	0.291

Values for reported environmental variables are:

Erosion
USLE — soil water erosion in tons per acre per year
YW — soil wind erosion in tons per acre per year
PRCP — annual precipitation in inches
Q — surface runoff

Nutrient Migration
YON — organic nitrogen (N) loss with sediment in pounds per acre per year
YP — phosphorous (P) runoff with sediment in pounds per acre per year
YAP — soluble phosphorous (P) loss in runoff in pounds per acre per year
YNO3 — NO_3 loss in subsurface flow in pounds per acre per year
SSFN — mineral nitrogen (N) loss in subsurface flow in pounds per acre per year
PRKN — mineral nitrogen (N) loss with percolated precipitation in pounds per acre per year

2.5.19 Summary Data Temp File Worksheet

After the ALMANAC analysis data for an individual soil for a single climate zone have been pasted to the Data Import worksheet, key results of the BEPCEE analysis are consolidated in the Summary Data Temp File. The data are strung in a long single row array to permiting joining with SSURGO data files based on a common soil name. Values saved include the following:

Climate and Soil	Climate Zone, BRC Name Code, Map Unit ID (MUID), Soil Series Name
Switchgrass and Black locust	
Yield	Maximum (tons/acre), Minimum (tons/acre), Average (tons/acre)
Fertilizer	Average Nitrogen (lbs/acre), Average P (lbs/acre)
Production Cost	
On truck at field edge	Maximum ($/ton), Minimum ($/tons), Average ($/tons), Average ($/MBtu)
Land rent	Conventional ($/ton), CRP ($/ton)
Fertilizer	Average ($/tons)
Chemicals, Seed & Materials	Average ($/tons)
Equipment	Average ($/tons)
Fuel & Oil	Average ($/tons)
Labor	Average ($/tons)
Other Costs	Average ($/tons)
BioEnergy Market Price	

Production Cost +10%	Average ($/MBtu)
Max. Profit Grain Crop	
10 Average	Grain crop name and Average cost ($/MBtu)
75th Percentile	Grain crop name and Average cost ($/MBtu)
95th Percentile	Grain crop name and Average cost ($/MBtu)
Embodied Energy	
Equipment	Average (MBtu/ton)
Fuel	Average (MBtu/ton)
Fertilizer	Average (MBtu/ton)
Chemicals & Materials	Average (MBtu/ton)
Labor	Average (MBtu/ton)
Total	Average (MBtu/ton)
Energy Profit Ratio	
Maximum	Ratio
Minimum	Ratio
Average	Ratio
Environmental Impacts	
USLE (water erosion)	Maximum (tons/acre), Minimum (tons/acre), Cumulative – 25 year (tons/acre)
YW (wind erosion)	Maximum (tons/acre), Minimum (tons/acre), Cumulative – 25 year (tons/acre)
Q (surface runoff)	Cumulative – 25 year (1bs/acre)
YON (organic N loss w/ sediment)	Cumulative – 25 year (1bs/acre)
YP (P loss w/ (sediment)	Cumulative – 25 year (1bs/acre)
YAP (soluble P loss in runoff)	Cumulative – 25 year (1bs/acre)
YNO3 (NO_3 loss in surface runoff)	Cumulative – 25 year (1bs/acre)
SSFN (mineral N loss in subsurface flow)	Cumulative – 25 year (1bs/acre)
PKRN (mineral N loss in percolate)	Cumulative – 25 year (1bs/acre)
Wheat, Corn, Soybeans & Grain Sorghum	Same as above except energy profit ratio omitted

The data retained in the Summary Data Temp File Worksheet is a small portion of what is generated in ALMANAC and BEPCEE. BEPCEE can be rerun for individual climate region/soil cases if further detail, particularly change from year to year, is desired.

2.5.20 BioEnergy Region 1, 2, 3, 4, 5, 6 Worksheets

The row of data described above for a single soil is cut and pasted into the same array design for the appropriate climate region in the BioEnergy Region worksheet. The ***ProcessRegion*** macro then loads the EPIC/ALMANAC file for the next soil series. When the BEPCEE analysis is complete the Summary Data Temp File data is copied and pasted in the row below the previous set. The final data array consists of all the values described above for each soil series within the region. The macro ***ProcessRegion*** is then reset to process the next climate region.

Prior to processing EPIC/ALMANAC data the Workbook is approximately 6.5 MB in size. With data from all six climate zones the file is approximately 10 MB. A copy of BEPCEE with the final analysis data is in the BEPCEE directory on the KRD-9573 CD. The process can be repeated to perform sensitivity analysis of the variables in BEPCEE, such as the impact changing interest rates or fuel prices. The BEPCEE data retained in the Regional Worksheets is summarized in tabular and graphic form in Section 2.8 below.

2.6 Matching Yield, Cost, and Environmental Data to Available Soils

The ALMANAC model provided estimates of bioenergy crop and competing grain crop yields and various environmental impacts at the soil series level for six Kansas climate regions east of US highway 183. BEPCEE.xls provided an estimate of production cost, embodied energy, and energy profit ratio for each soil/climate condition. Additional analysis was undertaken with a geographic information system (GIS) to meet several important project requirements. Three distinct data sets were used.

2.6.1 Detailed Soils Information: the SSURGO Database

A vast amount of data has been collected across much of the U.S. and virtually all of Kansas as part of the USDA's Soil Conservation Service (now NRCS) county level soil surveys. These detailed documents provide maps at a scale of 1:24,000 showing each distinct parcel of land of a specific soil. Additional tables and text provide an extensive description of soil properties. Maps and data from these surveys have been converted to electronic form and made available as part of the Detailed Soils or Soil Survey Geographic (SSURGO) database. The spatial (map) data is available in Arc/Info Interchange format in files approximately 2 MB in size covering tileable USGS 7.5 minute quadrangles. A total of 1041 files were required to cover the area investigated (some overlapped western county boundaries or state boundaries).

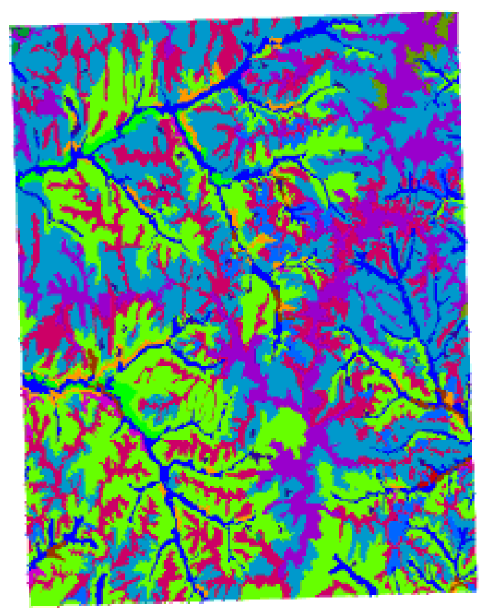

Figure 2.6.1 A SSURGO 7.5^0 Map

The SSURGO data provides the most detailed level of information and was designed primarily for farm and ranch, landowner/user, township, county, or parish natural resource planning and management. Using the soil attributes, this database serves as an excellent source for determining erodible areas and developing erosion control practices; reviewing site development

> *proposals and land use potential; making land use assessments and chemical fate assessments; and identifying potential wetlands and sand and gravel aquifer areas.*[56]

SSURGO soil information is consistent with that used by the ALMANAC/EPIC model. While SSURGO provides detail down to the individual soil level, of which there about 1,800 in Kansas, this analysis used the higher level classification of soil series. There are some 315 soils series in Kansas east of US 183. This simplification was expected to have only minor impact on the accuracy of yield estimates, while significantly reducing the number of data sets which were certain to stress available computing resources. Although the primary information used from SSURGO was the soil map, data on slope and erodability were used to evaluate CRP eligigility.

2.6.2 Finding Areas of Compatible Land Use: the Landcover Database

To convert yield, or even gross production, to estimated net achievable yield, land unsuitable for biomass crops needed to be eliminated from the land area in the SSURGO map. The LANDCOVER database developed by KARS classifies land use by the following ten catergories:

- residential
- commercial/industrial
- urban-grassland
- urban-woodland
- cropland
- grassland
- woodland
- water

Land Cover maps were acquired for all 74 counties being evaluated.

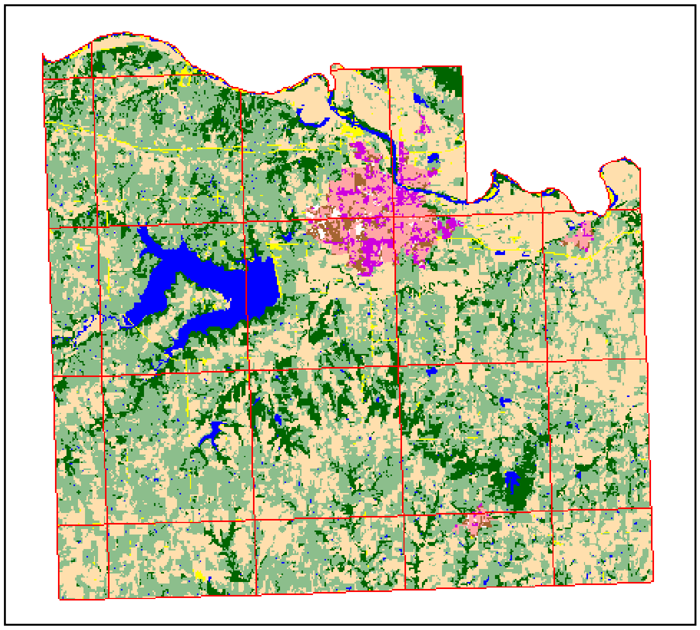

Figure 2.6.2 Douglas County Landcover
Source: DASC

2.6.3 Removing Road Rights-of-Way: the TIGER Road Database

Road rights-of-way represent a significant land use that should not be included in the analysis of land available for biomass crop production. The land use maps do not account for all road rights-of-way, nor are roads adequately described to permit transportation analysis. Census Bureau TIGER road files were the most comprehensive road files identified and files for all 74 counties were acquired. The Kansas Geological Survey's Data Access and Support Center provided the SSURGO, Land Cover, and TIGER road files on CD-ROMs in ARCInfo format.

56 ***Soil Geographic (SSURGO) Data Base: Data Use Information***, USDA National Resource Conservation Service, National Soil Survey Center, Misc. Publication No. 1527.

To prepare a map depicting areas of land suitable for potential biomass energy crop production by soil type the following steps were required:

1) Tile (join at their common boundaries) SSURGO quadrangle maps by county (quadrangles overlap most county boundaries),
2) trim tiled SSURGO files at county boundary edge,
3) assign width to road rights-of-way by hierarchy (wider for bigger roads),
4) assign acceptable or non-acceptable status to each Land Cover land use category,
5) sequentially overlay (cookie cutter) no. 3 and no. 4 on no. 2 by county,
6) tile counties together by climate region.

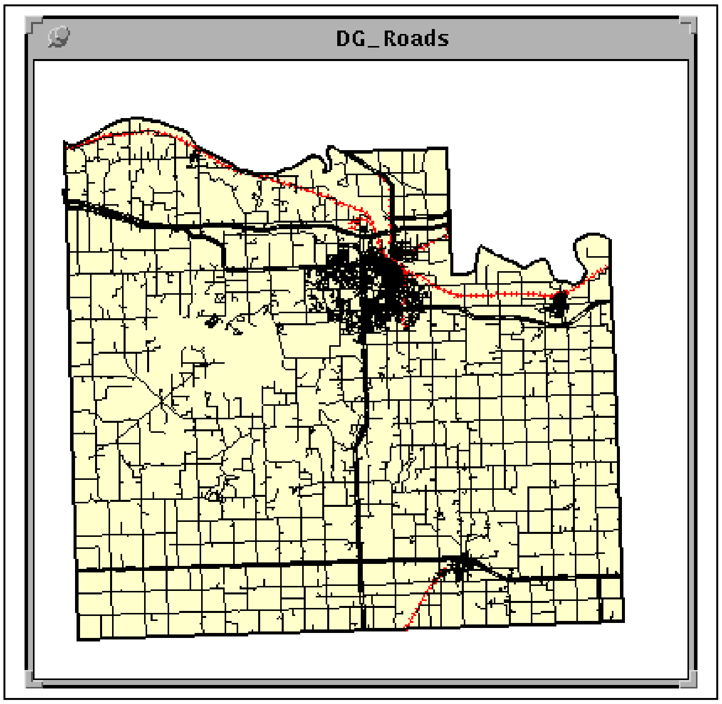

Figure 2.6.3 TIGER Roads for Douglas Co.
Source: DASC

Methodology for Biomass GIS Analysis

The spatial map could then be joined to the BEPCEE.xls data for each region by common map unit identification codes (MUID), permitting extensive spatial analysis, including visual identification of promising (low cost –high volume) sites. Preparing GIS files to meet this goal proved a more formidable task than anticipated.

Files received from DASC (TIGER, SSURGO, Landcover) were transported by CDROM in ARC/INFO Exchange (.e00) format. The spatial files were processed in a GIS to convert them into a common format, projection, and overlay for final use. PC ARC/INFO was used to manipulate these files so native PC ARC/INFO coverages were created from the input. Due to the number of files to be processed, PC ARC/INFO macros were created to automate the procedure. A common coordinate system was imposed on all files that were to be spatially overlayed, allowing proper data feature queries. The Road data were projected in a coordinate system that allowed for units of distance to be in either Meters or Feet so the buffering would reflect accurate measurements. Based on these requirements Universal Transverse Mercator (UTM, ZONE 14, METERS) was chosen for all projection and final output format. Due to the number of files to be processed, PC ARC/INFO macros were created to automate the procedure.

Projecting a Polygon coverage resulted in the need to maintain each coverage by using the PC ARC/INFO CLEAN command. Care must be taken as to the tolerance (FUZZY) of nodes or degradation of data may occur due to collapsed polygons. This was a continual problem when dealing with each level of processing that was performed.

Landcover Analysis

The Landcover county maps describe land according to the following classes: 1) Commercial/Industrial, 2) Residential, 3) Urban-Water, 4) Urban-Grassland, 5) Cropland, 6) Grassland, 7) Woodland, and 8) Water. Only the Cropland and Grassland coverage classes (COV_CLASS) were considered potentially useable for large scale biomass production and the area covered by all other land use classes needed to be removed from the SSURGO soil maps and associated database.

The data targeted for use in the Landcover dataset were those areas of Cropland and Grassland specified by the COV_CLASS field. The targeted data was affixed with a field of SUITABLE (Value of 1 or 0) designating whether the polygon will be used or not. The topology of the Land cover files shows the difficult nature of this dataset. The polygons are shown with heavily crenellated arc structure. This proved to be quite a disruptive dataset due to extraneous arcs. The size of the Landcover dataset needed to be reduced to a manageable level. After the SUITABLE field was added to each county's feature attribute table, the DISSOLVE operation was performed on each county. The DISSOLVE command removes the longest common boundary with another polygon with matching attributes, in this case the SUITABLE field. This reduced the number of polygons while maintaining their overall topology with respect to the biomass project scope.

The heavily crenellated structure of the polygon topology was due to the efforts of the creators to process the smooth arc definitions through a GENERALIZE function in ARC/INFO. The data provided was not originally meant to be used for analysis; however suitable replacement data were not available or could not be generated from satellite imagery in the span of this project.

Tiger Road Files

Roads also consume significant land area that needed to be removed from the SSURGO soil maps if an accurate estimate of potentially available land was to be made. The TIGER Roads dataset allowed for a hierarchy easement of buffered areas around roads. This was determined by the AFCC.char[2] field in the TIGER data. A value of 1 yielded a BUFF_DIST value of 100m; a value of 2 = 50m; and all other road values of AFCC.char[2] were calculated at 25m. The units only become relevant when the TIGER County Roads are projected into a UTM format with units of measurement changed from Decimal Degrees to Meters.

To eliminate areas comsumed by road rights-of-way road needed to be buffered for each county. Due to the hierarchical weight of roads the width of buffering was based on the TIGER file AFCC field indicating a size value for each road. The data field BUFF_DIST was added to the feature attribute table for each county. This field was assigned values corresponding to the value in the second character within the AFCC field also within the feature attribute table. The selection of those with AFCC.char[2] = 1 (Interstate and major US Highway) allow the assigning of BUFF_DIST value to 100. The units were placed in the coverage's distance units at the time of the buffering, after the projection placed the data in the correct format. Those with AFCC.char[2] = 2 (State Highways), BUFF_DIST assigned value of 50. All other roads were considered tertiary and the value of BUFF_DIST was assigned 25. The accuracy of the data in the AFCC field is in minor question. Due to limitations of PC ARC/INFO problems arose when trying to buffer roads in a county with metropolitan area. This process resulted in a polygon comprised of greater than 10,000 arcs. Roads were then deleted that spatially fell inside the intersection of the Landcover's unusable area. Re-buffering the result corrected the problem.

SSURGO Soils Analysis

The density of information provided in SSURGO files would not allow the joining of data at a regional level. Therefore joining was initially performed at the County scale which provided the best scale match with the Landcover and TIGER/Roads files. The procedure for mapjoining the SSURGO files by county was as follows:

After importing, cleaning, projecting and cleaning again, an index coverage for the state showing County Boundaries overlaid with Quadrangle boundaries, allowed a query to be automated giving a list of ROWCOL field for each county. The ROWCOL field was then used to index the ARC/INFO coverage name for each of the soil files, ignoring the first two characters of the SSURGO filename (which correspond to the primary county abbreviation, but not truly necessary in our exercise). With the list of quadrangle names modified to our UTM Projected output file nomenclature, the MAPJOIN command was performed on each county by using the index list as the input list, and a clipped coverage of the county boundary was applied according to the syntax of the ARC/INFO MAPJOIN command.

During the batch importing and projecting, several SSURGO files were omitted at each step. In reviewing the results of the MAPJOIN operation, 'Holes' were found in the data due to files not properly importing originally or not projected or files with unclean polygon topology. Approximately 1041 SSURGO coverages were included in the total dataset. With the inconsistencies inherent in the PC ARC/INFO system, the processing time at any level with SSURGO files took a great deal of computing resources.

Merging SSURGO Soils, Tiger Roads, and Suitable Land from Landcover

Performing the IDENTITY command on the Landcover and Buffered Roads yielded county coverages that displayed the final suitable/unsuitable areas targeted for analysis. The records in the resulting coverage had to be modified so that all polygons falling inside the buffered road areas would have the value of their SUITABLE field set to '0' designating unsuitable target sites. The final overlay operation performed was the result of the Land Cover/Buffered Road IDENTITY with the County map joined SSURGO files. Once more the issue of keeping data integrity consistent through each of the operations became paramount, failure to do so resulted in numerous failed attempts at the spatial overlay.

2.7 The Conservation Reserve Program (CRP)

2.7.1 Land Availability and The Potential Use of CRP Land for Energy Crops

Land area requirements for biomass energy production sufficient to fuel several sizes of electric power generation were discussed earlier. A key question in evaluating the feasibility of plantation biomass is the availability of adequate land acreage near a generating facility at rent rates that lead to the lowest possible biomass fuel cost. The federal Conservation Reserve Program (CRP) provides an indication of rent rates, albeit for lands that meet certain environmental criteria. The program may also represent an opportunity for access to land at what amounts to subsidized rates, provided land owners and the USDA agree.

To place biomass energy land requirements in perspective, a brief review of Kansas land use is appropriate.

The 1992 Census of Agriculture characterizes Kansas land use as follows:

TOTAL LAND AREA	52.4 million acres
TOTAL FARMLAND	46.7 million acres
of total land area	89.1%
CROPLAND	31.1 million acres
of total farmland	66.7%
irrigated	8.6%
in pasture	12.3%
in Fed. farm program	2.2%
in Conservation Reserve	7.3%
WOODLAND	0.6 million acres
of total farmland	1.4%
in pasture	49.2%
PASTURELAND	13.8 million acres
of total farmland	29.5%
OTHER LAND	1.1 million acres
of total farmland	2.5%
AVERAGE FARM SIZE	738 acres

Table 2.7.1 Kansas Crop Acreage and Hay Yield and Price (1980-1996)

Acres Planted (1,000)

Year	Wheat	Corn	Soybeans	Sorghum	Alfalfa	Other Hay	Yield Other Hay	$/ton Other Hay	Oats	Rye	Barley	Sun-flowers	Other Crops	Total Acres
1980	13,000	1,700	1,550	4,500	975	1,150	1.15	$114.79	175	60	60	na	41	23,327
1981	13,900	1,350	1,540	4,250	1,000	1,300	1.90	$88.90	260	75	63	na	63	23,892
1982	14,100	1,400	1,820	3,900	1,000	1,350	1.75	$78.10	215	50	70	na	40	24,025
1983	13,200	1,140	1,600	3,550	930	1,420	1.50	$105.45	145	65	100	na	19	22,275
1984	13,300	1,150	1,700	4,800	960	1,550	1.70	$94.36	175	75	180	na	21	24,007
1985	12,400	1,300	1,500	4,800	950	1,650	1.80	$58.85	235	60	240	na	17	23,213
1986	11,500	1,450	1,850	4,500	900	1,600	1.80	$53.26	280	64	350	na	24	22,573
1987	10,700	1,350	2,150	4,100	850	1,550	1.80	$64.78	240	35	140	na	26	21,208
1988	10,200	1,250	2,050	3,600	750	1,800	1.50	$85.13	225	40	100	na	21	20,123
1989	12,400	1,370	1,900	4,100	850	1,600	1.60	$78.12	280	45	60	na	24	22,709
1990	12,400	1,600	2,000	3,100	800	1,700	1.80	$55.89	160	35	25	75	40	21,993
1991	11,800	1,800	2,000	3,400	800	1,700	1.50	$60.48	160	70	30	105	34	21,961
1992	12,000	1,850	1,900	3,300	850	1,550	2.00	$58.17	200	50	27	130	26	21,943
1993	12,100	2,000	2,000	3,000	850	1,600	2.00	$59.24	70	70	18	160	29	21,958
1994	11,900	2,330	2,150	3,200	800	1,650	1.70	$59.85	160	90	15	260	34	22,651
1995	11,700	2,150	2,100	3,300	850	1,750	1.90	$58.19	130	100	10	300	38	22,488
1996	11,800	2,500	2,050	4,800	800	1,700	2.10	$63.00	130	60	13	285	33	24,236

Source: Kansas Agricultural Statistics

1996 Dollars

Table 2.7.1 provides greater detail on recent patterns in Kansas agricultural land use. Hay, excluding alfalfa, price data is also included, adjusted to 1996 dollars.

Each one-hundred megaWatts of power plant capacity would require approximately 100,000 acres with a 65% annual plant factor.[57]

2.7.2 CRP History and Current Status

Congress initiated the Conservation Reserve Program (CRP) with the Food Security Act of 1985. Under CRP, farmers could remove qualified land from agricultural production for ten years, provided they maintained an approved plant cover. The government compensates farmers with an annual rent payment.

The principal goals of the original CRP program were

- to reduce soil erosion on highly erodible cropland,
- protect the Nation's long-term ability to produce food and fiber,
- reduce sedimentation,
- improve water quality,
- foster wildlife habitat,
- curb production of surplus commodities,
- and provide income support for farmers.

To enroll cropland in the CRP, farmers applied at their Consolidated Farm Service Agency office (formerly Agricultural Stabilization and Conservation Service). Farmers indicated the fields that they proposed to enroll, the annual rental payment that they expected (rental bid), and the Commodity Credit Corporation (CCC) crop base (the amount of the farm's land that can be enrolled in CCC programs) that would be reduced during the 10-year life of the CRP contract. USDA enrolled 33.9 million acres into the CRP from a series of 12 signups.

Nationally, about 101 million acres met the basic highly erodible definition for CRP eligibility during 1986-89. However, CRP participation was generally limited to no more than 25 percent of the cropland in a county. This limitation reduced highly erodible cropland available for CRP to 70 million

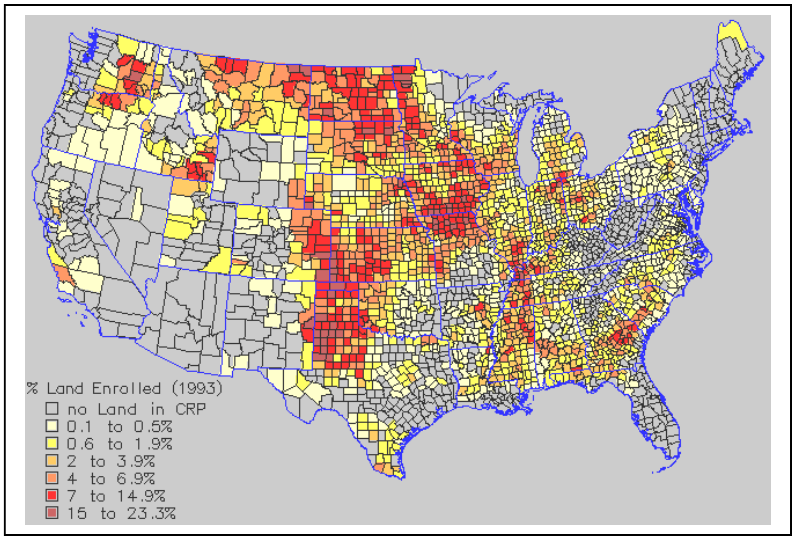

Figure 2.7.1 Percent of Land Enrolled in CRP (1993)
Source: USDA

[57] Many factors affect land requirement, including yield, field efficiency, haul distance, fuel processing, and plant efficiency. The ratio stated is intended to provide only a concept of land requirements.

acres. Additional changes affecting cropland eligibility were instituted in 1987.

Land Capability Class and Subclass

During the various sign-up phases differing rules applied regarding the eligibility and preferences of different land parcels based primarily on susceptibility to erosion as defined by USDA's land capability classification system described below.

> USDA's land capability classification system is a widely used system for judging the suitability of land for agricultural uses. The system is divided into classes I (the lowest) through VIII (the highest) and subclasses e, w, s, and c. The higher the class, the greater the limitations of the soils and the fewer the choices for appropriate agricultural use.
>
> ***Classes I, II, and III.*** Soil are suitable for cultivated crops.
>
> ***Class IV.*** Soils can be used for crops, but only if appropriate rotations and practices are used.
>
> ***Classes V, VI, and VII.*** Soils are not suited to cultivation but are suited to pasture, range forage, trees, certain special crops or wildlife habitat.
>
> ***Class VIII.*** Soils are limited to recreation, wildlife habitat, or water supply uses.
>
> All classes, except I, are divided into subclasses based on the dominant agricultural limitation. Class I has no subclasses because its soils have no significant limitations. The four subclasses are:
>
> > ***Subclass e.*** Soils are susceptible to erosion.
> >
> > ***Subclass w.*** Soils have excess water caused by poor drainage, a high water table, flooding, or seepage.
> >
> > ***Subclass s.*** Soils have limited root zones, including shallowness, stoniness, low water holding capacity, low fertility, or presence of salt or other minerals toxic to plants.
> >
> > ***Subclass c.*** Soils are limited by climatic conditions.

During the various sign-up periods between 1986 and 1989 land classes were eligible as follows:

Signup Period 1 Eligibility (March 3-14, 1986)

(1) Land in Land Capability Class (LCC, see above)) II-V with an annual erosion rate greater than 3T, or
(2) (2) land in LCC VI-VIII.

Signup Period 2 Eligibility (May 5-16, 1986)

Same as signup period 1.

Signup Period 3 Eligibility (August 4-15, 1986)

(1) Same as signup period 2, or
(2) land in LCC II-V with an annual erosion rate of 2T or greater and serious gully erosion.

Signup Period 4 Eligibility (February 9-27, 1987)

For 1987 contracts
(1) Same as signup period 3, or
(2) land with
    (a) an erodibility index (EI) equal to or 3 greater than 8, and

(b) an erosion rate, with cover, management, and practice factors reflecting crop years 1981-85, greater than that recommended by the Natural Resource Conservation Service (NRCS, formerly the Soil Conservation Service) Field Office Technical Guide (generally greater than T).

For 1988 contract
(1) Land with
(a) an EI equal to or greater than 8, and
(b) an erosion rate, with cover, management, and practice factors reflecting crop years 1981-85, greater than that recommended by the NRCS Field Office Technical Guide (generally greater than T).

Signup Period 5 Eligibility (July 20-31, 1987)
Same as signup period 4, 1987 contracts.

Signup Period 6 Eligibility (February 1-19, 1988)
(1) Same as signup period 5,
(2) land in LCC II-V with an annual erosion rate greater than 2T if planted to trees (only one-third of the field required to meet the erodibility criteria as opposed to the former two-thirds requirement), or
(3) filter strips 66 to 99 feet wide adjacent to waterbodies regardless of erodibility.

Signup Period 7 Eligibility (July 18-August 31, 1988)
Same as signup period 6.

The CRP program was amended by the Food, Agriculture, Conservation, and Trade Act of 1990, which extended CRP enrollment through 1995 and combined it with a new Wetlands Reserve Program (WRP) to form the Environmental Conservation Acreage Reserve Program (ECARP). The 1990 amendments mandated that 40-45 million acres be enrolled in the ECARP by the end of the 1995 calendar year, including the 33.9 million acres enrolled in the CRP during 1986-89. Later legislation capped CRP enrollment at 38 million acres.

A new CRP bid process, developed by USDA after passage of the 1990 amendments, targeted the following seven conservation and environmental goals:

- surface water quality improvement,
- ground water quality improvement,
- preservation of soil productivity,
- assistance to farmers most affected by conservation compliance,
- encouragement of tree planting,
- enrollment in areas identified under USDA's water quality initiative, and
- enrollment in conservation priority areas.

Responding to the 1990 Act, USDA developed new rules for operation of the CRP during 1991 through 1995, including new eligibility criteria. These new criteria were adopted in the 10th signup except that for marginal pastureland. Conservation on marginal pastureland could be achieved more efficiently under other USDA cost-sharing programs. By June of 1992 a total of 31,020 contracts had been signed in Kansas covering 2,937,863 acres, about 5.5% of the entire state. The average parcel was 94.7 acres.

Farmed wetlands (wetlands that may be farmed under natural conditions), formerly eligible for CRP enrollment, were made ineligible in signup periods 10-12 even if they would have been otherwise eligible under other criteria. This reflected the preference of Congress to place farmed wetlands in the Wetlands Reserve Program. Prior converted cropland (wetlands converted prior to December 23, 1985), however, remained eligible for enrollment in the CRP provided that such land otherwise met eligible land criteria.

USDA accepted an additional 2.5 million acres from these signups, held during 1991-92. No funds were appropriated for new CRP enrollment in fiscal years 1993-95. Land eligibility for the 10th-12th signup periods is listed below.

Signup Period 10 Eligibility (March 4-15, 1991)

(1) Land in LCC II-V with an annual erosion rate of 3T or greater,
(2) land in LCC II-V with an erosion rate of 2T or greater if trees are planted or a serious gully erosion problem exists,
(3) land in LCC VI-VIII,
(4) land with
    (a) an EI equal to or greater than 8, and
    (b) an erosion rate, with cover, management, and practice factors reflecting crop years 1981-85, greater than that recommended by the NRCS Field Office Technical Guide (generally greater than T),
(5) land devoted to useful life easements of 15 or 30 years for filter strips, waterways, contour grass strips, permanent wildlife habitat, field windbreaks, shelterbelts, living snow fences, salt tolerant vegetation, or terraces,
(6) land in identified State water quality areas (Hydrologic Unit Areas under the USDA Water Quality Initiative),
(7) land in conservation priority areas established by the 1990 Farm Act (Chesapeake Bay, Long Island Sound, and the Great Lakes Region),
(8) land within a public wellhead protection area established by the Environmental Protection Agency (EPA), or
(9) land with evidence of scour erosion caused by out-of-bank water flows.

Signup Period 11 Eligibility (July 8-19, 1991)

Same as signup period 10.

Signup Period 12 Eligibility (June 15-26, 1992)

Same as signup period 10, except that useful-life easements were not required for filter strips, waterways, contour grass strips, permanent wildlife habitat, field windbreaks, shelterbelts, living snow fences, salt tolerant vegetation, or terraces. Congress eliminated the useful-life easement requirement of the 1990 Act since it discouraged enrollment of this acreage in signup periods 10 and 11. Because of the change in the law, farmers who submitted easement bids in the 12th signup period were not required to file an easement. They were required, however, to maintain their CRP acreage in the selected practice for its useful life (15 or 30 years). Producers whose useful-life easement bids were accepted in the 10th and 11th signups, but who had not yet filed their easements, were not required to do so.

Signup Period 13 Eligibility (December 1994)

In December, 1994, the USDA announced its intention to allow CRP participants to release all or part of their contracted acreages before the contract expiration date, without penalty.

This optional provision was available to all acreage enrolled during Sign-Ups 1 through 12, with the exception of land devoted to certain conservation practices, or land located within 100 feet of streams or other water bodies.

With Sign-Up 13, USDA changed CRP's focus to providing significant soil erosion control, water quality, tree-planting, and wildlife benefits. The enrollment authority made available under the early-release option was re-targeted to enrolling replacement acres meeting enhanced environmental, wildlife, and conservation criteria.

Because of their important roles in water quality improvement, the enrollment of filter strips and riparian buffers adjacent to water bodies was encouraged with a 10-percent incentive payment. Kansas farmers offered a total of 1,175 land parcels. USDA accepted 643 offers totaling 30,221 acres with an average rent of $40.32/acre.

Signup Period 14 Eligibility (Continuous)

The USDA announced and implemented a"continuous CRP Sign-Up" beginning in September 1996, for producers wishing to enroll acreage designated for various environmentally related practices into the CRP. This provided management flexibility to farmers and ranchers to implement the following special practices on their cropland: Filterstrips, Riparian Buffers, Shelter Belts, Living Snow Fences, Field Windbreaks, Grassed Waterways, Salt Tolerant Vegetation, and Shallow Water Areas for Wildlife.

Eligible cropland acreage devoted to these practices is automatically accepted into CRP at a per acre rental rate not to exceed CCC's maximum payment amounts. Competitive bidding is not used, because relatively small acreage devoted to one of these practices provides a positive nvironmental impact for a much larger area. However, producers may bid to receive an amount less than the maximum payment rate.

In addition to the rental payments described, CCC also pays 50% of the cost of establishing the permanent cover.

Table 2.7.2 Conservation Reserve Signup Period 1-12: March 1986-June 1992

		ACRES ENROLLED		RENT RATE	EROSION REDUCTION	
Region/ State	Number of Contracts	Total	Average per Contract	Ave. $/Acre/ Year	Ave Tons/ Acre/Year	Cropland Base Reduction Acres
U. S. Total	375,205	36,422,733	97.1	40.97	19	23,278,085
Kansas	**31,020**	**2,937,863**	**94.7**	**52.82**	**16**	**2,161,826**
Nebraska	14,449	1,425,423	98.6			
Iowa	35,667	2,224,834	62.4	82.31	na	na
Missouri	22,804	1,726,835	33.3	63.33	19	836,894
Oklahoma	8,688	1,192,504	137.3			
Colorado	6,207	1,978,390	318.7	41.05	25	1,133,362

"1995 Farm Bill"

With congressional extension of the CRP program uncertain, a great debate began with the approach of the "1995 Farm Bill" regarding the potential impact of so many acres returning to grain production. As new criteria for enrollment began to emerge from the compromise required for continuing the program the debate shifted to who should be allowed to re-enroll. Charles M. Hume of Springfield, Colorado, writing in the High Plains Journal summed it up.

The intent of the proposed regulations seems to be to shift much of the new CRP to the Eastern Seaboard and the Corn Belt. The monies there would be spent largely on wetlands. Everyone seems to have forgotten that the Great Plains, just 60 odd years ago, was the heart of the Dust

> *Bowl, arguably the greatest environmental disaster of the 20th century. What seems to be happening here is politics as usual. There are many more votes to the east than what there are in the High Plains, and the money seems to be following the votes. Don't let this happen. Get involved in the comment process. More importantly, get your banker involved in the comment process. For some reason, politicians seem to place more credence in what a banker says than in what a farmer says.*

Many wheat producers feared that USDA's proposal to bar most land with an erodibility index of less than 8 from re-enrollment in the CRP could force millions of wheat acres back into production and drive wheat prices down.

Ultimately, Title III of the Federal Agricultural Improvement and Reform Act of 1996 extended the CRP program with changes that had significant impact on eligibility and modest impact on the distribution of enrolled acres. The act created the Environmental Conservation Acreage Reserve Program (ECARP) as the umbrella encompassing the Conservation Reserve Program (CRP), the Wetland Reserve Program (WRP), and the Environmental Quality Incentives Program (EQIP). The CRP program was re-authorized through 2002 with enrollment limited to a maximum of 36.4 million acres at any one time, representing an estimated 15% of eligible land. The act stated that "The Secretary is to allow participants to terminate any contract entered into prior to January 1, 1995, upon written notice provided the contract has been in effect for at least 5 years. The Secretary maintains discretionary authority to conduct future early outs and future sign-ups of lands that meet enrollment eligibility criteria." USDA issued the final rule for implementing the "New CRP" in February of 1997. The new rule was based on an Environmental Benefits Index (EBI) that gave greater emphasis to water quality and wildlife habitat improvement with particular emphasis on wetlands. Four national Conservation Priority Areas (CPAs) were established, including Long Island Sound, Chesapeake Bay, the Great Lakes, and the Prairie Pothole regions. Key components of the EBI include:

- wildlife habitat benefits,
- water quality benefits from reduced erosion, runoff, and leaching,
- on-farm benefits of reduced erosion,
- long-term retention benefits,
- air-quality benefits from reduced wind erosion,
- the land's location in a CPA, and
- the cost of enrollment per acre.

The Commodity Credit Corporation makes annual rental payments based on the agriculture rental value of the land and provides cost-share assistance in an amount equal to not more than 50 percent of the participant's costs in establishing approved practices. The duration of contracts are from 10 to 15 years. Specific land eligibility requirements based on the new rule are summarized below for sign-up periods 15 and 16 (the most recent).

Signup Period 15 Eligibility (March 3 – March 28, 1997)[58]
To be eligible to be placed in CRP, land must be

[58] USDA Farm Service Agency Fact Sheet, Conservation Reserve Program 15th Sign-Up Period March 3 - March 28, 1997 February 1997.

(1) Cropland that has been planted or considered planted to an agricultural commodity 2 of the 5 most recent crop years (including field margins) which is also physically and legally capable of being planted in a normal manner to an agricultural commodity; or
(2) Marginal pasture land that is either
    a) Certain acreage enrolled or recently enrolled in the Water Bank Program; or
    b) Suitable for use as a riparian buffer to be planted to trees.In addition to basic eligibility requirements, the cropland must also meet at least one of the following conditions.

Land must meet the following qualifications:
(1) Have an Erosion Index (EI) of 8 or higher or be considered highly erodible land according to the conservation compliance provisions (Redefined fields must have an EI of 8 or higher);
(2) Be considered a cropped wetland;
(3) Be devoted to any number of highly beneficial environmental practices, such as filter strips, riparian buffers, grass waterways, shelter belts, wellhead protection areas, and other similar practices;
(4) Be subject to scour erosion;
(5) Be located in a national or state CRP conservation priority area; or, (6) Be cropland associated with or surrounding non-cropped wetlands.

Ranking Criteria
Offers for CRP contracts are ranked according to the Environmental Benefits Index (EBI). The Natural Resources Conservation Service collects data for each of the EBI factors based upon the relative environmental benefits for the land offered. Bids are then ranked in comparison to all other bids offered and selections made from that ranking.EBI factors are the following:

• Wildlife habitat benefits resulting from covers on contract acreage;
• Water quality benefits from reduced erosion, runoff, and leaching;
• On-farm benefits of reduced erosion;
• Likely long-term benefits beyond the contract period from certain practices such as tree plantings;
• Air quality benefits from reduced wind erosion;
• Benefits of enrollment in conservation priority areas where enrollment would contribute to the improvement of identified adverse water quality, wildlife habitat, or air quality; and
• Cost.

Producer Eligibility Requirements
An applicant must have owned or operated the land for at least 12 months prior to close of the sign-up period unless:

• The new owner acquired the land as a result of death of the previous owner;
• The only ownership change occurred due to foreclosure where the owner exercised a timely right or redemption in accordance with State law; or
• The circumstances of the acquisition present adequate assurance to the Commodity Credit Corporation that the new owner did not acquire the land for the purpose of placing it in CRP.

Sign-Up 15

USDA processed a quarter of a million offers on over 23 million acres for sign-up 15 in about two months.

Signup Period 16 Eligibility (October 14 – November 14, 1997)[59]
Sign-Up 16 presented a new Environmental Benefits Index (EBI) which

[59] USDA Farm Services Agency Fact Sheet: Conservation Reserve Program 16th Sign-Up Period October 14 - November 14, 1997, October, 1997.

(1) Adjusted the EBI factor for Wildlife Habitat Benefits to award points for the cover subfactor for cover mixes with up to 5 different species.
(2) Defines the minimum percent-ages of offered acreage on which cover must be improved before awarding greater points for improved cover, The minimums are:
• 51 percent of the acres must have improved cover for offers containing only existing acres (offered acres already under contract);
• 70 percent of the acres must have improved cover for offers with a mixture of existing and new acres;
• 90 percent for offers for only new acres;
• 100 percent of the acres to be devoted to trees for tree practices.

(1) Changes the name from 'Long-Term Retention Benefits' factor to 'Enduring Benefits' and includes points for the following:
• Restoration of rare and declining habitat;
• Cultural resource areas such as historic sites and certain tribal lands;
• Shrub planting for certain wildlife;
• Non-CRP obligations to maintain the functions of CRP practices by entities, such as State governments and private organizations such as The Nature Conservancy.

(2) Improves the Air Quality factor by replacing the 1 factor used in signup 15 with 3 subfactors:
• to evaluate wind erosion impacts using a county rather than ZIP code basis. Revised tables give greater weight to rural areas;
• recognizing soils with a high percentage of fine material that are more likely to be suspended, such as volcanic soils;
• for air quality zones to evaluate areas in which agriculture impacts air quality or that are located within 50 miles of Class 1 air quality areas, such as National Parks.

(3) Adds to the cost factor a subfactor to provide points for every whole dollar for which an offer is below the Maximum Payment Rate, not to exceed 15 points. To avoid a repeat of some errors that plagued sign-up 15, additional oversight was added for sign-up 16:

• A longer lead-time was provided to State and county offices between national training and the beginning of sign-up to help ensure that a complete information campaign is conducted;
• Every applicant will be required to certify on the CRP-2 Worksheet that all of the EBI except the cost factor has been explained and that the applicant has been informed that certain actions such as planting an approved cover mixture, enhancing existing cover, offering less than the maximum payment rate, and/or declining cost-share assistance may enhance the acceptability of the offer.
• Offer data will be uploaded weekly during signup and analyses per-formed to identify any trends or major discrepancies immediately so that areas of concern may be addressed and corrected before the close of sign-up;
• NRCS national Oversight and Evaluation Teams will be in the field during sign-up to monitor offer evaluation.

The EBI cutoff score for sign-up 16 will not be known until after sign-up ends and all eligible offers are evaluated. There is no guarantee that the EBI cutoff score will again be 259 points as in sign-up 15 .

Amount of acreage to be enrolled will be determined after sign-up ends and all eligible offers are evaluated. Enrollment will be de-pendent in large part upon the quality of the acres offered.

Current Status of the CRP

Since the first sign-up, conducted in the Spring of 1986, through the 12th sign-up held in mid 1992, 36,422,772 acres were contracted into CRP. As of January 1, 1997 there were 32,956,477 acres under active CRP contract.

Continuous Sign-up

While most of the re-enrolled and new acreage committed to CRP was accepted during the cyclical sign-up periods, the program also permits continuous sign-up for certain high-priority conservation practices, including the following:[60]

1) Planting filter strips of grass, legumes, and other vegetation that filter runoff and waster water by trapping sediment, pesticides, organic matter, and other pollutants. Eligible filter strips are planted on cropland and the lower edge of fields or adjacent to bodies of water. Filter strips must be planted according to technical standards established by the Natural Resource Conservation Service.

2) Establishing riparian buffers of trees and/or shrubs next to ponds, lakes, and streams that filter out pollution from runoff as well as providing shade for fish and other wildlife. Runoff must filter through the plant buffer before reaching the water.

3) Planting shelter belts, field windbreaks, and living snow fences in single or multiple rows to reduce wind erosion, improve air quality, protect growing plants, and provide food, shelter, and breeding territory for wildlife.

4) Planting grass waterways in natural or constructed channels to prevent soil erosion.

5) Construction of shallow water areas for wildlife, planting to reduce saline water seepage, and plantings at EPA designated wellhead protection areas.

Sign-up for these specific practices is open continuously provided eligibility requirements are met. Rental rates are based on the established maximum rates for site specific soils and local prevailing cash-equivalent rents.

Conservation Reserve Enhancement Program

The Conservation Reserve Enhancement Program (CREP) [61] is a State-federal conservation partnership program targeted to address specific State and nationally significant water quality, soil erosion and wildlife habitat issues related to agricultural use. The program uses financial incentives to encourage farmers and ranchers to voluntarily enroll in contracts of 10 to 15 years in duration to remove lands from agricultural production. This community-based conservation program provides a flexible design of conservation practices and financial incentives to address environmental issues.

Basic CREP Features

1) Projects must address resource issues of state and national significance such as nutrient reduction in the Chesapeake Bay.

2) Projects must be cost-effective in comparison to other conservation programs at the State and Federal level.

---

[60] ***The New Conservation Reserve Program***, http://www.dsa.usda.gov/dafp/cepd/12crplogo.newcrp.htm.

[61] USDA Farm Services Agency Fact Sheet: Conservation Reserve Enhancement Program, http://www/fsa.usda.gov/dafp/cepd/crep/fact_sheet.htm

3) Projects must be results oriented by providing measurable goals and outline a monitoring program to evaluate whether the program goals are being accomplished.

4) Proposals must provide for significant non-federal funding, generally anticipated to be 20% of total project costs.

5) Proposals must demonstrate support from farmers and ranchers and other interested groups.

6) Proposals must be consistent with applicable laws and regulations, however USDA will consider adjustments to conservation practices and payment schedules upon review of adequate justification.

7) Proposals will initially be limited to 100,000 acres for each state.

8) Producer enrollment is voluntary and will be offered on a continuous basis.

Kansas does not currently have an approved CREP program.

Table 2.7.3 below lists Kansas CRP acreage by county after completion of sign-up 12 in mid-1992 at near the maximum acreage, and after completion of sign-up 16 in 1998 under the new USDA rule resulting from 1996 legislation. Total Kansas acreage enrolled in CRP dropped from around 2.94 million to 2.53 million acres, or 14 percent. A goal of the new program was to reduce cost, and average Kansas rental rates fell from around $53.00 per acre to around $37.50. CRP acreage in the 67 counties in the eastern 2/3 of the state which were evaluated for biomass energy production fell from 1.78 million to 1.28 million acres, while average rental rates declined from around $54.50 to around $40.50.

Table 2.7.3 Kansas Conservation Reserve Program (CRP) Acreage by County

County	Acres After SignUp 12	Rent ($/Acre)	Acres After SignUp 16	Rent ($/Acre)	County	Acres After SignUp 12	Rent ($/Acre)	Acres After SignUp 16	Rent ($/Acre)
ALLEN	6,578	$57.81	2,593	$54.01	LINN	27,237	$59.02	16,510	$54.02
ANDERSON	8,582	$58.67	2,723	$45.90	*LOGAN*	*35,666*	*$49.65*	*18,881*	*$31.50*
ATCHISON	5,915	$66.89	6,204	$56.69	LYON	22,166	$57.85	13,449	$52.32
BARBER	28,575	$53.44	21,333	$32.92	MCPHERSON	16,438	$53.35	10,123	$35.64
BARTON	28,525	$53.39	19,635	$35.56	MARION	18,369	$58.49	16,351	$39.14
BOURBON	22,590	$57.81	7,842	$53.36	MARSHALL	22,081	$63.10	20,188	$53.80
BROWN	10,953	$64.61	9,006	$67.11	*MEADE*	*35,717*	*$49.62*	*41,528*	*$35.99*
BUTLER	6,864	$57.18	3,054	$39.58	MIAMI	12,934	$58.32	5,941	$49.02
CHASE	1,568	$59.27	1,139	$43.03	MITCHELL	20,001	$53.82	17,389	$41.21
CHAUTAUQUA	4,802	$58.30	4,131	$37.80	MONTGOMERY	3,854	$59.41	2,499	$41.24
CHEROKEE	5,120	$59.12	1,310	$52.49	MORRIS	5,875	$57.56	4,267	$43.78
CHEYENNE	*49,997*	*$49.44*	*38,388*	*$31.75*	*MORTON*	*88,766*	*$48.88*	*95,832*	*na*
CLARK	*46,218*	*$48.66*	*45,613*	*$34.37*	NEMAHA	32,789	$63.45	25,918	$57.52
CLAY	22,911	$63.66	17,689	$49.66	NEOSHO	18,393	$57.99	7,368	$45.06
CLOUD	16,973	$53.90	13,620	$40.24	*NESS*	*38,245*	*$49.15*	*41,668*	*$39.51*
COFFEY	11,956	$58.49	11,782	$53.63	*NORTON*	*43,995*	*$49.32*	*34,405*	*$30.64*
COMANCHE	42,291	$51.18	40,758	$30.41	OSAGE	16,995	$58.08	13,757	$47.67
COWLEY	7,148	$56.53	6,433	$37.59	OSBORNE	24,072	$53.95	18,103	$37.16
CRAWFORD	12,063	$58.83	3,132	$47.54	OTTAWA	17,950	$53.96	14,399	$44.28
DECATUR	*8,310*	*$48.68*	*7,550*	*$31.26*	PAWNEE	59,149	$54.39	44,798	$36.13
DICKINSON	24,078	$62.68	26,857	$50.04	PHILLIPS	27,181	$54.20	21,130	$35.11
DONIPHAN	11,556	$78.36	12,951	$70.78	POTTAWATOMIE	14,732	$61.52	13,346	$54.24
DOUGLAS	6,266	$62.95	4,986	$61.25	PRATT	47,712	$53.39	47,566	$34.84
EDWARDS	48,857	$53.95	38,701	$35.38	*RAWLINS*	*12,639*	*$49.59*	*6,792*	*$29.69*
ELK	8,254	$57.06	5,205	$40.12	RENO	95,116	$53.78	80,650	$39.14
ELLIS	35,281	$53.82	24,934	$34.32	REPUBLIC	15,812	$54.53	11,177	$44.79
ELLSWORTH	27,041	$53.46	27,301	$40.72	RICE	17,400	$54.27	14,749	$38.71
FINNEY	*57,896*	*$49.33*	*60,882*	*$39.53*	RILEY	4,044	$62.73	3,880	$47.90
FORD	*50,434*	*$49.83*	*49,041*	*$36.11*	ROOKS	44,300	$53.97	29,836	$30.99
FRANKLIN	9,358	$58.42	4,731	$54.01	RUSH	35,743	$53.77	30,972	$36.76
GEARY	2,270	$62.29	3,195	$48.03	RUSSELL	51,916	$52.97	42,427	$34.56
GOVE	*20,148*	*$49.42*	*15,123*	*$35.47*	SALINE	21,878	$54.81	19,126	$42.71
GRAHAM	*74,366*	*$49.90*	*55,116*	*$29.63*	*SCOTT*	*23,858*	*$49.65*	*15,994*	*$39.17*
GRANT	*29,644*	*$49.32*	*31,961*	*$35.36*	SEDGWICK	7,356	$54.18	5,181	$36.55
GRAY	*40,212*	*$49.78*	*39,099*	*$39.76*	*SEWARD*	*42,968*	*$49.70*	*41,626*	*$34.14*
GREELEY	*80,966*	*$49.53*	*78,345*	*$36.35*	SHAWNEE	7,543	$63.50	5,460	$56.93
GREENWOOD	5,263	$57.32	3,414	$46.91	*SHERIDAN*	*8,973*	*$49.46*	*3,891*	*$34.18*
HAMILTON	*127,130*	*$48.15*	*134,139*	na	*SHERMAN*	*41,661*	*$48.27*	*39,082*	*$36.30*
HARPER	32,234	$54.30	26,551	$37.78	SMITH	23,092	$53.68	15,995	$41.58
HARVEY	6,631	$54.88	4,500	$33.30	STAFFORD	37,259	$53.94	39,207	$43.16
HASKELL	*19,640*	*$49.82*	*23,363*	*$39.42*	*STANTON*	*101,458*	*$49.52*	*102,051*	*$33.50*
HODGEMAN	*27,952*	*$49.61*	*40,768*	*$39.01*	*STEVENS*	*68,314*	*$49.67*	*54,442*	*$29.38*
JACKSON	20,901	$62.14	17,645	$57.61	SUMNER	8,272	$54.23	7,001	$39.17
JEFFERSON	16,008	$63.47	11,305	$56.50	*THOMAS*	*19,571*	*$49.69*	*15,885*	*$36.74*
JEWELL	26,729	$54.30	21,285	$44.60	*TREGO*	*33,969*	*$49.53*	*27,691*	*$31.75*
JOHNSON	2,770	$62.13	1,625	$55.98	WABAUNSEE	14,272	$62.68	10,300	$56.55
KEARNY	*73,442*	*$49.50*	*66,472*	*$36.07*	*WALLACE*	*66,674*	*$49.13*	*54,960*	*$32.30*
KINGMAN	45,875	$53.65	31,510	$38.08	WASHINGTON	30,024	$63.98	22,556	$51.70
KIOWA	56,429	$52.26	49,544	$30.31	*WICHITA*	*42,915*	*$49.78*	*44,883*	*$37.89*
LABETTE	7,270	$57.12	4,407	$48.06	WILSON	12,630	$58.98	4,857	$41.98
LANE	*25,075*	*$49.57*	*28,766*	*$39.11*	WOODSON	4,494	$59.00	1,804	$46.54
LEAVENWORTH	5,926	$62.95	5,088	$59.54	WYANDOTTE	169.8	$60.65	166	na
LINCOLN	19,382	$53.52	16,775	$42.00					
STATE (all 105 Counties)						**2,937,863**	**$52.82**	**2,527,577**	**$37.47**
STATE (less 38 counties west of climate zones 1-6, *in italics above*)						**1,636,032**	**$54.99**	**1,173,340**	**$41.18**

Rental rate data from several USDA sources. Average may not be exact.

Table 2.7.4 Kansas CRP Enrollment by Climate Region

Acres (1,000)

Region	After Sign-up 12	After Sign-up 16
0 (western Kansas)	1,436,819	1,354,237
1	380,664	300,531
2	198,191	164,379
3	281,111	213,081
4	111,311	48,562
5	36,270	26,169
6	493,497	420,618

2.7.3 CRP Land Use for Biomass Energy Production

If ten percent of the land now in CRP in the eastern 2/3 of Kansas was dedicated to biomass energy production with an average yield of 4 dry tons per acre and a field efficiency of 85%, the biofuel produced could fire a 115 megaWatt power plant with an average efficiency of 30% and a 65% annual plant factor. This simplified case ignores many important variables, but does give some indication of the energy scale of CRP.

Most land that could provide acceptable bioenergy yields is more profitable producing grain. The market price for switchgrass hay is often twice what a utility might pay for it as fuel. But land enrolled in the CRP program can not be used to produce marketable crops. Even grazing is normally prohibited. The USDA has the authority to waive some of these restrictions and has done so in several circumstances.

The concept of using CRP land to produce biomass energy crops has been analyzed and debated within the biomass community. Walsh, Becker and Graham at ORNL evaluated the potential impact of planting HECs and SRWCs on 17.4 and 14.2 million acres respectively [7.0 and 5.7 million hectares]. Under a 40% reduction strategy the subsidized delivered cost was $2.48/MBtu [$2.35/GJ] for SRWCs and $2.21/MBtu [$2.09/MJ] for HECs (switchgrass).[62]

Integrating biomass production with the CRP program could offer the following important advantages:

1) subject to approval of USDA and acceptance by the landowner land rental rates paid for bioenergy crop production could be lower than market rates,

2) long term CRP contracts (10-15 years) could offer some assurance that land would continue to be dedicated to biomass production and not shifted to more profitable crops if grain prices rise,

3) biomass cost, based on production costs and competitive overhead and profit rates, would likely be less than required to shift land from grain production to biomass production based on gross profit per acre from such crops.

---

[62] Walsh, M. E., Becker, D., Graham, R. L., ***The Conservation Reserve Program as a Means to Subsidize Bioenergy Crop Prices***, BIOENERGY '96, Nashville, 1996.

Integration with CRP offers the best opportunity for achieving the lowest possible cost of biomass energy production in sufficient quantities for electric power generation.

However, such integration with the CRP program could present several problems, now and in the future, including the following:

1) current CRP enrollment agreements are for a maximum of 15 years which may be less than the amortization period of a utility scale biofuel generating facility,

2) the program runs for the most part on a ten year cycle which we are just now beginning and as a result land currently enrolled in CROP would need to be replanted to energy crops or establishment would need to wait until around 2005,

3) if global grain demand were to increase sufficiently to cause a sustained increase in domestic food prices the program might not be renewed and could even be terminated prematurely.

Some members in the agricultural community also believe that it is inappropriate to use land removed from agricultural production to produce any crop marketable in any form. If biomass can be produced and sold at a profit, then the private sector should be allowed to compete for the opportunity. This argument may wither somewhat if a strategy for producing biomass at an acceptable price outside the CRP program cannot be identified.

2.8 The Cost and Availability of Biomass at the Field Edge

ALMANAC was used to estimate yields and related environmental impacts for switchgrass, black locust, wheat, corn, soybeans and grain sorghum for a 24-year period for individual soil series in six Kansas climate regions. BEPCEE used these yield values to estimate production cost for each crop and the market price required for biomass crops to compete with the most profitable grain crop and on CRP land with a rent equal to 40% of the federal CRP payment. BEPCEE also evaluated embodied energy. Summary files of key data were developed for each soil for each region. The GIS system was used to determine available parcels of land (or portions of parcels) in the SSURGO detailed soils database were actually available for potential biomass production based on land use criteria in the Landcover database. This process generated many very large files totaling around four gigabytes (GB). Map files for a single variable for a single county may be one – three Mb. The key files are on the KRD 9573 CD should KEURP wish to reuse this analysis at a future date. Identifying key decision making variables and distilling them for presentation in a clear and usable manner has been a real challenge. The discussion below, accompanied with tables and maps, focuses on the most important factors regarding biomass cost, production potential, and candidate sites. It is but a small part of the data generated. Tables and maps not essential for explaining the analysis process and key findings, but of value for the further investigation of biomass energy potential in Kansas have been placed on the KRD 9573 CD.

Using estimated yields and costs along with area of each available land parcel to estimate total production potential required assumptions regarding market penetration. While concentrating biomass production has transportation cost savings advantages, it increases other risks for all participants and is therefore unlikely to occur. CRP limits total enrollment to no more than 20% of the land within a county. This analysis is based on the following two key assumptions:

- penetration of land use in any one county will be limited to 10 percent of all available acres of all soil types,
- No more than 50% of the area of any individual soil series within a county will be dedicated to biomass production.

The two land use options, conventional rent and use of CRP lands required two parallel paths of analysis and presentation. The single CRP eligibility criteria determinable from available data was the soil erosion index (EI). An Excel spreadsheet was developed to calculate EI for each soil being evaluated in each county. BEPCEE output for each region was further processed in Excel to join the EI for each soil in each county to all other summary data. The GIS system further processed SSURGO/Landcover/TIGER Roads data to determine available land area by soil series by county.

Table 2.8.1 indicates the most profitable grain crop, as calculated by BEPCEE, for each soil series for each climate region. The actual crops planted do not follow this pattern closely, since farmers consider many variables, including risk of crop failure and market price decline, crop rotation and erosion control, complementary scheduling of planting and harvest, and local markets in deciding what mix of crops to plant. The most profitable crop does represent the average “worst case” competition for land use for biomass crops.

Current CRP eligibility rules are complex and require first hand knowledge of many factors about a land parcel being evaluated. The environmental benefits index calculation procedure addresses a wide range of historical, existing, and modifiable land attributes. While the GIS system used for this project provided extensive analysis capabilities, it did not permit screening much of the land across 74 Kansas counties at the parcel level for CRP eligibility. The criteria of an erosion index (EI) greater than 8.0 has been used as a surrogate for all other CRP eligibility criteria for this project. Table 2.8.2 indicates the erosion index and acreages of each soil series by county for each of the six climate regions.

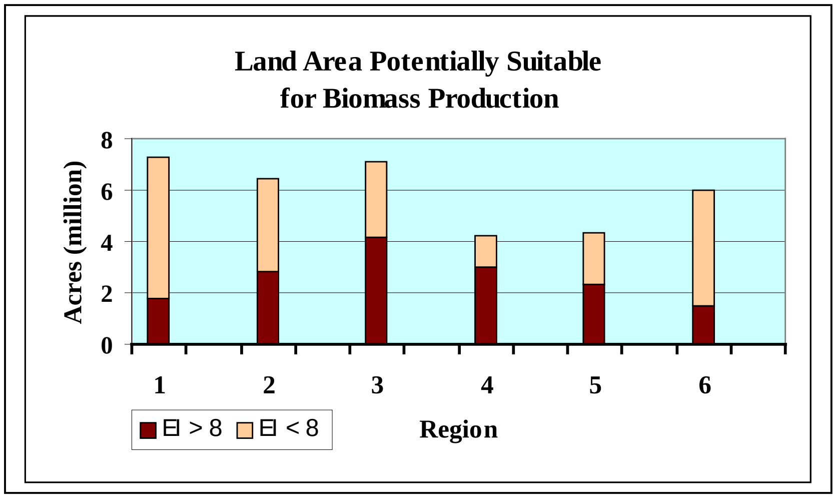

Figure 2.8.1 Land Potentially Suitable for Biomass Production

Table 2.8.1 Land Potentially Suitable for Biomass Production

Soil	Area (acres)	Acres w/ EI >8	% of Total County
Region 1			
Barton County	490,602	31,443	6.41%
Ellis County	618,873	182,582	29.50%
Ellsworth County	566,098	339,885	60.04%
Jewell County	609,978	85,649	14.04%
Lincoln County	519,823	182,214	35.05%
Mitchell County	549,218	47,284	8.61%
Osborne County	789,455	286,402	36.28%
Phillips County	563,259	45,251	8.03%
Rice County	485,061	110,698	22.82%
Rush County	398,065	89,153	22.40%
Rooks County	583,789	114,923	19.69%
Russel County	497,967	165,849	33.31%
Smith County	603,931	84,978	14.07%
Region 1 Total	**7,276,121**	**1,766,310**	**24.28%**
Region 2			
Cloud County	387,159	98,990	25.57%
Chase County	682,339	540,044	79.15%
Clay County	398,157	90,921	22.84%
Dickinson County	520,082	98,035	18.85%
Geary County	312,921	199,951	63.90%
Marion County	602,255	293,715	48.77%
McPherson County	582,146	214,828	36.90%
Morris County	531,858	295,334	55.53%
Ottawa County	509,087	205,490	40.36%
Riley County	429,743	227,890	53.03%
Republic County	441,520	37,160	8.42%
Saline County	506,962	286,286	56.47%
Washington County	552,767	217,255	39.30%
Region 2 Total	**6,456,996**	**2,805,899**	**43.46%**
Region 3			
Atchison County	296,204	175,796	59.35%
Brown County	800,752	317,805	39.69%
Douglas County	253,444	163,607	64.55%
Doniphan County	241,112	60,649	25.15%
Franklin County	391,334	194,768	49.77%
Jackson County	440,903	353,775	80.24%
Jefferson County	337,434	255,304	75.66%
Johnson County	209,510	100,279	47.86%
Leavenworth County	231,054	141,996	61.46%
Lyon County	580,562	299,632	51.61%
Miami County	305,926	154,970	50.66%
Marshall County	568,660	272,246	47.87%
Nemaha County	493,372	373,281	75.66%
Osage County	454,920	228,985	50.34%
Pottawatomie County	592,226	389,449	65.76%
Shawnee County	279,462	179,672	64.29%
Wabaunsee County	626,686	493,913	78.81%
Wyandotte County	32,194	17,614	54.71%
Region 3 Total	**7,135,756**	**4,173,742**	**58.49%**

Table 2.8.1 Land Potentially Suitable for Biomass Production (continued)

Soil	Area (acres)	Acres w/ EI >8	% of Total County
Region 4			
Allen County	291,717	192,418	65.96%
Anderson County	362,926	303,552	83.64%
Bourbon County	345,999	221,741	64.09%
Coffey County	417,600	294,974	70.64%
Cherokee County	305,576	216,664	70.90%
Crawford County	301,752	183,667	60.87%
Labette County	391,461	297,431	75.98%
Linn County	289,834	223,402	77.08%
Montgomery County	428,538	318,589	74.34%
Neosho County	350,348	233,470	66.64%
Wilson County	398,942	300,681	75.37%
Woodson County	329,169	238,070	72.32%
Region 4 Total	**4,213,861**	**3,024,659**	**71.78%**
Region 5			
Butler County	1,027,556	610,141	59.38%
Cowley County	758,352	530,156	69.91%
Chautauqua County	443,829	372,506	83.93%
Elk County	499,661	446,728	89.41%
Greenwood County	377,894	326,827	86.49%
Harvey County	317,762	32,528	10.24%
Sedgwick County	167,712	6,522	3.89%
Sumner County	745,064	21,043	2.82%
Region 5 Total	**4,337,831**	**2,346,450**	**54.09%**
Region 6			
Barber County	897,822	418,980	46.67%
Comanche	645,885	302,474	46.83%
Edwards County	415,605	52,100	12.54%
Harper County	503,207	60,334	11.99%
Kingman County	550,024	72,347	13.15%
Kiowa County	512,259	177,773	34.70%
Pawnee County	471,135	55,163	11.71%
Pratt County	507,177	197,331	38.91%
Reno County	934,980	106,606	11.40%
Stafford County	548,100	48,310	8.81%
Region 6 Total	**5,986,194**	**1,491,418**	**24.91%**

2.8.1 Switchgrass Average Yields and Cost (edge of field)

Figure 2.8.2 shows the 24 year maximum, average, and minimum yields, area weighted average for all soils within each of the six climate regions. Switchgrass average annual yields were highest in region 4 (6.22 dry tons/acre) [13.97 Mg/ha], followed closely by region 5 (6.05 dry tons/acre) [13.59 Mg/ha]. The maximum single year average yield occurred in region 3 (10.87 dry tons/acre) [24.41 Mg/ha] and the minimum single year yield average occurred in region 1 (0.26 dry tons/acre) [0.58 Mg/ha]. The 24 year area weighted average of all soil series provides an indication of the potential productivity within a region, however, invidual soil series average yields were evaluated to identify potentially lowest cost opportunities. Soil series with the highest maximum yields were; Tulley (7.29 dry tons/acre) [16.37 Mg/ha] in Region 1, Kennebec (11.72 dry tons/acre) [26.32 Mg/ha] in Region 2, Kennebec (14.87 dry tons/acre) [33.39 Mg/ha] in Region 3, Prue (12.53 dry tons/acre) [28.14 Mg/ha] in Region 4, Reinach (10.14 dry tons/acre) [22.77 Mg/ha] in Region 5, and Kirkland (9.80 dry tons/acre) [22.01 Mg/ha] in Region 6. Switchgrass responds well to moisture, heat, and productive soils. Additional yield information is provided in Table 2.8.2 and Figure 2.8.5 below and Appendix B.2.

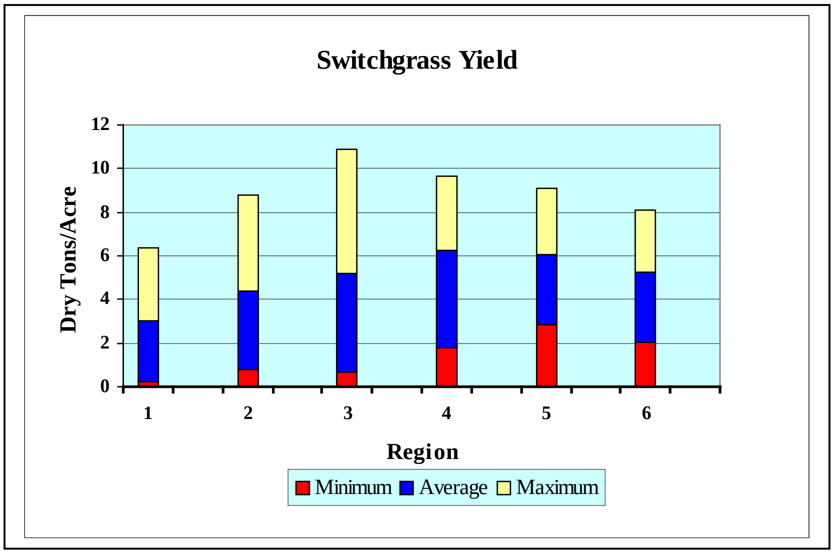

Figure 2.8.2 Switchgrass 24 Year Average Yield

Figure 2.8.3 shows switchgrass average 24 year production cost per dry ton in current non-discounted dollars by region. Costs are shown for the CRP case (rent at 40% of federal CRP rate plus 10% profit), the added incremental cost for full conventional rent (before profit), and the cost required to equal the average profit from the most profitable grain. For the CRP scenario the lowest average cost was region 4 at ($21.25/dry ton)

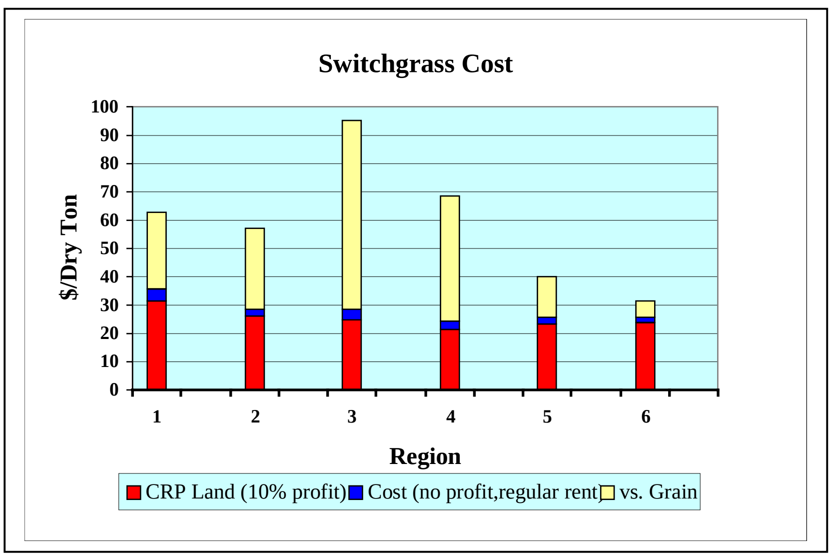

Figure 2.8.3 Switchgrass 24 Year Average Cost
(edge of field)

[$24.43/Mg]. Regions 2, 3, 5, and 6 were within 22% with only region 1 notably higher at ($31.33/dry ton) [$34.54/Mg]. Competing with grain dramatically raised switchgrass cost in regions 1,2, 3, and 4. Regions 5 and 6 where switchgrass yields were still relatively high and the most profitable crop generally changed from soybeans to wheat were less impacted by grain competition. As with yield, the lowest cost soil series was significantly different from the average. Soil series with the lowest 24 year average edge of field cost for the CRP scenario were Gibbon, ($23.98/dry ton) [$26.44/Mg] for region 1, Kennebec, ($18.00/dry ton) [$19.85 /Mg] for region 2, Kennebec, ($17.74/dry ton) [$19.56/Mg] for region 3, Summit, ($17.95/dry ton) [$19.79/Mg] for region 4, Verdigris, ($17.91/dry ton) [$19.75/Mg] for region 5, and Lesho, ($20.35/dry ton) [$22.44/Mg] for region 6. Additional detail on edge of field cost is provided Table 2.8.2 and Figures 2.8.6 and 2.8.7 below and Appendix B.2.

Figure 2.8.4 provides a breakdown of switchgrass average production cost by major component by region. The ALMANAC model applied nitrogen in response to plant stress to maximize yield. Nitrogen application levels are summarized in Table 2.8.2 below and detailed in Appendix B.2. Nitrogen is the single largest cost after land, and changes in nitrogen cost will directly affect switchgrass production cost. Table 2.8.2 below shows key yield and market cost values for soil series, the lowest and highest estimated switchgrass edge of field cost. Soil series potentially eligible for CRP, based on an erosion index greater than 8, are shown in italics, followed by values for all other soils. Data on all soil series are in Appendix B.2.

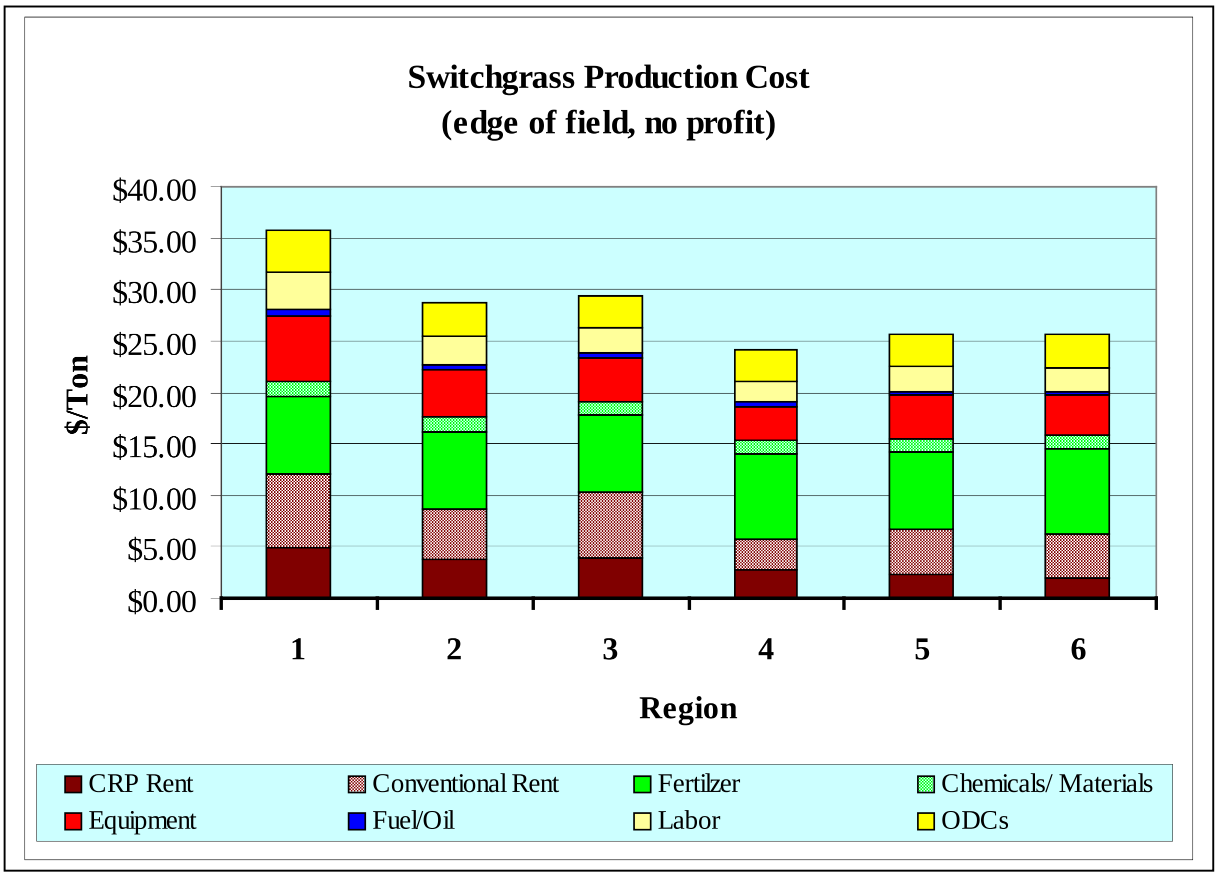

Figure 2.8.4 Switchgrass Production Cost Breakdown (edge of field)

Table 2.8.2 Switchgrass Yield and Market Cost ($1998) Region 1

(low and high price by soil for *CRP (in italics)* and all other soils)

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	**Area (acres)**	**Erosion Index (EI)**	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conven-tional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Barton County											
NUCKOLLS	*166*	*14.77*	*6.44*	*0.25*	*3.14*	*75*	*$2.22*	*$4.04*	*$4.72*	*$4.95*	***$1.95***
NIBSON	*19,369*	*40.28*	*5.25*	*0.14*	*2.07*	*49*	*$2.97*	*$4.36*	*$5.36*	*$5.66*	***$2.34***
NESS	693	1.16	7.01	0.30	3.53	63	**$1.90**	**$3.70**	$4.32	$4.56	$1.55
DILLWYN	2,756	1.53	5.56	0.24	2.80	80	**$2.50**	**$4.20**	$4.94	$5.24	$2.09
Ellis County											
CARLSON	*57,986*	*19.95*	*6.68*	*0.26*	*3.22*	*84*	*$2.23*	*$4.22*	*$4.87*	*$5.15*	***$1.91***
CANLON	*3,075*	*41.94*	*4.24*	*0.10*	*1.65*	*43*	*$3.63*	*$5.26*	*$6.94*	*$7.32*	***$2.92***
ROXBURY	42,053	2.99	6.97	0.30	3.36	68	**$2.05**	**$3.71**	$4.38	$4.60	$1.88
INAVALE	2,754	6.94	5.97	0.25	3.01	86	**$2.40**	**$4.40**	$5.08	$5.42	$2.03
Ellsworth County											
SMOLAN	*37*	*19.28*	*6.57*	*0.27*	*3.20*	*84*	*$2.25*	*$3.98*	*$4.61*	*$4.87*	***$1.67***
HEDVILLE	*103,656*	*24.62*	*4.34*	*0.11*	*2.02*	*39*	*$2.94*	*$3.79*	*$4.91*	*$5.14*	***$2.39***
ROXBURY	9,005	3.28	6.97	0.30	3.36	68	**$2.05**	**$3.71**	$4.38	$4.60	$1.88
JANSEN	6,170	4.73	6.18	0.26	3.00	73	**$2.30**	**$4.06**	$4.76	$5.03	$2.04
Jewell County											
NUCKOLLS	*23,987*	*14.77*	*6.44*	*0.25*	*3.14*	*75*	*$2.22*	*$4.04*	*$4.72*	*$4.95*	***$1.95***
HEIZER	*20,178*	*199.91*	*3.21*	*0.06*	*1.58*	*38*	*$3.72*	*$3.39*	*$4.82*	*$5.06*	***$2.83***
ROXBURY	61,499	2.87	6.97	0.30	3.36	68	**$2.05**	**$3.71**	$4.38	$4.60	$1.88
CORINTH	12,644	7.72	6.33	0.18	2.52	64	**$2.64**	**$4.98**	$5.78	$6.22	$2.11
Lincoln County											
EDALGO	*18,372*	*19.46*	*6.35*	*0.22*	*2.91*	*60*	*$2.25*	*$4.36*	*$5.12*	*$5.35*	***$1.85***
HEDVILLE	*39,270*	*22.31*	*4.34*	*0.11*	*2.02*	*39*	*$2.94*	*$3.79*	*$4.91*	*$5.14*	***$2.39***
ROXBURY	36,282	2.97	6.97	0.30	3.36	68	**$2.05**	**$3.71**	$4.38	$4.60	$1.88
NEW CAMBRIA	15,518	1.20	6.15	0.23	2.96	65	**$2.26**	**$4.06**	$4.75	$4.96	$1.96
Mitchell County											
EDALGO	*26*	*18.79*	*6.35*	*0.22*	*2.91*	*60*	*$2.25*	*$4.36*	*$5.12*	*$5.35*	***$1.85***
TIMKEN	*2,659*	*45.90*	*3.64*	*0.01*	*1.41*	*36*	*$4.11*	*$17.22*	*$23.52*	*$23.76*	***$3.39***
TULLY	7,245	6.12	7.29	0.31	3.48	72	**$1.98**	**$3.99**	$4.60	$4.80	$1.69
CORINTH	32,576	7.72	6.33	0.18	2.52	64	**$2.64**	**$4.98**	$5.78	$6.22	$2.11
Osborne County											
NUCKOLLS	*71,875*	*13.72*	*6.44*	*0.25*	*3.14*	*75*	*$2.22*	*$4.04*	*$4.72*	*$4.95*	***$1.95***
TIMKEN	*9,612*	*42.62*	*3.64*	*0.01*	*1.41*	*36*	*$4.11*	*$17.22*	*$23.52*	*$23.76*	***$3.39***
ROXBURY	45,687	2.67	6.97	0.30	3.36	68	**$2.05**	**$3.71**	$4.38	$4.60	$1.88
CORINTH	8,961	7.17	6.33	0.18	2.52	64	**$2.64**	**$4.98**	$5.78	$6.22	**$2.11**
Phillips County											
VALENTINE	*638*	*8.56*	*5.66*	*0.24*	*2.84*	*82*	*$2.50*	*$4.24*	*$4.97*	*$5.26*	***$1.84***
CANLON	*3,297*	*40.26*	*4.24*	*0.10*	*1.65*	*43*	*$3.63*	*$5.26*	*$6.94*	*$7.32*	***$2.92***
ROXBURY	35,310	2.87	6.97	0.30	3.36	68	**$2.05**	**$3.71**	$4.38	$4.60	$1.88
INAVALE	2,222	6.67	5.97	0.25	3.01	86	**$2.40**	**$4.40**	$5.08	$5.42	$2.03
Rice County											
SMOLAN	*36,469*	*19.28*	*6.57*	*0.27*	*3.20*	*84*	*$2.25*	*$3.98*	*$4.61*	*$4.87*	***$1.67***
HEDVILLE	*8,862*	*24.62*	*4.34*	*0.11*	*2.02*	*39*	*$2.94*	*$3.79*	*$4.91*	*$5.14*	***$2.39***
KASKI	5,108	1.33	6.98	0.30	3.47	70	**$2.00**	**$4.09**	$4.72	$5.01	$1.82
DILLWYN	30,878	1.74	5.56	0.24	2.80	80	**$2.50**	**$4.20**	$4.94	$5.24	$2.09
Rush County											
ARMO	*180*	*8.30*	*6.92*	*0.28*	*3.31*	*81*	*$2.15*	*$4.31*	*$4.95*	*$5.26*	***$1.88***
BOGUE	*1,521*	*15.39*	*3.95*	*0.12*	*1.93*	*54*	*$3.25*	*$2.76*	*$3.68*	*$3.75*	***$2.55***
ROXBURY	46,983	3.11	6.97	0.30	3.36	68	**$2.05**	**$3.71**	$4.38	$4.60	$1.88
INAVALE	4	7.22	5.97	0.25	3.01	86	**$2.40**	**$4.40**	$5.08	$5.42	$2.03
Rooks County											
CARLSON	*756*	*19.95*	*6.68*	*0.26*	*3.22*	*84*	*$2.23*	*$4.22*	*$4.87*	*$5.15*	***$1.91***
CANLON	*219*	*41.94*	*4.24*	*0.10*	*1.65*	*43*	*$3.63*	*$5.26*	*$6.94*	*$7.32*	***$2.92***
ROXBURY	33,366	2.99	6.97	0.30	3.36	68	**$2.05**	**$3.71**	$4.38	$4.60	$1.88
INAVALE	6,069	6.94	5.97	0.25	3.01	86	**$2.40**	**$4.40**	$5.08	$5.42	$2.03

Table 2.8.2 Switchgrass Yield and Market Cost ($1998) Region 1 (continued)

(low and high price by soil for *CRP (in italics)* and all other soils)

Land Area & Erosion Index			**Yield**			**Nitrogen**	**Market Price**				
Soil	**Area (acres)**	**Erosion Index (EI)**	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conventional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Russel County											
EDALGO	*1,519*	*18.79*	*6.35*	*0.22*	*2.91*	*60*	*$2.25*	*$4.36*	*$5.12*	*$5.35*	***$1.85***
HEIZER	*663*	*199.91*	*3.21*	*0.06*	*1.58*	*38*	*$3.72*	*$3.39*	*$4.82*	*$5.06*	***$2.83***
ROXBURY	43,567	2.87	6.97	0.30	3.36	68	**$2.05**	**$3.71**	$4.38	$4.60	$1.88
CORINTH	22,841	7.72	6.33	0.18	2.52	64	**$2.64**	**$4.98**	$5.78	$6.22	$2.11
Smith County											
CAMPUS	*4,172*	*37.40*	*7.08*	*0.25*	*3.24*	*88*	*$2.25*	*$4.48*	*$5.20*	*$5.47*	***$1.93***
CANLON	*4,172*	*37.40*	*4.24*	*0.10*	*1.65*	*43*	*$3.63*	*$5.26*	*$6.94*	*$7.32*	***$2.92***
ROXBURY	70,292	2.67	6.97	0.30	3.36	68	**$2.05**	**$3.71**	$4.38	$4.60	$1.88
CORINTH	1	7.17	6.33	0.18	2.52	64	**$2.64**	**$4.98**	$5.78	$6.22	$2.11
Region Total	**7,276,121**										

Table 2.8.2 Switchgrass Yield and Market Cost ($1998) Region 2

(low and high price by soil for *CRP (in italics)* and all other soils)

Land Area & Erosion Index			**Yield**			**Nitrogen**	**Market Price**				
Soil	**Area (acres)**	**Erosion Index (EI)**	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conventional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Cloud County											
LONGFORD	*29,956*	*11.30*	*10.39*	*1.04*	*4.94*	*127*	*$1.70*	*$3.05*	*$3.40*	*$3.63*	***$1.55***
HEDVILLE	*16,143*	*23.85*	*5.06*	*0.03*	*2.58*	*56*	*$2.47*	*$8.88*	*$11.22*	*$11.65*	***$2.14***
TULLY	374	6.78	10.98	1.25	5.40	128	**$1.58**	**$2.70**	$3.03	$3.22	$1.51
SARPY	2,731	5.13	7.79	0.83	4.12	120	**$2.00**	**$2.35**	$2.73	$2.92	$1.98
Chase County											
MATFIELD	*30,241*	*49.45*	*10.27*	*1.15*	*5.11*	*126*	*$1.64*	*$2.98*	*$3.30*	*$3.55*	***$1.47***
SOGN	*149,416*	*30.04*	*3.96*	*0.03*	*1.69*	*30*	*$3.33*	*$11.11*	*$13.47*	*$15.00*	***$2.65***
CHASE	8,246	4.08	11.62	1.36	5.68	132	**$1.53**	**$2.85**	$3.16	$3.41	$1.46
OSAGE	7,127	3.53	8.59	1.01	4.58	120	**$1.80**	**$2.62**	$2.99	$3.14	$1.70
Clay County											
HOLDER	*2,811*	*9.34*	*9.92*	*1.02*	*4.70*	*134*	*$1.82*	*$2.96*	*$3.32*	*$3.52*	***$1.45***
SOGN	*12,356*	*26.10*	*3.96*	*0.03*	*1.69*	*30*	*$3.33*	*$11.11*	*$13.47*	*$15.00*	***$2.65***
CALCO	451	1.24	11.20	1.35	5.54	106	**$1.45**	**$3.10**	$3.40	$3.70	$1.33
SARPY	2,155	4.94	7.79	0.83	4.12	120	**$2.00**	**$2.35**	$2.73	$2.92	$1.98
Dickinson County											
WELLS	*11,748*	*8.92*	*10.40*	*1.09*	*5.01*	*134*	*$1.72*	*$3.25*	*$3.56*	*$3.92*	***$1.66***
SOGN	*22,700*	*28.48*	*3.96*	*0.03*	*1.69*	*30*	*$3.33*	*$11.11*	*$13.47*	*$15.00*	***$2.65***
TULLY	752	7.12	10.98	1.25	5.40	128	**$1.58**	**$2.70**	$3.03	$3.22	$1.51
ELSMERE	668	3.48	8.68	0.91	4.43	115	**$1.84**	**$2.59**	$2.93	$3.15	$1.77
Geary County											
HOLDER	*3,673*	*10.48*	*9.92*	*1.02*	*4.70*	*134*	*$1.82*	*$2.96*	*$3.32*	*$3.52*	*$1.45*
SOGN	*49,102*	*29.27*	*3.96*	*0.03*	*1.69*	*30*	*$3.33*	*$11.11*	*$13.47*	*$15.00*	*$2.65*
KAHOLA	10,544	3.44	10.84	1.36	5.38	118	**$1.56**	**$2.66**	$2.99	$3.22	$1.55
SARPY	884	5.54	7.79	0.83	4.12	120	**$2.00**	**$2.35**	$2.73	$2.92	$1.98
Marion County											
FLORENCE	*4,135*	*50.05*	*8.05*	*0.81*	*4.06*	*100*	*$1.88*	*$2.57*	*$2.93*	*$3.08*	***$1.63***
SOGN	*51,446*	*29.27*	*3.96*	*0.03*	*1.69*	*30*	*$3.33*	*$11.11*	*$13.47*	*$15.00*	***$2.65***
VERDIGRIS	40,532	3.44	11.24	1.39	5.50	112	**$1.48**	**$3.21**	$3.51	$3.83	$1.31
ROSEHILL	19,069	6.99	7.20	0.17	3.58	91	**$2.07**	**$4.45**	$5.15	$5.38	$1.89

Table 2.8.2 Switchgrass Yield and Market Cost ($1998) Region 2 (continued)

(low and high price by soil for *CRP (in italics)* and all other soils)

Land Area & Erosion Index			**Yield**			**Nitrogen**	**Market Price**				
Soil	**Area (acres)**	**Erosion Index (EI)**	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conven-tional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
McPherson County											
PRATT	*355*	*8.34*	*9.37*	*0.91*	*4.63*	*139*	*$1.87*	*$3.05*	*$3.36*	*$3.65*	***$1.50***
HEDVILLE	*59,205*	*26.93*	*5.06*	*0.03*	*2.58*	*56*	*$2.47*	*$8.88*	*$11.22*	*$11.65*	***$2.14***
NESS	681	1.45	10.11	1.24	5.27	119	**$1.57**	**$2.87**	$3.18	$3.41	$1.24
DRUMMOND	1,240	6.35	9.49	0.96	4.63	139	**$1.86**	**$3.02**	$3.36	$3.58	$1.71
Morris County											
SMOLAN	*2,626*	*20.72*	*10.15*	*0.99*	*4.75*	*134*	*$1.79*	*$3.09*	*$3.44*	*$3.68*	***$1.61***
SOGN	*37,493*	*30.06*	*3.96*	*0.03*	*1.69*	*30*	*$3.33*	*$11.11*	*$13.47*	*$15.00*	***$2.65***
CHASE	2,505	4.08	11.62	1.36	5.68	132	**$1.53**	**$2.85**	$3.16	$3.41	$1.46
OSAGE	330	3.53	8.59	1.01	4.58	120	**$1.80**	**$2.62**	$2.99	$3.14	$1.70
Ottawa County											
ARMO	*3,409*	*8.76*	*10.52*	*1.06*	*4.93*	*132*	*$1.73*	*$3.40*	*$3.71*	*$4.07*	***$1.62***
HEDVILLE	*86,667*	*24.62*	*5.06*	*0.03*	*2.58*	*56*	*$2.47*	*$8.88*	*$11.22*	*$11.65*	***$2.14***
TULLY	21	7.00	10.98	1.25	5.40	128	**$1.58**	**$2.70**	$3.03	$3.22	$1.51
ELS	984	2.05	7.59	0.80	4.06	118	**$1.99**	**$2.56**	$2.90	$3.09	$1.83
Riley County											
PAWNEE	*160*	*11.78*	*9.68*	*1.04*	*4.97*	*106*	*$1.60*	*$2.56*	*$2.90*	*$3.06*	***$1.48***
SOGN	*69,085*	*28.48*	*3.96*	*0.03*	*1.69*	*30*	*$3.33*	*$11.11*	*$13.47*	*$15.00*	***$2.65***
KENNEBEC	7,790	2.92	11.72	1.43	5.87	68	**$1.23**	**$2.58**	$2.90	$3.11	$1.14
SARPY	2,919	5.39	7.79	0.83	4.12	120	**$2.00**	**$2.35**	$2.73	$2.92	$1.98
Republic County											
LONGFORD	*252*	*10.57*	*10.39*	*1.04*	*4.94*	*127*	*$1.70*	*$3.05*	*$3.40*	*$3.63*	***$1.55***
HEDVILLE	*4,162*	*22.31*	*5.06*	*0.03*	*2.58*	*56*	*$2.47*	*$8.88*	*$11.22*	*$11.65*	***$2.14***
TULLY	9,054	6.34	10.98	1.25	5.40	128	**$1.58**	**$2.70**	$3.03	$3.22	$1.51
SARPY	2,650	4.80	7.79	0.83	4.12	120	**$2.00**	**$2.35**	$2.73	$2.92	$1.98
Saline County											
LONGFORD	*25,081*	*12.02*	*10.39*	*1.04*	*4.94*	*127*	*$1.70*	*$3.05*	*$3.40*	*$3.63*	***$1.55***
HEDVILLE	*86,300*	*25.39*	*5.06*	*0.03*	*2.58*	*56*	*$2.47*	*$8.88*	*$11.22*	*$11.65*	***$2.14***
IRWIN	19,145	1.81	10.47	1.20	5.31	124	**$1.58**	**$2.52**	$2.85	$3.00	$1.49
ORTELLO	1,022	7.05	9.15	0.96	4.63	129	**$1.83**	**$2.83**	$3.17	$3.42	$1.78
Washington County											
PAWNEE	*2,041*	*10.48*	*9.68*	*1.04*	*4.97*	*106*	*$1.60*	*$2.56*	*$2.90*	*$3.06*	***$1.48***
SOGN	*14,534*	*25.31*	*3.96*	*0.03*	*1.69*	*30*	*$3.33*	*$11.11*	*$13.47*	*$15.00*	***$2.65***
KENNEBEC	553	2.60	11.72	1.43	5.87	68	**$1.23**	**$2.58**	$2.90	$3.11	$1.14
SARPY	7	4.79	7.79	0.83	4.12	120	**$2.00**	**$2.35**	$2.73	$2.92	$1.98
Region Total	**6,456,996**										

Table 2.8.2 Switchgrass Yield and Market Cost ($1998) Region 3

(low and high price by soil for *CRP (in italics)* and all other soils)

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	**Area (acres)**	**Erosion Index (EI)**	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conven-tional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Atchison County											
PAWNEE	*57,287*	*11.66*	*10.99*	*1.25*	*5.57*	*121*	*$1.66*	*$3.64*	*$3.96*	*$4.38*	***$1.47***
KIPSON	*6*	*28.17*	*6.84*	*0.01*	*2.72*	*68*	*$2.77*	*$57.21*	*$59.10*	*$71.59*	***$2.28***
KENNEBEC	19,993	2.89	14.87	1.52	7.03	92	**$1.25**	**$4.00**	$4.26	$4.82	$1.12
SARPY	553	5.33	8.70	0.96	4.48	126	**$2.06**	**$3.18**	$3.44	$3.86	$1.84
Brown County											
BURCHARD	*2,786*	*16.55*	*11.36*	*1.30*	*5.60*	*133*	*$1.69*	*$4.83*	*$5.01*	*$5.83*	***$1.49***
SOGN	*2,505*	*27.41*	*4.52*	*0.01*	*1.76*	*32*	*$3.73*	*$32.61*	*$38.19*	*$44.81*	***$2.91***
KENNEBEC	132,433	2.82	14.87	1.52	7.03	92	**$1.25**	**$4.00**	$4.26	$4.82	$1.12
WAMEGO	7,121	16.35	8.05	0.14	3.37	76	**$2.32**	**$10.56**	$11.15	$13.11	$1.94
Douglas County											
JUDSON	*928*	*9.30*	*13.78*	*0.78*	*6.30*	*116*	*$1.49*	*$5.25*	*$5.52*	*$6.42*	***$1.40***
SOGN	*9,823*	*29.69*	*4.52*	*0.01*	*1.76*	*32*	*$3.73*	*$32.61*	*$38.19*	*$44.81*	***$2.91***
KENNEBEC	10,169	3.05	14.87	1.52	7.03	92	**$1.25**	**$4.00**	$4.26	$4.82	$1.12
SARPY	1,446	5.62	8.70	0.96	4.48	126	**$2.06**	**$3.18**	$3.44	$3.86	$1.84
Doniphan County											
JUDSON	*4,343*	*8.82*	*13.78*	*0.78*	*6.30*	*116*	*$1.49*	*$5.25*	*$5.52*	*$6.42*	***$1.40***
SOGN	*1,418*	*28.17*	*4.52*	*0.01*	*1.76*	*32*	*$3.73*	*$32.61*	*$38.19*	*$44.81*	***$2.91***
KENNEBEC	13,218	2.89	14.87	1.52	7.03	92	**$1.25**	**$4.00**	$4.26	$4.82	$1.12
ONAWA	12,540	3.82	10.22	1.09	5.02	138	**$1.92**	**$3.28**	$3.58	$3.95	$1.79
SARPY	1,579	5.33	8.70	0.96	4.48	126	**$2.06**	**$3.18**	$3.44	$3.86	$1.84
Franklin County											
LULA	*54,940*	*9.57*	*11.06*	*0.37*	*4.83*	*137*	*$1.96*	*$6.08*	*$6.55*	*$7.35*	***$1.43***
HECTOR	*1,502*	*24.97*	*4.62*	*0.05*	*2.06*	*55*	*$3.44*	*$5.83*	*$7.45*	*$8.56*	***$2.56***
VERDIGRIS	24,812	3.56	14.04	0.28	6.14	131	**$1.55**	**$7.56**	$7.76	$9.17	$1.31
WOODSON	42,801	7.97	10.13	1.12	5.13	136	**$1.86**	**$3.40**	$3.64	$4.10	$1.67
Jackson County											
PAWNEE	*127,723*	*11.66*	*10.99*	*1.25*	*5.57*	*121*	*$1.66*	*$3.64*	*$3.96*	*$4.38*	***$1.47***
SOGN	*22,754*	*28.17*	*4.52*	*0.01*	*1.76*	*32*	*$3.73*	*$32.61*	*$38.19*	*$44.81*	***$2.91***
KENNEBEC	32,084	2.89	14.87	1.52	7.03	92	**$1.25**	**$4.00**	$4.26	$4.82	$1.12
WYMORE	30,058	6.50	9.85	1.10	4.98	130	**$1.90**	**$3.44**	$3.74	$4.18	$1.75
Jefferson County											
JUDSON	*2,314*	*9.06*	*13.78*	*0.78*	*6.30*	*116*	*$1.49*	*$5.25*	*$5.52*	*$6.42*	***$1.40***
SOGN	*8,174*	*28.93*	*4.52*	*0.01*	*1.76*	*32*	*$3.73*	*$32.61*	*$38.19*	*$44.81*	***$2.91***
KENNEBEC	16,988	2.97	14.87	1.52	7.03	92	**$1.25**	**$4.00**	$4.26	$4.82	$1.12
SARPY	1,404	5.48	8.70	0.96	4.48	126	**$2.06**	**$3.18**	$3.44	$3.86	$1.84
Johnson County											
PAWNEE	*3,000*	*12.24*	*10.99*	*1.25*	*5.57*	*121*	*$1.66*	*$3.64*	*$3.96*	*$4.38*	***$1.47***
SOGN	*6,308*	*29.58*	*4.52*	*0.01*	*1.76*	*32*	*$3.73*	*$32.61*	*$38.19*	*$44.81*	***$2.91***
KENNEBEC	7,652	3.04	14.87	1.52	7.03	92	**$1.25**	**$4.00**	$4.26	$4.82	$1.12
WOODSON	33,973	7.78	10.13	1.12	5.13	136	**$1.86**	**$3.40**	$3.64	$4.10	$1.67
Leavenworth County											
JUDSON	*1,243*	*9.06*	*13.78*	*0.78*	*6.30*	*116*	*$1.49*	*$5.25*	*$5.52*	*$6.42*	***$1.40***
SOGN	*8,975*	*28.93*	*4.52*	*0.01*	*1.76*	*32*	*$3.73*	*$32.61*	*$38.19*	*$44.81*	***$2.91***
KENNEBEC	9,289	2.97	14.87	1.52	7.03	92	**$1.25**	**$4.00**	$4.26	$4.82	$1.12
SARPY	353	5.48	8.70	0.96	4.48	126	**$2.06**	**$3.18**	$3.44	$3.86	$1.84
Lyon County											
DWIGHT	*13,153*	*11.85*	*10.06*	*1.05*	*5.09*	*129*	*$1.83*	*$3.57*	*$3.83*	*$4.29*	***$1.33***
SOGN	*52,879*	*30.04*	*4.52*	*0.01*	*1.76*	*32*	*$3.73*	*$32.61*	*$38.19*	*$44.81*	***$2.91***
CHASE	19,176	4.08	13.90	1.46	6.81	160	**$1.53**	**$3.93**	$4.13	$4.76	$1.47
WOODSON	2,385	7.90	10.13	1.12	5.13	136	**$1.86**	**$3.40**	$3.64	$4.10	$1.67

Table 2.8.2 Switchgrass Yield and Market Cost ($1998) Region 3 (continued)

(low and high price by soil for *CRP (in italics)* and all other soils)

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	Area (acres)	Erosion Index (EI)	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conven-tional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Miami County											
LULA	*281*	*9.81*	*11.06*	*0.37*	*4.83*	*137*	*$1.96*	*$6.08*	*$6.55*	*$7.35*	***$1.43***
ERAM	*34,489*	*12.96*	*8.92*	*0.18*	*3.87*	*102*	*$2.21*	*$8.57*	*$8.77*	*$10.51*	***$1.91***
VERDIGRIS	13,891	3.65	14.04	0.28	6.14	131	**$1.55**	**$7.56**	$7.76	$9.17	$1.31
OSAGE	8,497	3.65	10.33	1.16	5.19	134	**$1.82**	**$3.70**	$4.02	$4.42	$1.56
Marshall County											
BENFIELD	*717*	*69.76*	*9.13*	*0.19*	*4.20*	*91*	*$2.00*	*$7.68*	*$8.33*	*$9.42*	***$1.76***
PAWNEE	*145,336*	*11.13*	*10.99*	*1.25*	*5.57*	*121*	*$1.66*	*$3.64*	*$3.96*	*$4.38*	***$1.47***
KENNEBEC	33,216	2.76	14.87	1.52	7.03	92	**$1.25**	**$4.00**	$4.26	$4.82	$1.12
WYMORE	182,591	6.21	9.85	1.10	4.98	130	**$1.90**	**$3.44**	$3.74	$4.18	$1.75
Nemaha County											
PAWNEE	*174,669*	*11.34*	*10.99*	*1.25*	*5.57*	*121*	*$1.66*	*$3.64*	*$3.96*	*$4.38*	***$1.47***
SOGN	*166*	*27.41*	*4.52*	*0.01*	*1.76*	*32*	*$3.73*	*$32.61*	*$38.19*	*$44.81*	***$2.91***
KENNEBEC	39,643	2.82	14.87	1.52	7.03	92	**$1.25**	**$4.00**	$4.26	$4.82	$1.12
WYMORE	66,101	6.33	9.85	1.10	4.98	130	**$1.90**	**$3.44**	$3.74	$4.18	$1.75
Osage County											
DWIGHT	*2,759*	*11.66*	*10.06*	*1.05*	*5.09*	*129*	*$1.83*	*$3.57*	*$3.83*	*$4.29*	***$1.33***
SOGN	*4,761*	*29.58*	*4.52*	*0.01*	*1.76*	*32*	*$3.73*	*$32.61*	*$38.19*	*$44.81*	***$2.91***
KENNEBEC	245	3.04	14.87	1.52	7.03	92	**$1.25**	**$4.00**	$4.26	$4.82	$1.12
WOODSON	14,456	7.78	10.13	1.12	5.13	136	**$1.86**	**$3.40**	$3.64	$4.10	$1.67
Pottawatomie County											
FLORENCE	*40,525*	*48.70*	*8.87*	*0.97*	*4.27*	*107*	*$2.03*	*$3.21*	*$3.58*	*$3.88*	***$1.42***
SOGN	*94,362*	*28.48*	*4.52*	*0.01*	*1.76*	*32*	*$3.73*	*$32.61*	*$38.19*	*$44.81*	***$2.91***
KENNEBEC	27,562	2.92	14.87	1.52	7.03	92	**$1.25**	**$4.00**	$4.26	$4.82	$1.12
SARPY	3,107	5.39	8.70	0.96	4.48	126	**$2.06**	**$3.18**	$3.44	$3.86	$1.84
Shawnee County											
DWIGHT	*4,430*	*11.41*	*10.06*	*1.05*	*5.09*	*129*	*$1.83*	*$3.57*	*$3.83*	*$4.29*	***$1.33***
SOGN	*23,005*	*28.93*	*4.52*	*0.01*	*1.76*	*32*	*$3.73*	*$32.61*	*$38.19*	*$44.81*	***$2.91***
KENNEBEC	4,849	2.97	14.87	1.52	7.03	92	**$1.25**	**$4.00**	$4.26	$4.82	$1.12
SARPY	2,180	5.48	8.70	0.96	4.48	126	**$2.06**	**$3.18**	$3.44	$3.86	$1.84
Wabaunsee County											
FLORENCE	*57,568*	*51.41*	*8.87*	*0.97*	*4.27*	*107*	*$2.03*	*$3.21*	*$3.58*	*$3.88*	***$1.42***
SOGN	*130,009*	*30.06*	*4.52*	*0.01*	*1.76*	*32*	*$3.73*	*$32.61*	*$38.19*	*$44.81*	***$2.91***
CHASE	6,038	4.08	13.90	1.46	6.81	160	**$1.53**	**$3.93**	$4.13	$4.76	$1.47
SARPY	1,346	5.69	8.70	0.96	4.48	126	**$2.06**	**$3.18**	$3.44	$3.86	$1.84
Wyandotte County											
JUDSON	*226*	*9.06*	*13.78*	*0.78*	*6.30*	*116*	*$1.49*	*$5.25*	*$5.52*	*$6.42*	***$1.40***
SOGN	*1,515*	*28.93*	*4.52*	*0.01*	*1.76*	*32*	*$3.73*	*$32.61*	*$38.19*	*$44.81*	***$2.91***
KENNEBEC	597	2.97	14.87	1.52	7.03	92	**$1.25**	**$4.00**	$4.26	$4.82	$1.12
SARPY	255	5.48	8.70	0.96	4.48	126	**$2.06**	**$3.18**	$3.44	$3.86	$1.84
Region Total	**7,135,756**										

Table 2.8.2 Switchgrass Yield and Market Cost ($1998) — Region 4

(low and high price by soil for *CRP (in italics)* and all other soils)

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	**Area (acres)**	**Erosion Index (EI)**	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conventional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Allen County											
SUMMIT	*246*	*8.35*	*11.59*	*3.75*	*8.43*	*217*	*$1.29*	*$2.28*	*$2.41*	*$2.67*	***$1.13***
COLLINSVILLE	*3,216*	*68.66*	*5.22*	*0.07*	*2.60*	*66*	*$2.52*	*$7.50*	*$9.16*	*$9.95*	***$2.00***
VERDIGRIS	23,735	3.92	11.95	0.86	7.67	165	**$1.26**	**$4.76**	$4.88	$5.81	$1.17
LANTON	94	4.53	10.03	0.16	6.39	166	**$1.49**	**$7.58**	$7.74	$9.31	$1.35
Anderson County											
SUMMIT	*20,570*	*8.16*	*11.59*	*3.75*	*8.43*	*217*	*$1.29*	*$2.28*	*$2.41*	*$2.67*	***$1.13***
COLLINSVILLE	*3,296*	*67.10*	*5.22*	*0.07*	*2.60*	*66*	*$2.52*	*$7.50*	*$9.16*	*$9.95*	***$2.00***
VERDIGRIS	26,359	3.83	11.95	0.86	7.67	165	**$1.26**	**$4.76**	$4.88	$5.81	$1.17
LANTON	4,247	4.43	10.03	0.16	6.39	166	**$1.49**	**$7.58**	$7.74	$9.31	$1.35
Bourbon County											
SUMMIT	*1,509*	*8.35*	*11.59*	*3.75*	*8.43*	*217*	*$1.29*	*$2.28*	*$2.41*	*$2.67*	***$1.13***
HECTOR	*679*	*27.46*	*3.63*	*0.49*	*2.38*	*64*	*$2.72*	*$1.99*	*$2.36*	*$2.80*	***$2.11***
VERDIGRIS	12,566	3.92	11.95	0.86	7.67	165	**$1.26**	**$4.76**	$4.88	$5.81	$1.17
LANTON	6,164	4.53	10.03	0.16	6.39	166	**$1.49**	**$7.58**	$7.74	$9.31	$1.35
Coffey County											
DWIGHT	*852*	*12.56*	*9.53*	*2.55*	*6.39*	*170*	*$1.49*	*$2.44*	*$2.60*	*$2.88*	***$1.15***
COLLINSVILLE	*9,161*	*65.54*	*5.22*	*0.07*	*2.60*	*66*	*$2.52*	*$7.50*	*$9.16*	*$9.95*	***$2.00***
VERDIGRIS	29,101	3.74	11.95	0.86	7.67	165	**$1.26**	**$4.76**	$4.88	$5.81	$1.17
LANTON	5,808	4.32	10.03	0.16	6.39	166	**$1.49**	**$7.58**	$7.74	$9.31	$1.35
Cherokee County											
DENNIS	*81,870*	*8.01*	*11.14*	*3.47*	*8.17*	*234*	*$1.38*	*$2.06*	*$2.14*	*$2.41*	***$1.23***
HECTOR	*1,682*	*29.96*	*3.63*	*0.49*	*2.38*	*64*	*$2.72*	*$1.99*	*$2.36*	*$2.80*	***$2.11***
VERDIGRIS	1,353	4.27	11.95	0.86	7.67	165	**$1.26**	**$4.76**	$4.88	$5.81	$1.17
HEPLER	36,612	2.28	9.62	2.44	6.47	191	**$1.56**	**$2.09**	$2.22	$2.47	$1.43
Crawford County											
KENOMA	*2,052*	*9.37*	*10.73*	*3.27*	*7.55*	*206*	*$1.40*	*$2.08*	*$2.24*	*$2.45*	***$1.26***
HECTOR	*1,352*	*29.34*	*3.63*	*0.49*	*2.38*	*64*	*$2.72*	*$1.99*	*$2.36*	*$2.80*	***$2.11***
VERDIGRIS	1,652	4.18	11.95	0.86	7.67	165	**$1.26**	**$4.76**	$4.88	$5.81	$1.17
GIRARD	5,130	5.58	8.16	0.10	4.67	96	**$1.63**	**$10.06**	$10.28	$12.33	$1.16
Labette County											
DENNIS	*38,879*	*8.01*	*11.14*	*3.47*	*8.17*	*234*	*$1.38*	*$2.06*	*$2.14*	*$2.41*	***$1.23***
HECTOR	*1,895*	*29.96*	*3.63*	*0.49*	*2.38*	*64*	*$2.72*	*$1.99*	*$2.36*	*$2.80*	***$2.11***
VERDIGRIS	16,590	4.27	11.95	0.86	7.67	165	**$1.26**	**$4.76**	$4.88	$5.81	$1.17
HEPLER	9,143	2.28	9.62	2.44	6.47	191	**$1.56**	**$2.09**	$2.22	$2.47	$1.43
Linn County											
SUMMIT	*29,319*	*8.16*	*11.59*	*3.75*	*8.43*	*217*	*$1.29*	*$2.28*	*$2.41*	*$2.67*	***$1.13***
COLLINSVILLE	*683*	*67.10*	*5.22*	*0.07*	*2.60*	*66*	*$2.52*	*$7.50*	*$9.16*	*$9.95*	***$2.00***
VERDIGRIS	13,380	3.83	11.95	0.86	7.67	165	**$1.26**	**$4.76**	$4.88	$5.81	$1.17
HEPLER	256	2.04	9.62	2.44	6.47	191	**$1.56**	**$2.09**	$2.22	$2.47	$1.43
Montgomery County											
STEPHENVILLE	*5,822*	*9.64*	*7.30*	*1.96*	*5.52*	*155*	*$1.64*	*$2.09*	*$2.20*	*$2.46*	***$1.24***
COLLINSVILLE	*43,822*	*73.34*	*5.22*	*0.07*	*2.60*	*66*	*$2.52*	*$7.50*	*$9.16*	*$9.95*	***$2.00***
VERDIGRIS	21,286	4.18	11.95	0.86	7.67	165	**$1.26**	**$4.76**	$4.88	$5.81	$1.17
LANTON	11,058	4.84	10.03	0.16	6.39	166	**$1.49**	**$7.58**	$7.74	$9.31	$1.35
Neosho County											
DARNELL	*3,536*	*87.25*	*6.32*	*0.14*	*3.53*	*102*	*$2.15*	*$7.68*	*$7.89*	*$9.42*	***$1.72***
COLLINSVILLE	*4,860*	*71.78*	*5.22*	*0.07*	*2.60*	*66*	*$2.52*	*$7.50*	*$9.16*	*$9.95*	***$2.00***
WOODSON	*7,609*	*9.17*	*10.13*	*2.67*	*6.62*	*184*	*$1.50*	*$2.27*	*$2.42*	*$2.70*	***$1.35***
VERDIGRIS	20,020	4.09	11.95	0.86	7.67	165	**$1.26**	**$4.76**	$4.88	$5.81	$1.17
CHEROKEE	19	4.83	9.96	2.61	6.50	188	**$1.54**	**$2.32**	$2.46	$2.75	$1.39
Wilson County											
DWIGHT	*5,707*	*13.46*	*9.53*	*2.55*	*6.39*	*170*	*$1.49*	*$2.44*	*$2.60*	*$2.88*	***$1.15***
COLLINSVILLE	*24,427*	*70.22*	*5.22*	*0.07*	*2.60*	*66*	*$2.52*	*$7.50*	*$9.16*	*$9.95*	***$2.00***
VERDIGRIS	23,776	4.01	11.95	0.86	7.67	165	**$1.26**	**$4.76**	$4.88	$5.81	$1.17
GIRARD	808	5.35	8.16	0.10	4.67	96	**$1.63**	**$10.06**	$10.28	$12.33	$1.16

Table 2.8.2 Switchgrass Yield and Market Cost ($1998) Region 4 (continued)

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	**Area (acres)**	**Erosion Index (EI)**	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conven-tional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Woodson County											
SUMMIT	*14,074*	*8.16*	*11.59*	*3.75*	*8.43*	*217*	*$1.29*	*$2.28*	*$2.41*	*$2.67*	***$1.13***
COLLINSVILLE	*28,293*	*67.10*	*5.22*	*0.07*	*2.60*	*66*	*$2.52*	*$7.50*	*$9.16*	*$9.95*	***$2.00***
VERDIGRIS	18,922	3.83	11.95	0.86	7.67	165	**$1.26**	**$4.76**	$4.88	$5.81	$1.17
HEPLER	7,597	2.04	9.62	2.44	6.47	191	**$1.56**	**$2.09**	$2.22	$2.47	$1.43
Region Total	**4,213,861**										

Table 2.8.2 Switchgrass Yield and Market Cost ($1998) Region 5

(low and high price by soil for *CRP (in italics)* and all other soils)

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	**Area (acres)**	**Erosion Index (EI)**	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conven-tional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Butler County											
TULLY	*12,527*	*8.09*	*9.45*	*3.04*	*6.27*	*143*	*$1.40*	*$2.06*	*$2.16*	*$2.29*	***$1.36***
SOGN	*81,847*	*32.35*	*3.61*	*0.03*	*1.78*	*30*	*$3.05*	*$10.74*	*$14.94*	*$16.30*	***$2.07***
VERDIGRIS	71,438	3.80	9.57	3.09	6.27	117	**$1.31**	**$2.48**	$2.56	$2.79	$1.28
ROSEHILL	12,224	7.72	6.35	1.48	3.98	97	**$1.85**	**$2.02**	$2.30	$2.43	$1.67
Cowley County											
SMOLAN	*38,623*	*22.84*	*8.16*	*2.21*	*5.41*	*148*	*$1.61*	*$2.37*	*$2.47*	*$2.65*	***$1.35***
SOGN	*133,892*	*33.12*	*3.61*	*0.03*	*1.78*	*30*	*$3.05*	*$10.74*	*$14.94*	*$16.30*	***$2.07***
VERDIGRIS	32,863	3.89	9.57	3.09	6.27	117	**$1.31**	**$2.48**	$2.56	$2.79	$1.28
ROSEHILL	8,101	7.91	6.35	1.48	3.98	97	**$1.85**	**$2.02**	$2.30	$2.43	$1.67
Chautauqua County											
SMOLAN	*52*	*24.43*	*8.16*	*2.21*	*5.41*	*148*	*$1.61*	*$2.37*	*$2.47*	*$2.65*	***$1.35***
COLLINSVILLE	*10,037*	*72.90*	*4.00*	*0.31*	*2.50*	*60*	*$2.48*	*$1.78*	*$2.31*	*$2.45*	***$2.18***
DENNIS	34,416	7.79	9.58	3.16	6.45	176	**$1.48**	**$1.79**	$2.00	$2.10	$1.45
CLEORA	470	2.60	8.79	2.73	5.93	158	**$1.52**	**$2.21**	$2.28	$2.50	$1.48
Elk County											
MARTIN	*29,226*	*17.53*	*9.32*	*3.05*	*6.37*	*168*	*$1.46*	*$2.14*	*$2.24*	*$2.37*	***$1.39***
COLLINSVILLE	*2,495*	*69.73*	*4.00*	*0.31*	*2.50*	*60*	*$2.48*	*$1.78*	*$2.31*	*$2.45*	***$2.18***
VERDIGRIS	8,012	3.98	9.57	3.09	6.27	117	**$1.31**	**$2.48**	$2.56	$2.79	$1.28
LANTON	4,618	4.60	7.72	2.03	5.16	127	**$1.59**	**$2.40**	$2.46	$2.67	$1.50
Greenwood County											
LULA	*855*	*10.45*	*7.93*	*1.91*	*5.16*	*141*	*$1.65*	*$2.44*	*$2.51*	*$2.72*	***$1.37***
COLLINSVILLE	*12*	*68.15*	*4.00*	*0.31*	*2.50*	*60*	*$2.48*	*$1.78*	*$2.31*	*$2.45*	***$2.18***
VERDIGRIS	120	3.89	9.57	3.09	6.27	117	**$1.31**	**$2.48**	$2.56	$2.79	$1.28
OSAGE	356	3.89	7.42	2.12	5.31	133	**$1.58**	**$2.03**	$2.26	$2.37	$1.44
Harvey County											
SMOLAN	*9,355*	*19.65*	*8.16*	*2.21*	*5.41*	*148*	*$1.61*	*$2.37*	*$2.47*	*$2.65*	***$1.35***
CLIME	*14,046*	*27.37*	*6.52*	*1.30*	*3.95*	*86*	*$1.79*	*$2.39*	*$2.68*	*$2.83*	***$1.60***
VERDIGRIS	0	3.35	9.57	3.09	6.27	117	**$1.31**	**$2.48**	$2.56	$2.79	$1.28
ROSEHILL	19,955	6.80	6.35	1.48	3.98	97	**$1.85**	**$2.02**	$2.30	$2.43	$1.67
Sedgwick County											
VERNON	*1,961*	*9.23*	*8.24*	*2.82*	*6.08*	*177*	*$1.56*	*$1.97*	*$2.18*	*$2.29*	***$1.33***
CLIME	*2,313*	*28.11*	*6.52*	*1.30*	*3.95*	*86*	*$1.79*	*$2.39*	*$2.68*	*$2.83*	***$1.60***
REINACH	240	1.83	10.14	3.53	6.66	154	**$1.36**	**$2.14**	$2.20	$2.38	$1.33
ROSEHILL	6,580	6.99	6.35	1.48	3.98	97	**$1.85**	**$2.02**	$2.30	$2.43	$1.67
Sumner County											
PRATT	*1,830*	*8.40*	*8.08*	*1.93*	*5.38*	*158*	*$1.66*	*$2.23*	*$2.42*	*$2.64*	***$1.40***
TIVOLI	*3,347*	*10.78*	*7.23*	*2.14*	*5.22*	*158*	*$1.71*	*$2.19*	*$2.39*	*$2.59*	***$1.44***
VERDIGRIS	43	3.62	9.57	3.09	6.27	117	**$1.31**	**$2.48**	$2.56	$2.79	$1.28
GRAINOLA	24,605	6.78	6.69	1.40	4.29	123	**$1.86**	**$3.02**	$3.43	$3.55	$1.76
Region Total	**4,337,831**										

Table 2.8.2 Switchgrass Yield and Low to High Market Cost ($1998) Region 6

(low and high price by soil for *CRP (in italics)* and all other soils)

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	**Area (acres)**	**Erosion Index (EI)**	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conventional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Barber County											
VERNON	*115,520*	*9.78*	*9.36*	*2.71*	*5.95*	*172*	*$1.57*	*$1.72*	*$1.89*	*$2.01*	***$1.45***
WOODWARD	*97,464*	*58.98*	*6.85*	*1.13*	*4.12*	*114*	*$1.89*	*$2.42*	*$2.63*	*$2.94*	***$1.67***
PORT	21,090	1.94	9.56	2.62	6.09	145	**$1.44**	**$1.91**	$2.08	$2.25	$1.36
LINCOLN	22,952	1.05	7.65	2.08	4.98	151	**$1.76**	**$2.02**	$2.18	$2.42	$1.58
Comanche											
HARNEY	*1,284*	*5.69*	*8.31*	*2.06*	*5.47*	*135*	*$1.54*	*$2.00*	*$2.18*	*$2.38*	***$1.44***
WELLSFORD	*5,370*	*62.49*	*4.26*	*0.12*	*2.43*	*62*	*$2.59*	*$4.30*	*$5.09*	*$5.52*	***$2.13***
ALBION	61,984	5.33	7.94	2.22	5.15	143	**$1.67**	**$1.82**	$2.00	$2.18	$1.51
KANZA	3,562	0.76	7.88	2.18	5.13	140	**$1.67**	**$1.66**	$1.83	$2.02	$1.60
Edwards County											
CAMPUS	*308*	*45.29*	*8.05*	*1.97*	*5.27*	*151*	*$1.67*	*$2.13*	*$2.32*	*$2.51*	***$1.53***
CANLON	*308*	*45.29*	*4.01*	*0.11*	*2.18*	*58*	*$2.81*	*$3.28*	*$3.96*	*$4.53*	***$2.36***
NESS	805	1.30	8.43	2.34	5.75	123	**$1.43**	**$1.83**	$1.99	$2.18	$1.32
LINCOLN	24	0.93	7.65	2.08	4.98	151	**$1.76**	**$2.02**	$2.18	$2.42	$1.58
Harper County											
VERNON	*2,045*	*8.99*	*9.36*	*2.71*	*5.95*	*172*	*$1.57*	*$1.72*	*$1.89*	*$2.01*	***$1.45***
WOODWARD	*20,171*	*54.24*	*6.85*	*1.13*	*4.12*	*114*	*$1.89*	*$2.42*	*$2.63*	*$2.94*	***$1.67***
ELANDCO	379	2.08	9.01	2.42	5.82	123	**$1.42**	**$2.02**	$2.20	$2.39	$1.32
GRAINOLA	274	6.27	6.64	1.16	4.22	122	**$1.89**	**$2.22**	$2.47	$2.68	$1.54
Kingman County											
VERNON	*173*	*8.50*	*9.36*	*2.71*	*5.95*	*172*	*$1.57*	*$1.72*	*$1.89*	*$2.01*	***$1.45***
TIVOLI	*5,377*	*9.43*	*8.00*	*1.75*	*5.03*	*152*	*$1.74*	*$2.12*	*$2.26*	*$2.53*	***$1.60***
BETHANY	0	1.69	9.43	2.95	6.16	149	**$1.45**	**$1.63**	$1.78	$1.94	$1.41
GRAINOLA	19	5.93	6.64	1.16	4.22	122	**$1.89**	**$2.22**	$2.47	$2.68	$1.54
Kiowa County											
CLARK	*11,552*	*8.22*	*8.39*	*1.92*	*5.39*	*145*	*$1.61*	*$2.29*	*$2.47*	*$2.72*	***$1.47***
CANLON	*3,971*	*43.28*	*4.01*	*0.11*	*2.18*	*58*	*$2.81*	*$3.28*	*$3.96*	*$4.53*	***$2.36***
ELANDCO	1,037	1.91	9.01	2.42	5.82	123	**$1.42**	**$2.02**	$2.20	$2.39	$1.32
LINCOLN	3,443	0.89	7.65	2.08	4.98	151	**$1.76**	**$2.02**	$2.18	$2.42	$1.58
Pawnee County											
ULY	*42,601*	*8.61*	*7.85*	*1.94*	*5.18*	*142*	*$1.66*	*$1.97*	*$2.16*	*$2.32*	***$1.57***
NIBSON	*3,635*	*45.29*	*4.92*	*0.36*	*2.98*	*72*	*$2.22*	*$2.68*	*$2.99*	*$3.41*	***$1.97***
NESS	726	1.30	8.43	2.34	5.75	123	**$1.43**	**$1.83**	$1.99	$2.18	$1.32
ATTICA	18,789	3.86	7.67	1.95	5.11	152	**$1.72**	**$2.25**	$2.39	$2.68	$1.61
Pratt County											
CLARK	*52,490*	*9.40*	*8.39*	*1.92*	*5.39*	*145*	*$1.61*	*$2.29*	*$2.47*	*$2.72*	***$1.47***
TIVOLI	*29,394*	*10.51*	*8.00*	*1.75*	*5.03*	*152*	*$1.74*	*$2.12*	*$2.26*	*$2.53*	***$1.60***
BETHANY	60,271	1.88	9.43	2.95	6.16	149	**$1.45**	**$1.63**	$1.78	$1.94	$1.41
LINCOLN	186	1.02	7.65	2.08	4.98	151	**$1.76**	**$2.02**	$2.18	$2.42	$1.58
Reno County											
SMOLAN	*2,052*	*18.06*	*8.23*	*1.97*	*5.26*	*146*	*$1.65*	*$1.95*	*$2.15*	*$2.32*	***$1.38***
NASH	*6,776*	*8.26*	*6.79*	*1.34*	*4.27*	*112*	*$1.81*	*$2.32*	*$2.51*	*$2.81*	***$1.63***
PORT	816	1.64	9.56	2.62	6.09	145	**$1.44**	**$1.91**	$2.08	$2.25	$1.36
LINCOLN	5	0.89	7.65	2.08	4.98	151	**$1.76**	**$2.02**	$2.18	$2.42	$1.58
Stafford County											
CLARK	*2,633*	*8.81*	*8.39*	*1.92*	*5.39*	*145*	*$1.61*	*$2.29*	*$2.47*	*$2.72*	***$1.47***
TIVOLI	*45,676*	*9.85*	*8.00*	*1.75*	*5.03*	*152*	*$1.74*	*$2.12*	*$2.26*	*$2.53*	***$1.60***
FARNUM	33,621	0.95	9.55	2.44	6.00	160	**$1.52**	**$1.97**	$2.13	$2.33	$1.46
BLANKET	16,945	1.77	9.29	2.56	5.90	156	**$1.53**	**$1.75**	$1.91	$2.09	$1.49
DILLWYN	20,964	1.76	7.57	1.97	4.93	145	**$1.74**	**$1.87**	$2.05	$2.24	$1.62
Region Total	**5,986,194**										

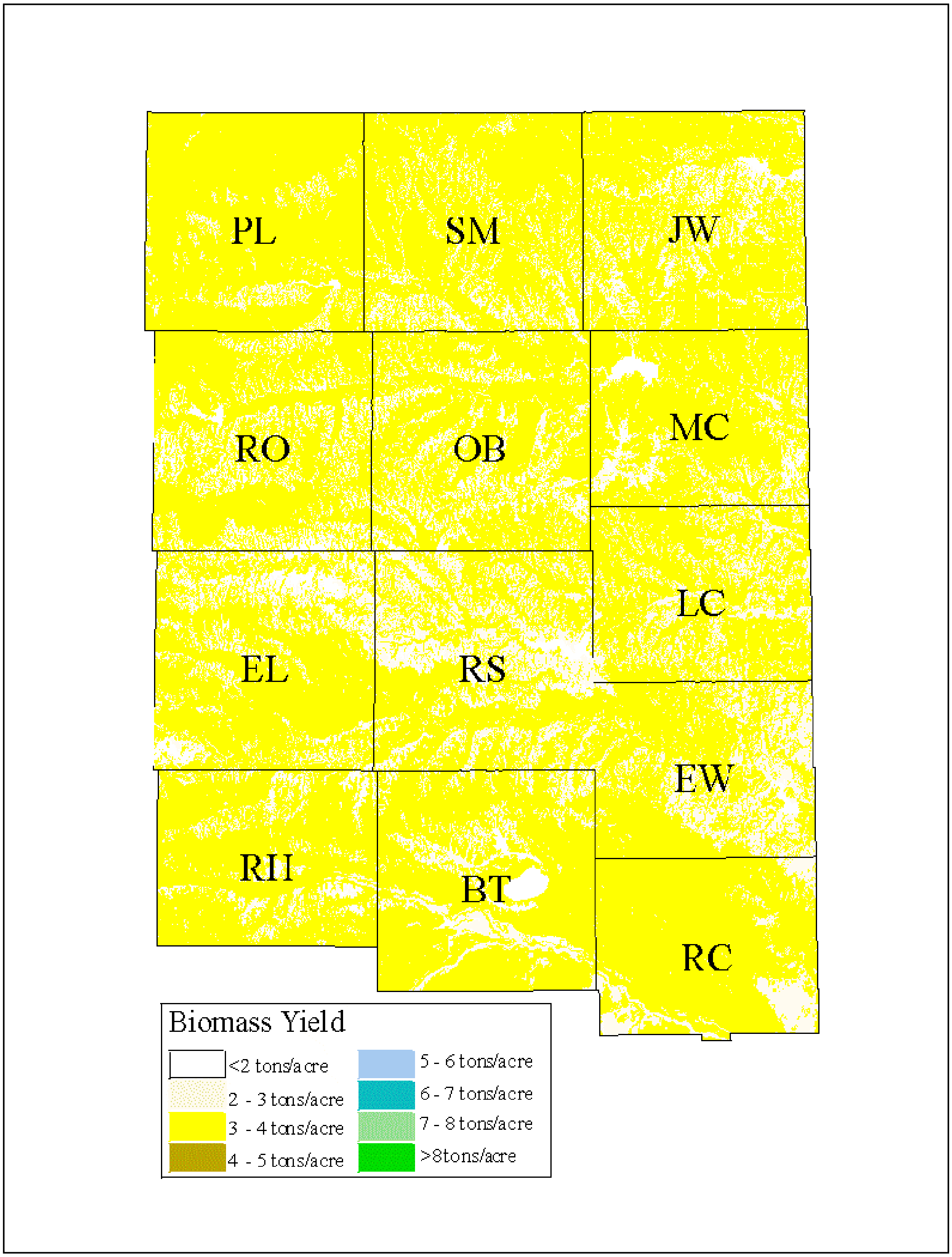

Figure 2.8.5 Map of Switchgrass Average Yield (tons per acre) by Soil Series Region 1
Region 1 had the lowest average switchgrass yield, generally ranging from 3 – 4 dry tons per acre [6.7 – 9.0 Mg/ha].

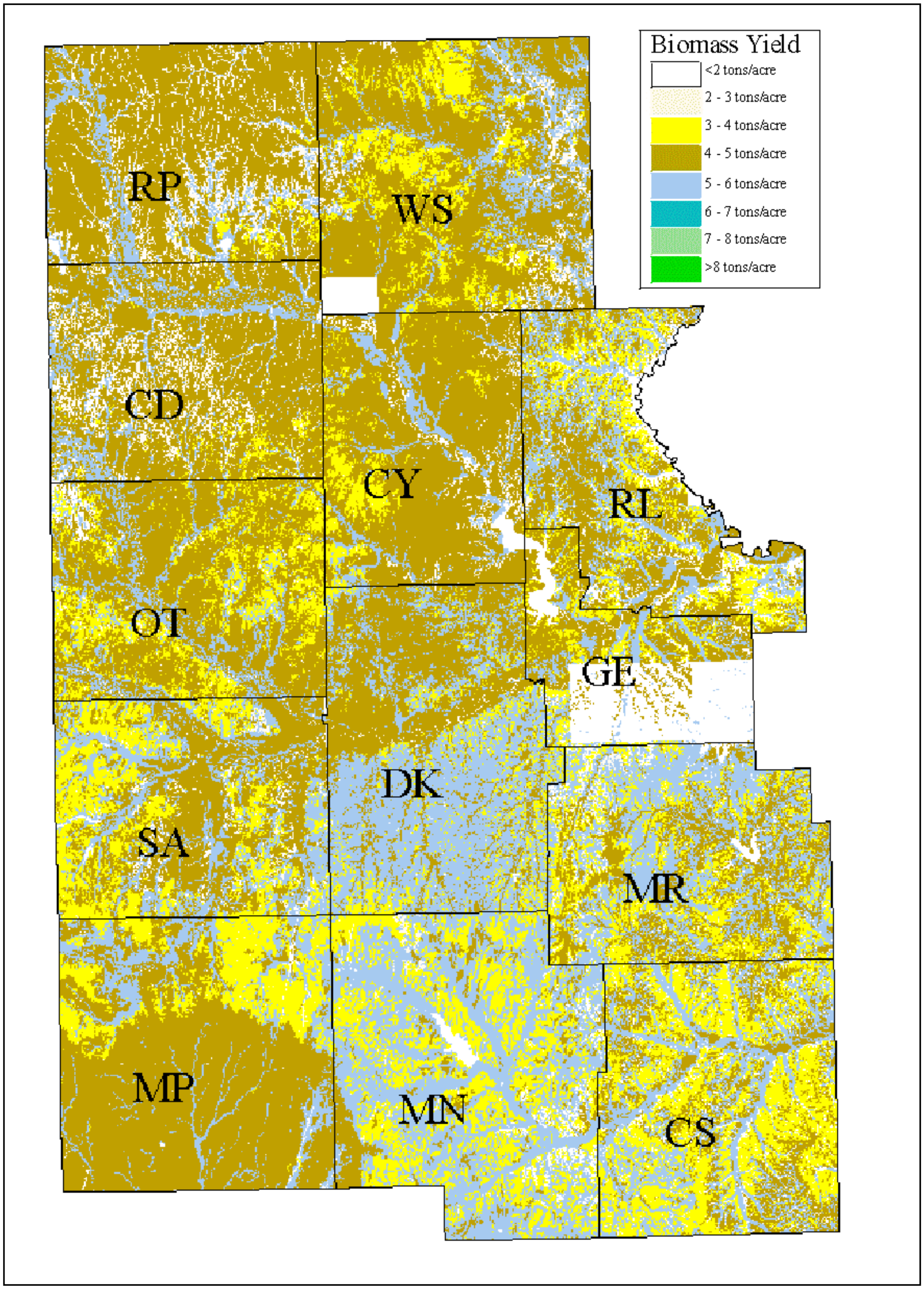

Figure 2.8.5 Map of Switchgrass Average Yield (tons per acre) by Soil Series Region 2
Region 2 switchgrass 24 year average yields reflect the increase in precipitation and diversity of soils, with significant areas with yields in the 5-6 dry tons/year [11.2 – 3.5 Mg/ha] range. White areas in Washington and Geary Counties reflect a case mismatch between SSURGO and BRC data files.

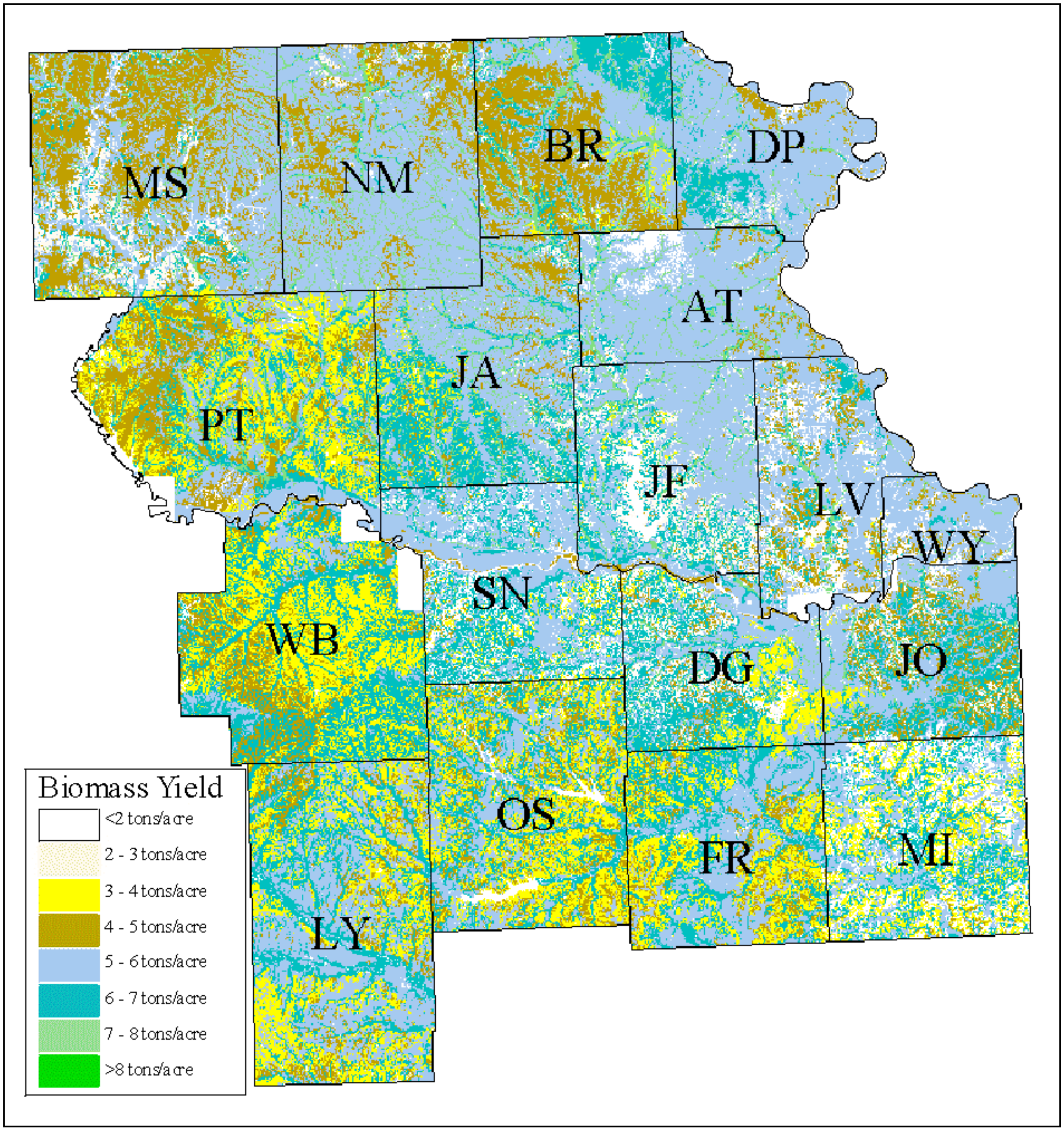

Figure 2.8.5 Map of Switchgrass Average Yield (tons per acre) by Soil Series Region 3
Average yields for Northeast Kansas indicate the response of switchgrass to even greater moisture with significant areas yielding a 24 year average of 6 – 7 dry tons/acre [13.5 – 15.7 Mg/ha]. White areas in Pottawatomie and Wabaunsee Counties stem from a case mismatch between SSURGO and BRC files.

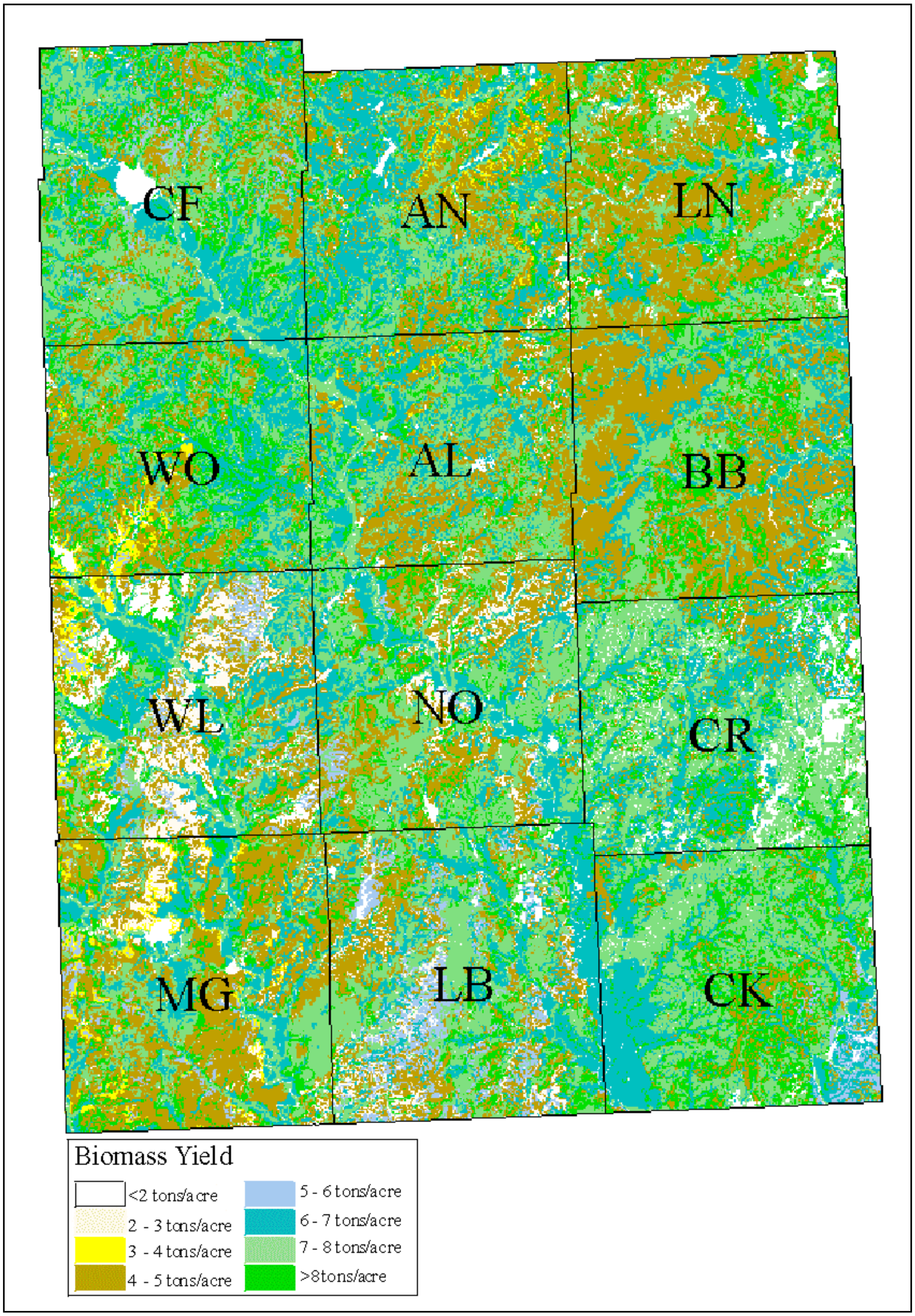

Figure 2.8.5 Map of Switchgrass Average Yield (tons per acre) by Soil Series Region 4
Region 4 in Southeast Kansas had the highest 24 year average annual switchgrass yields with significant areas producing 7 - 8 dry tons/year [Mg/ha] and some areas exceeding 8 dry tons/acre [15.7 – 18.0 Mg/ha].

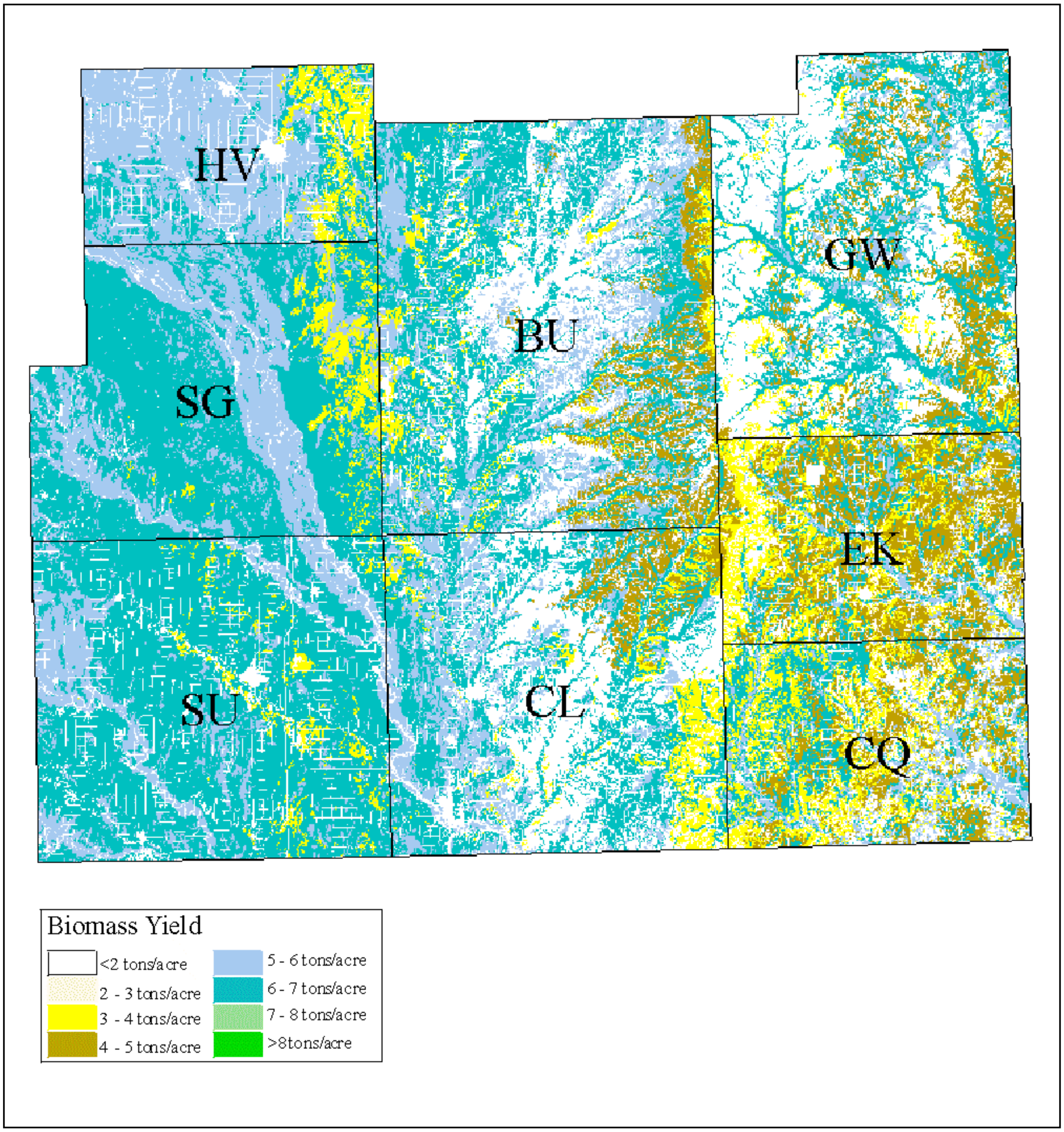

Figure 2.8.5 Map of Switchgrass Average Yield (tons per acre) by Soil Series Region 5
Average yields in the southern Flint Hills area of region 5 show a significant decline from region 4, but average yields in the western portion of the region are often in the 6 – 7 dry tons range [13.5 – 15.7 Mg/ha].

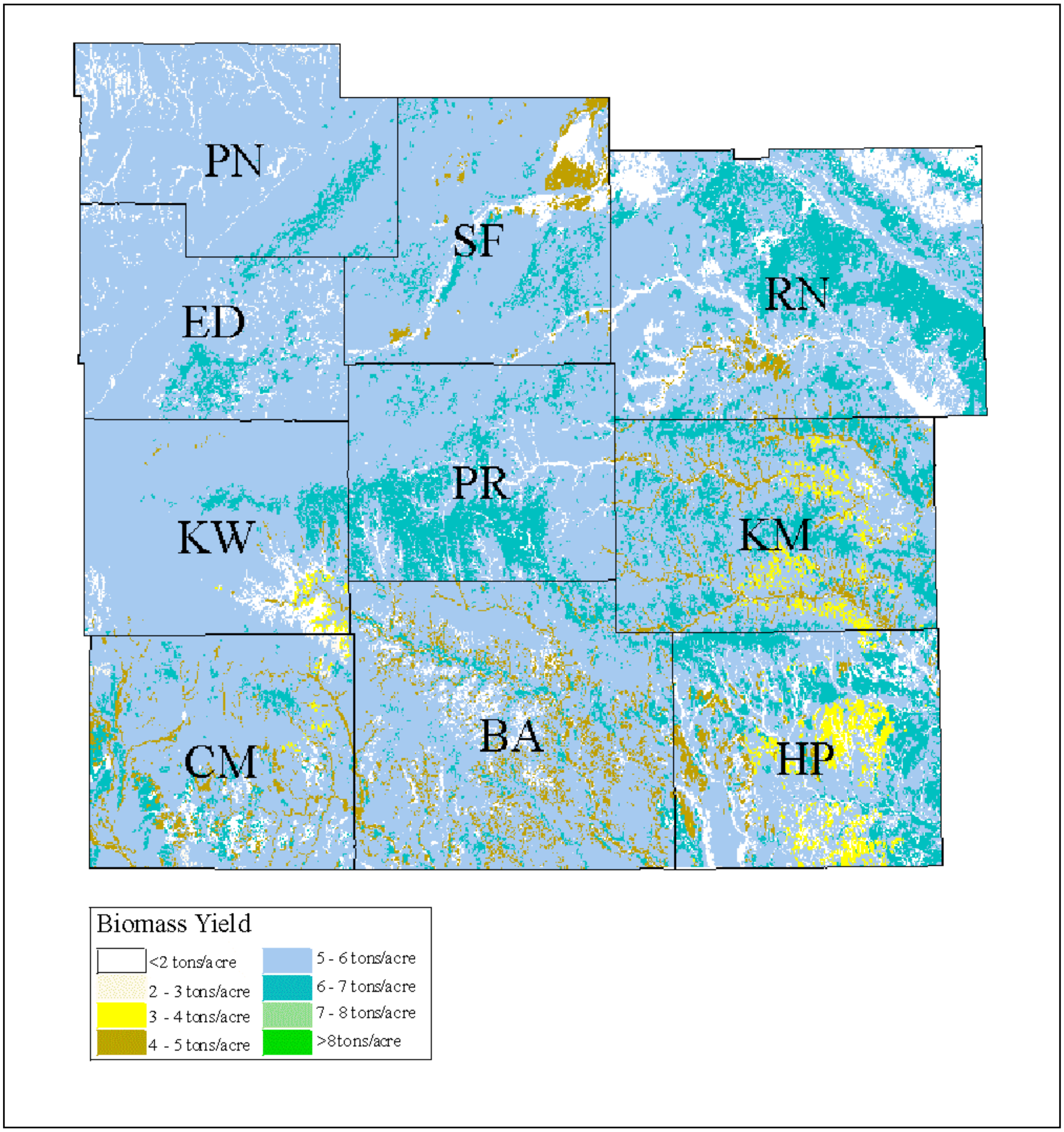

Figure 2.8.5 Map of Switchgrass Average Yield (tons per acre) by Soil Series Region 6

Region 6, has significanly higher average yields than region 1 directly to the north, with much of the region yielding 5 – 6 tons/acre [11.2 – 13.5 Mg/ha] and significant areas exceeding 6 – 7 tons/acre [13.5 – 15.7 Mg/ha]. This may reflect switchgrass's preference for warmer conditions.

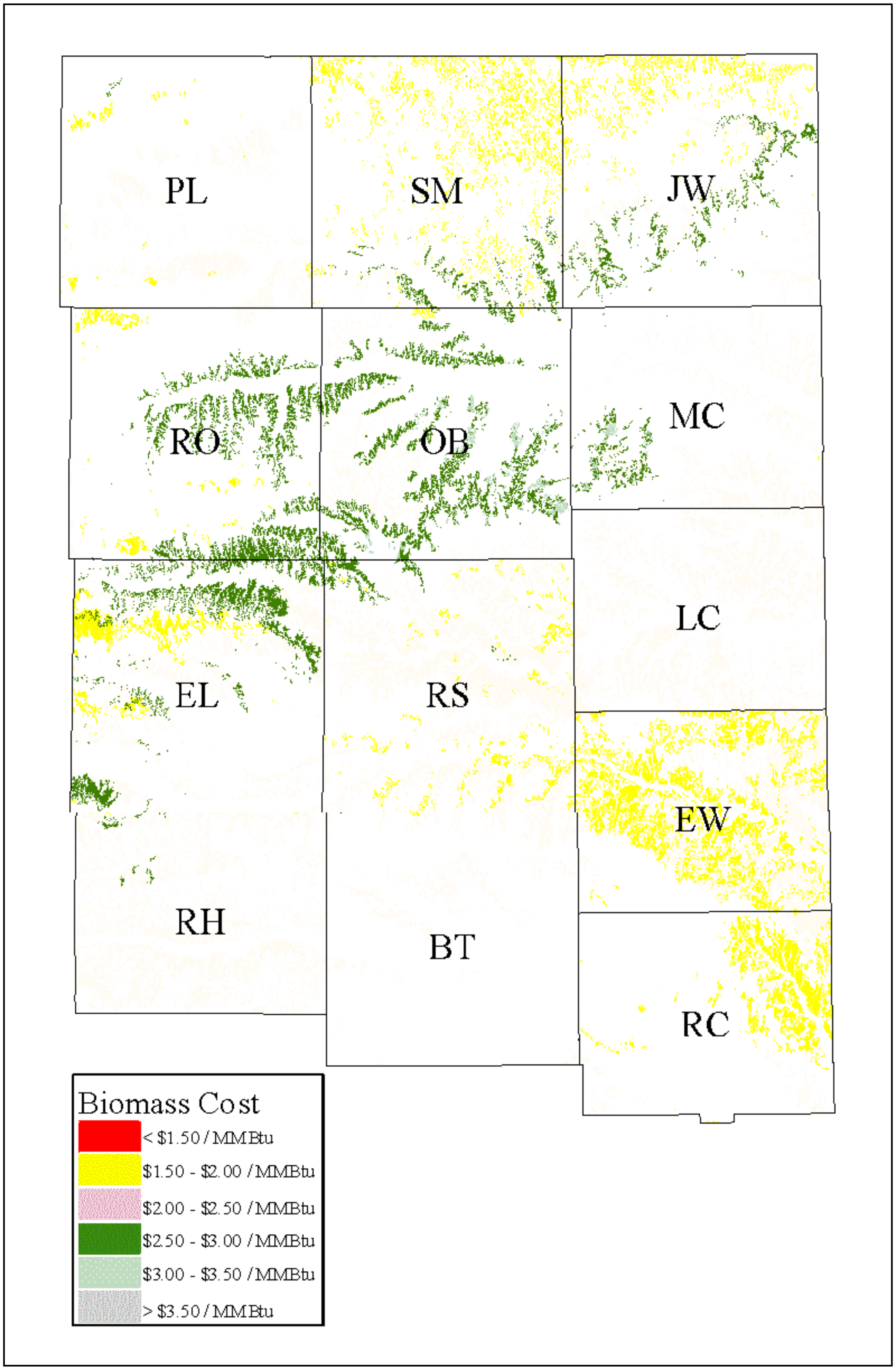

Figure 2.8.6 Map of Switchgrass Edge of Field Cost, $/MBtu (40% of CRP Land Rent) **Region 1** Low average yield generally result in higher switchgrass edge of field costs, although yield is somewhat offset by relatively low CRP rental rates. Significant areas have an estimated energy cost of $1.50 - $2.00/MBtu [$1.58 –2.11/MJ]. Large areas of white generally have an erosion index >8 and are therefore not considered potentially eligible for CRP.

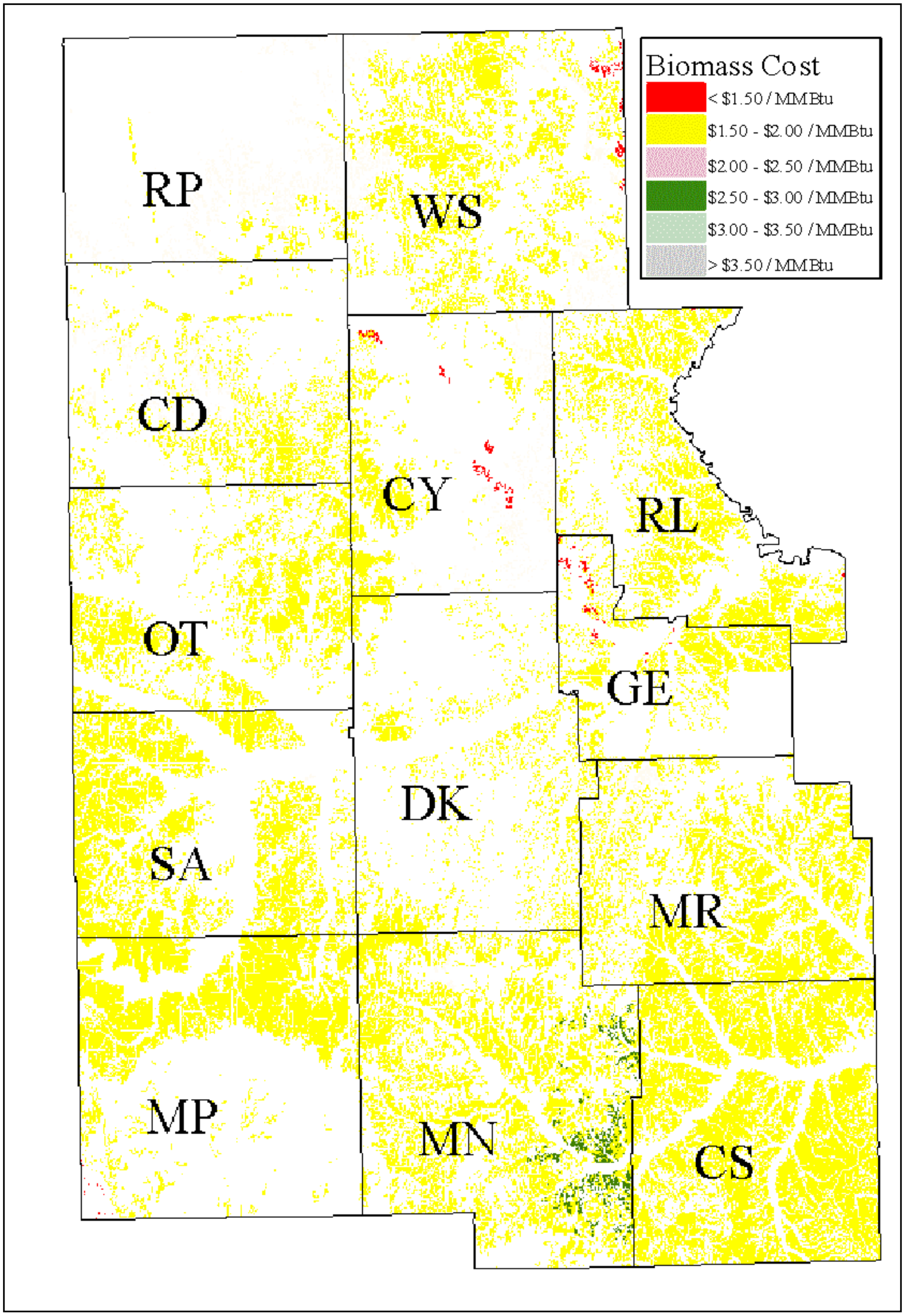

Figure 2.8.6 Map of Switchgrass Edge of Field Cost, $/MBtu (40% of CRP Land Rent) **Region 2**
Region 2 also has significant areas with an erosion index <8 (white), and therefore considered not potentially eligible for CRP. Under the CRP scenario much of the remaining land area has an estimated edge of field energy cost in the $1.50 – 2.00/MBtu [$1.58 – 2.11/MJ] with small areas less than $1.50/MBtu [$1.58/MJ].

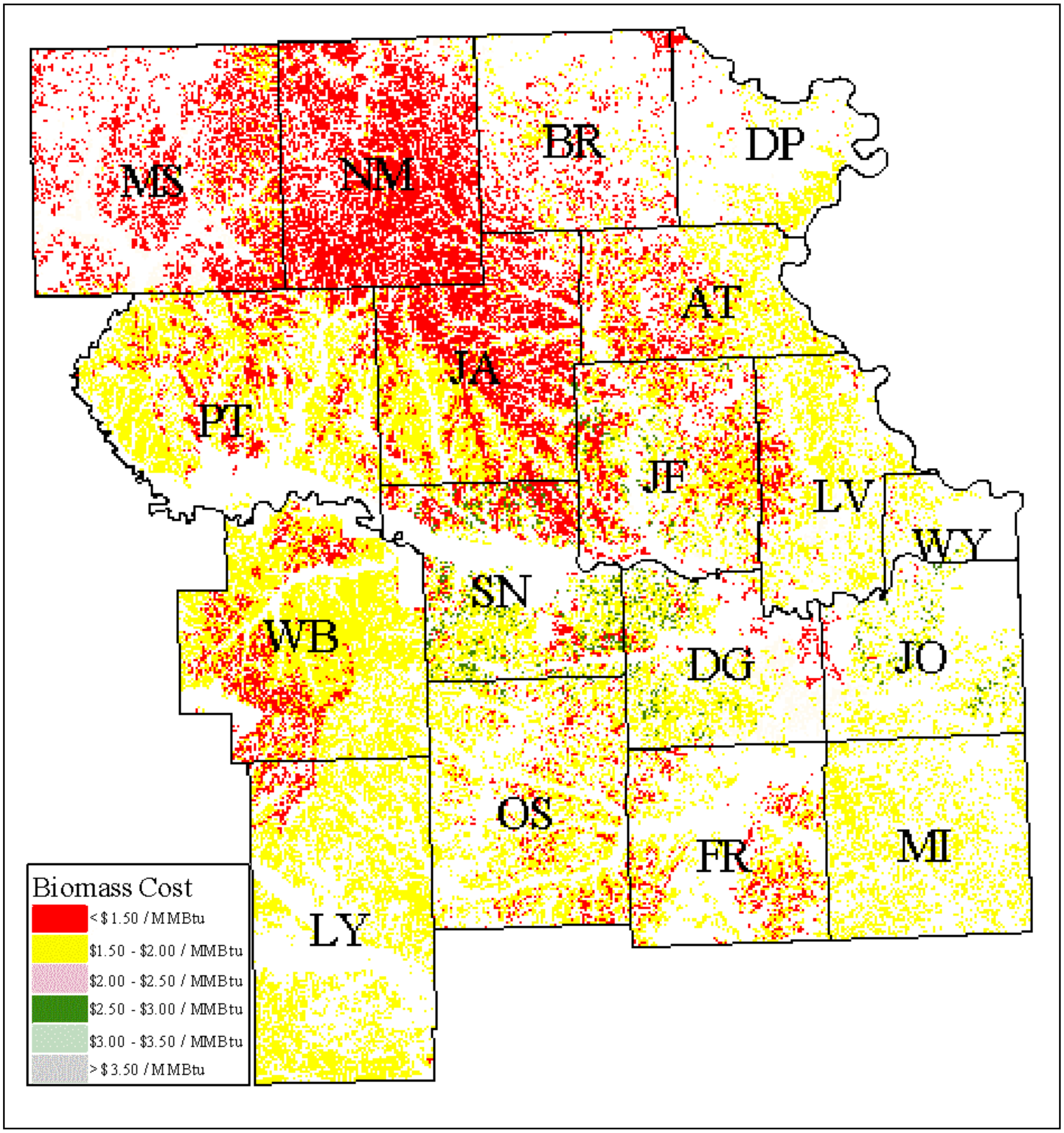

Figure 2.8.6 Map of Switchgrass Edge of Field Cost, $/MBtu (40% of CRP Land Rent) **Region 3**
The fertile soils and higher precipitation resulting in high average yields in much of region 3 produce edge of field switchgrass costs of less than $1.50/MBtu [$1.58/MJ] over large areas, as well as significant areas with costs in the $1.50 – 2.00/MBtu [$1.58 – 2.11/MJ] range under the CRP scenario.

Figure 2.8.6 Map of Switchgrass Edge of Field Cost, $/MBtu (40% of CRP Land Rent) **Region 4**
Region 4, with the highest precipitation and warmest weather, has the highest average annual yields and lowest cost. Large areas have estimated edge of cield energy cost below $1.50/MBtu/ [$1.58/MJ].

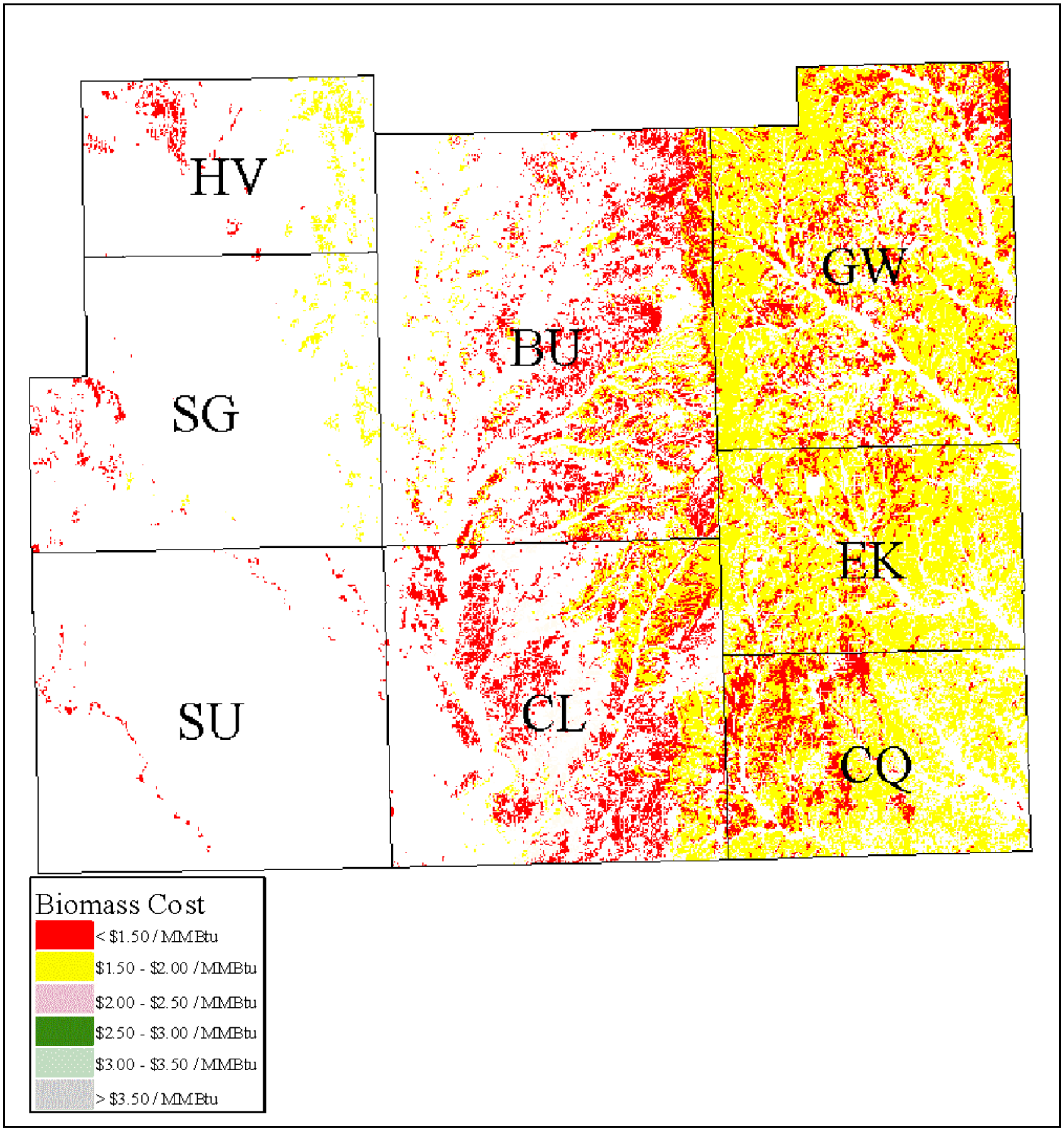

Figure 2.8.6 Map of Switchgrass Edge of Field Cost, $/MBtu (40% of CRP Land Rent) **Region 5**
Region 5 average switchgrass edge of field cost represents a transition toward lower precipitation. Large areas of the region with relatively high yield have an erosion index <8 and are not considered potentially eligible for CRP. Significant areas remain with an estimated energy cost less than $1.50/MBtu [$1.58/MJ] with much of the eastern portion of the region in the $1.50 – 2.00/MBtu [$1.58 – 2.11/MJ] range.

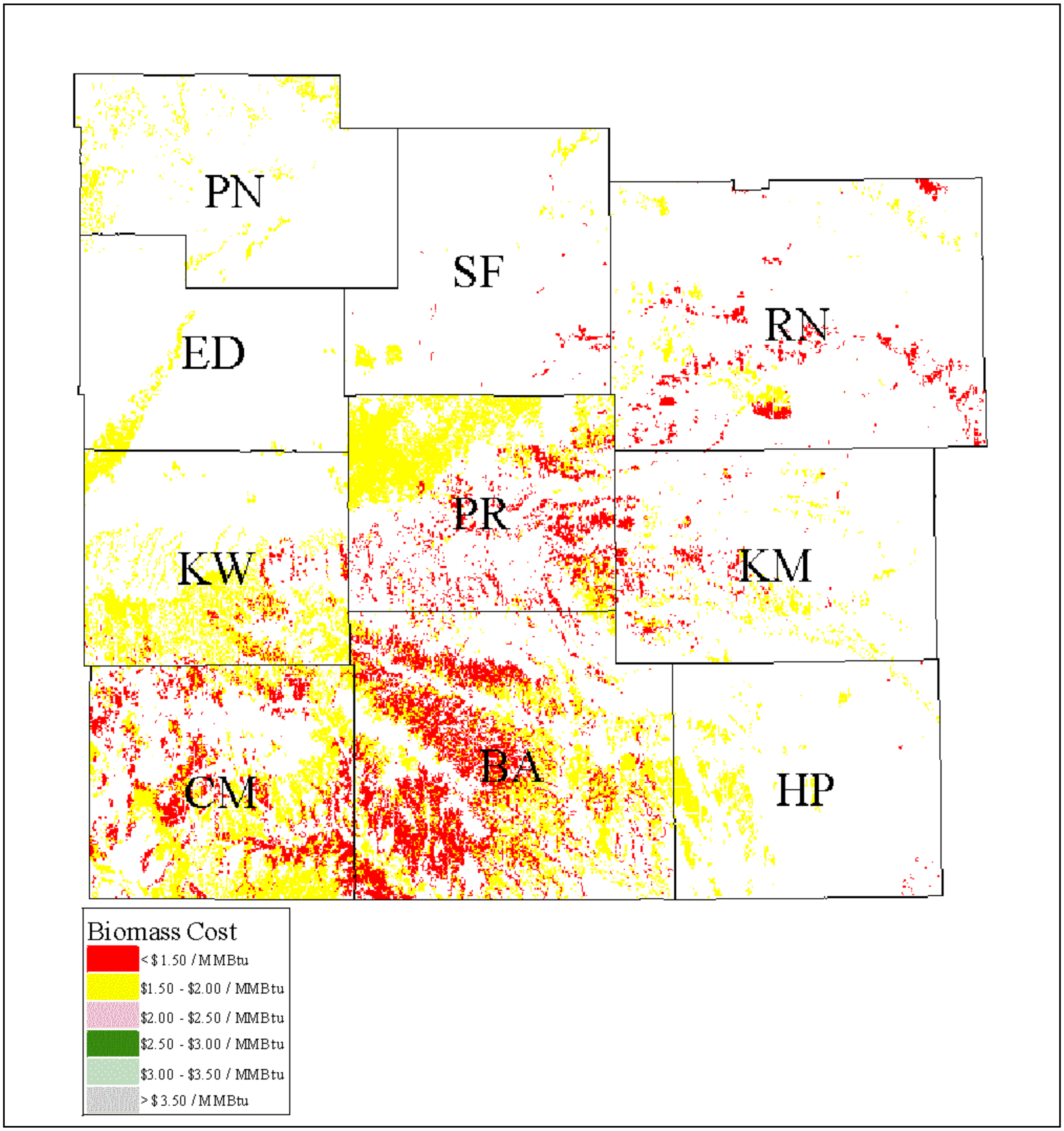

Figure 2.8.6 Map of Switchgrass Edge of Field Cost, $/MBtu (40% of CRP Land Rent) **Region 6**
Region 6 also has large areas with an erosion index <8 and therefore not considered potentially eligible for CRP. Despite lower precipitation and lower yields, significant areas have estimated average edge of fields cost <$1.50/MBtu [$1.58/MJ] and in the $1.50 – 2.00/MBtu [$1.58-2.11/MJ] range.

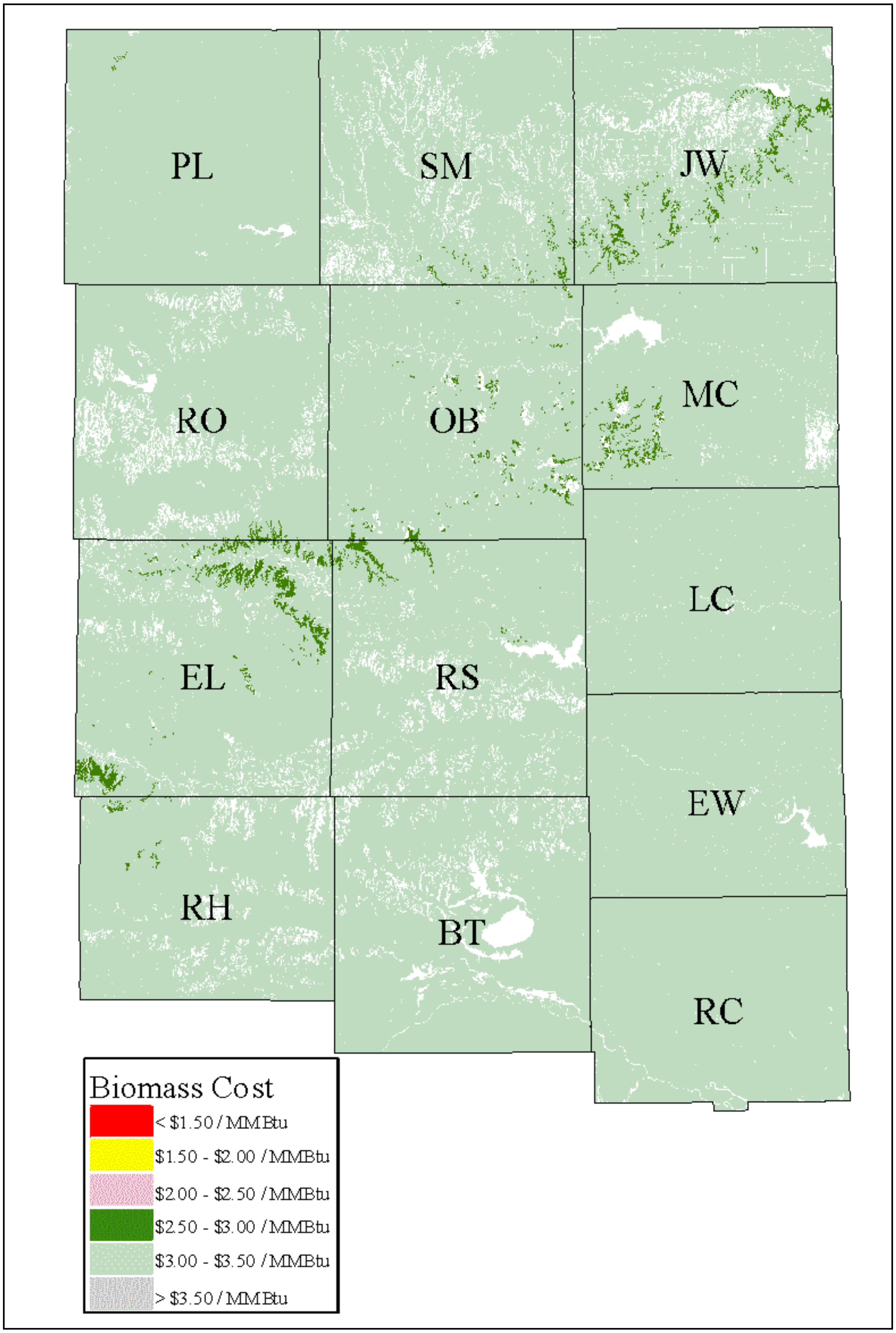

Figure 2.8.7 Map of Switchgrass Edge of Field Cost, $/MBtu (Competing with Grain) **Region 1**
In the CRP scenario limited areas of region 1 had edge of field costs in the $1.50 – 2.00/MBtu [$1.58 – 2.11/MJ] range. Competing with grain the lowest biomass energy cost in the region rises to the $2.50 – 3.00 [$2.64 – 3.17/MJ] in a limited area in the north central portion of the region.

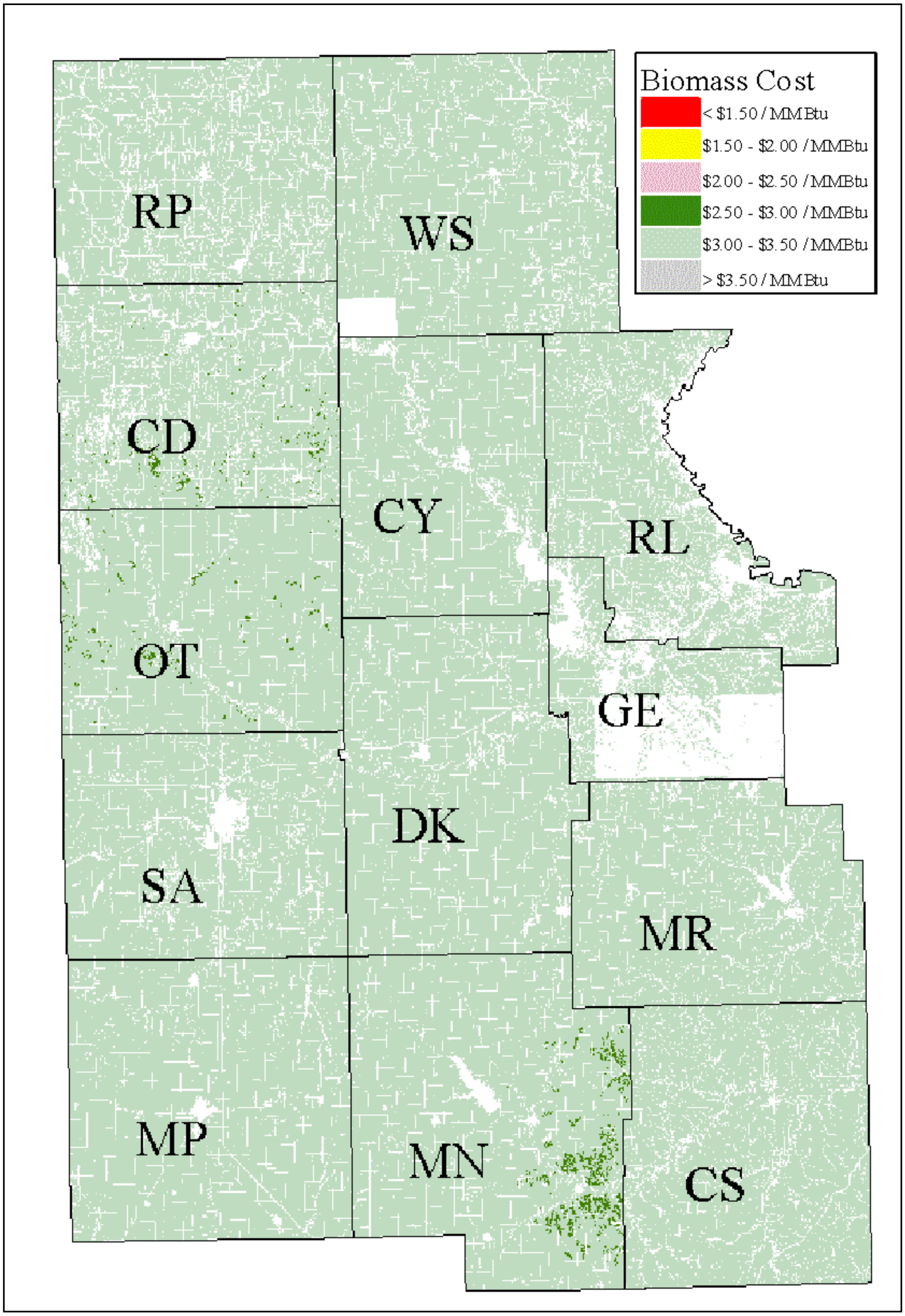

Figure 2.8.7 Map of Switchgrass Edge of Field Cost, $/MBtu (Competing with Grain) **Region 2**
In the CRP scenario large areas of region 2 had an average energy cost of $1.50 – 2.00/MBtu [$1.58 – 2.11/MJ]. Competing with grain, small areas of the region have an estimated energy cost in the $2.00 – 2.50 [$2.11 – 2.64/MJ] range and very large areas with an energy cost of $2.50 – 3.00/MBtu [$2.64 – 3.11/MJ] range.

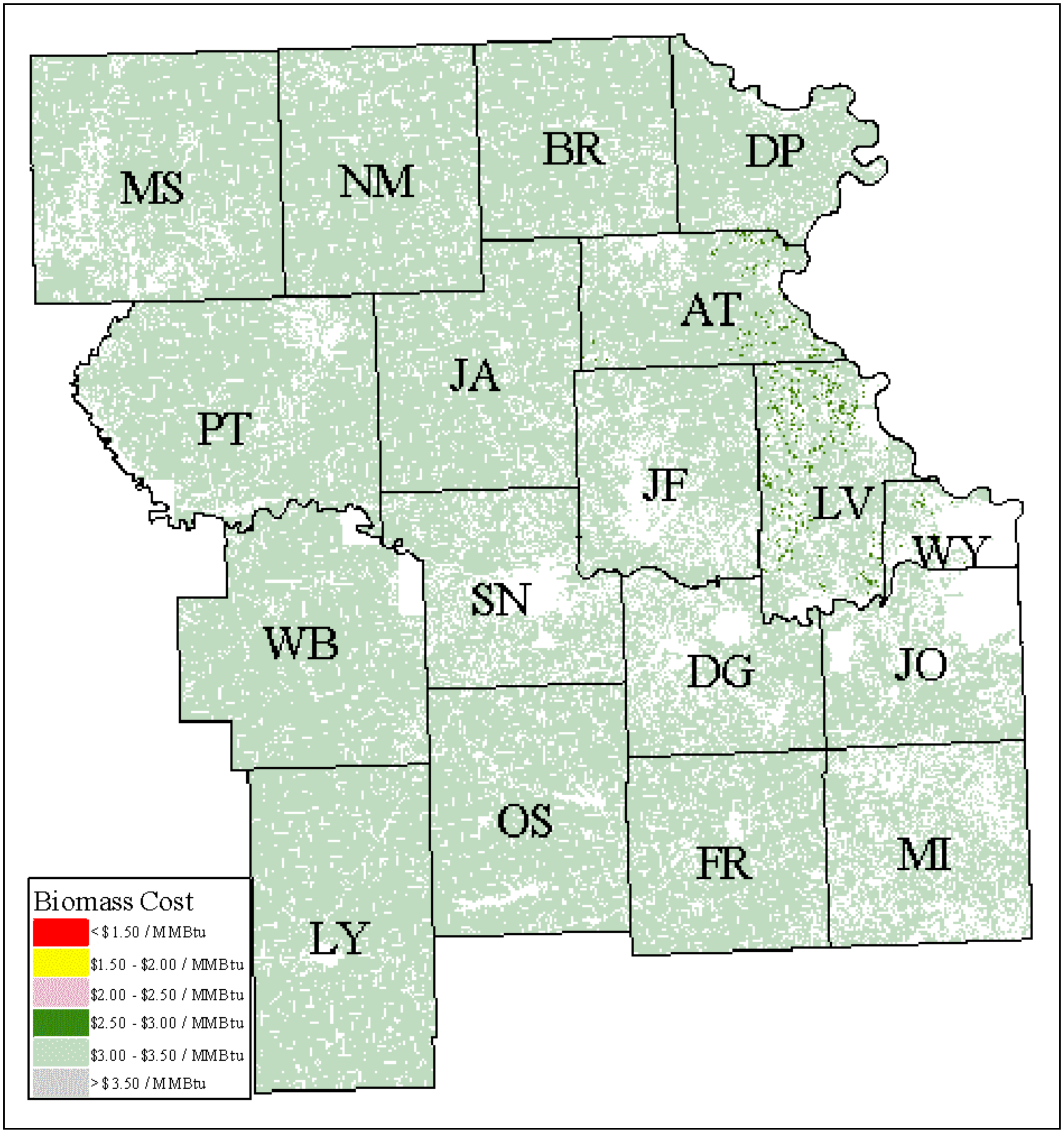

Figure 2.8.7 Map of Switchgrass Edge of Field Cost, $/MBtu (Competing with Grain) **Region 3**

In the CRP scenario most of land area potentially eligible for CRP had an energy cost of <$2.00/MBtu [$ /MJ] with much of it <$1.50/MBtu [$1.58/MJ]. With the regions high yields of conventional grain crops the cost of biomass energy required to compete rises significantly. Small area have an estimated cost in the $2.50 – 3.00/MBtu [$2.64 – 3.17/MJ] range, with significant areas along the north and south perimiter in the $3.00 - $3.50/MBtu [$3.17 – 3.69/MJ] range.

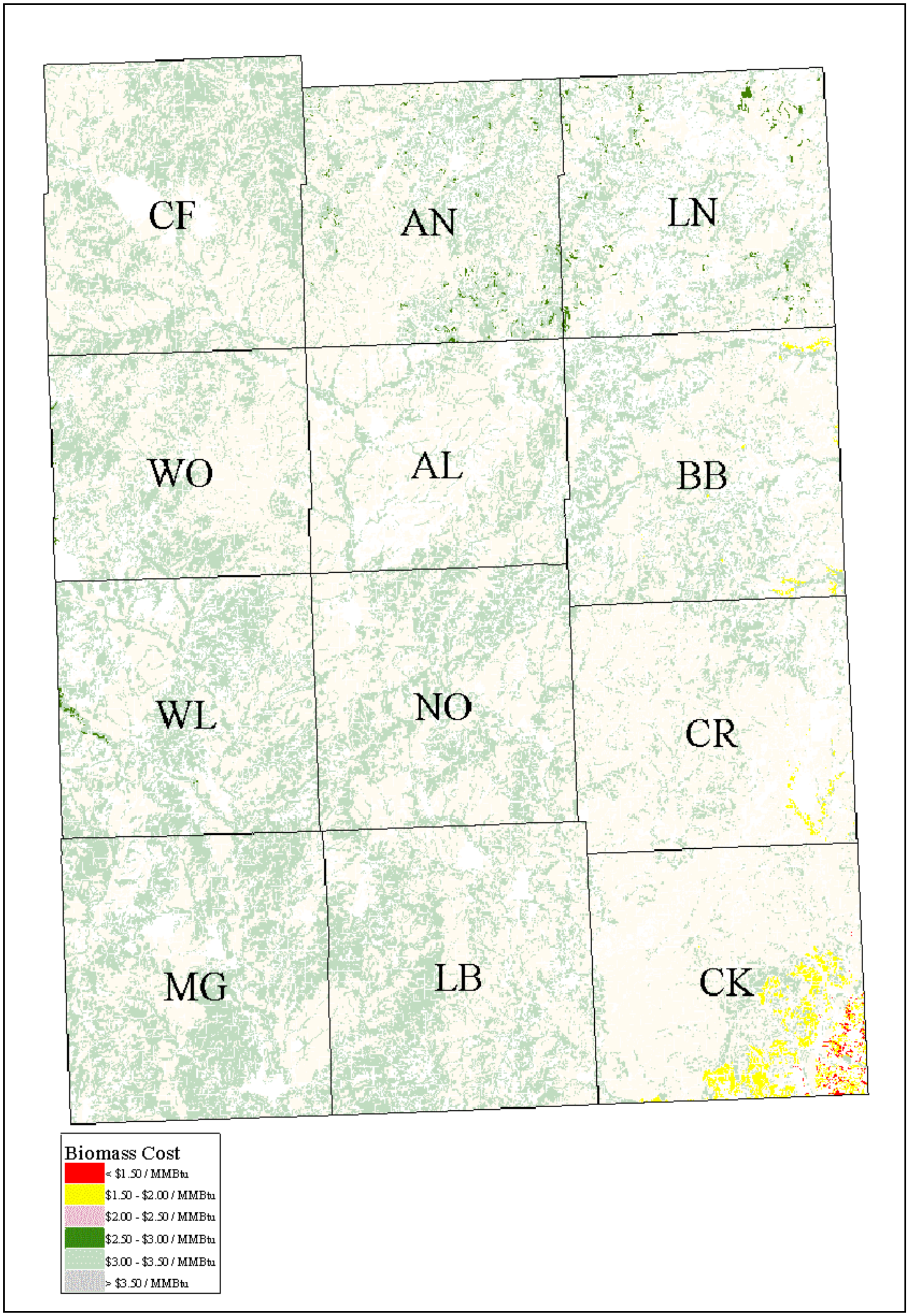

Figure 2.8.7 Map of Switchgrass Edge of Field Cost, $/MBtu (Competing with Grain) **Region 4**
The large portion of region 4 with an estimated energy cost <$1.50/MBtu in the CRP scenario is reduced to small parcels in the far southeast corner of the state. Small areas with energy costs in the $1.50 – 2.00/MBtu [$1.58 – 2.11/MJ] occur along the Missouri border. Much of the region has estimated energy costs in the $2.00 - $2.50/MBtu [$2.11 – 2.64/MJ] range.

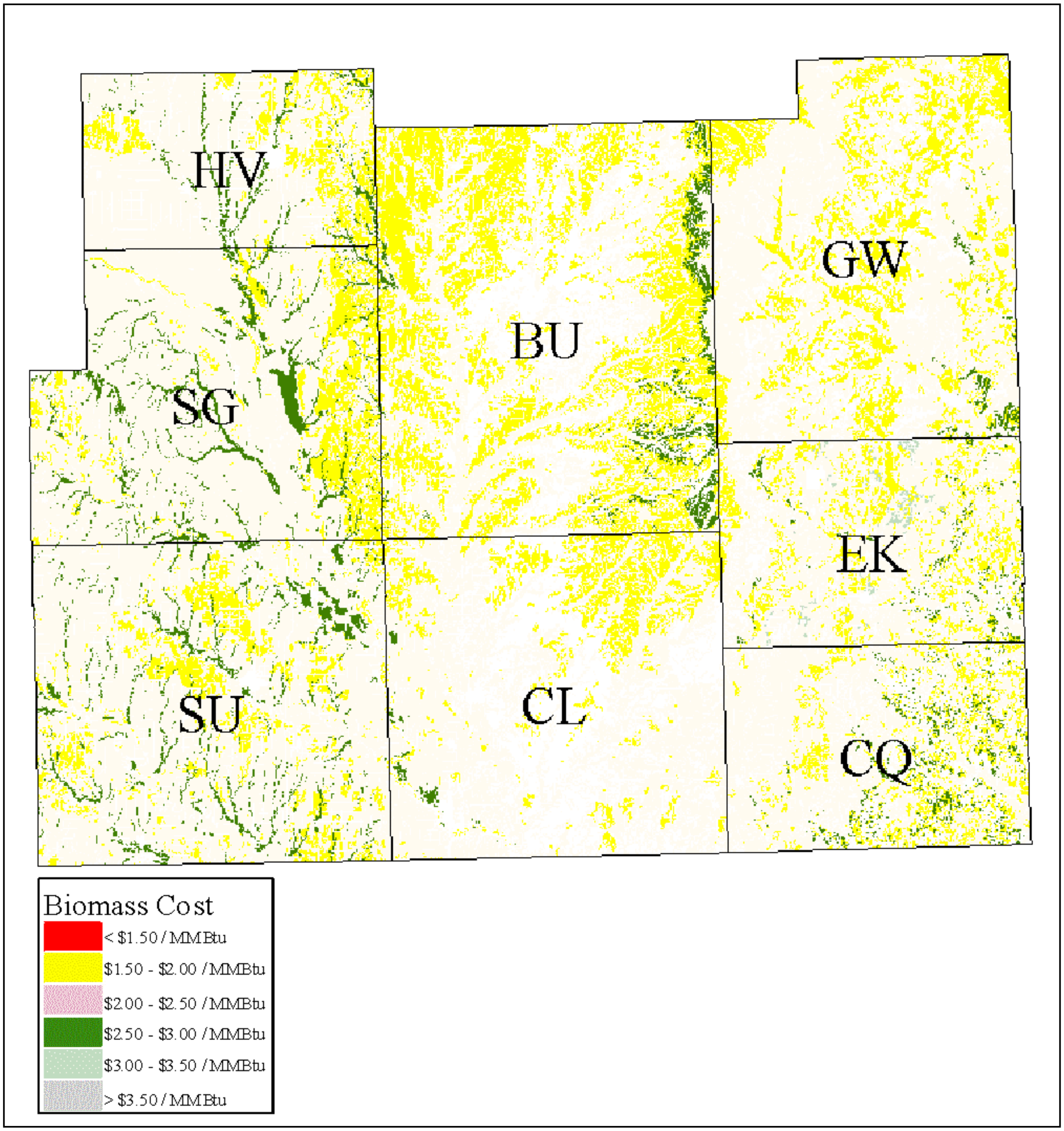

Figure 2.8.7 Map of Switchgrass Edge of Field Cost, $/MBtu (Competing with Grain) **Region 5**

Regions 5 and 6 are, somewhat surprisingly, the lowest switchgrass energy cost regions in competition with prevailing conventional grain crops. A combination of relatively high estimated switchgrass yields and lower estimated grain profits resulting from a shift to wheat and lower yields are the driving factors. Significant areas have edge of field costs in the $1.50 – 2.00/MBtu [$1.58-2.11/MJ] range.

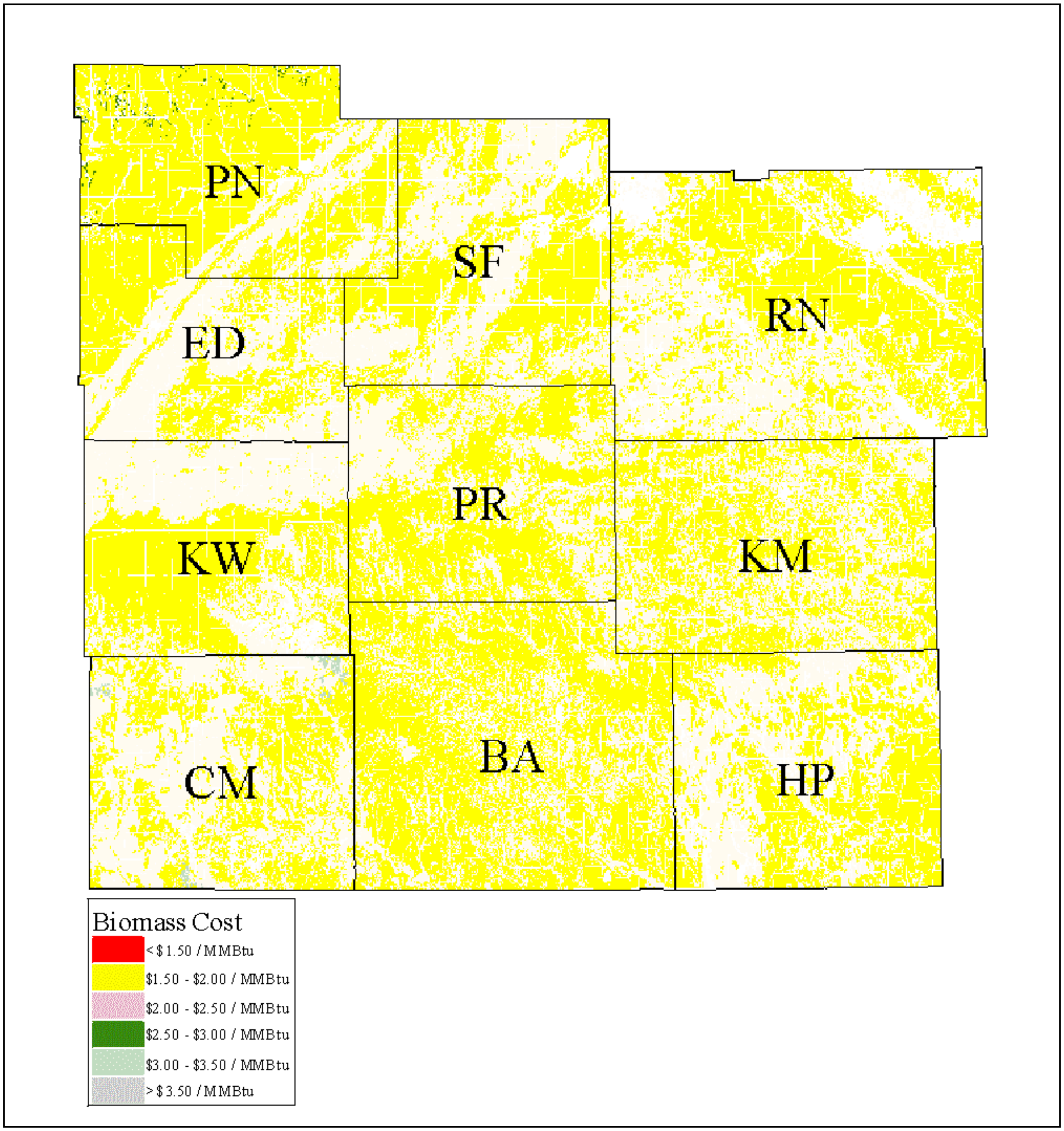

Figure 2.8.7 Map of Switchgrass Edge of Field Cost, $/MBtu (Competing with Grain) **Region 6**
The large areas with estimated average switchgrass energy cost in the $1.50 – 2.00/MBtu [$1.58 – 2.11/MJ] range this far west represents one of the biggest surprises resulting from this study.

2.8.2 Switchgrass Production Volume and Potential MW of Generation

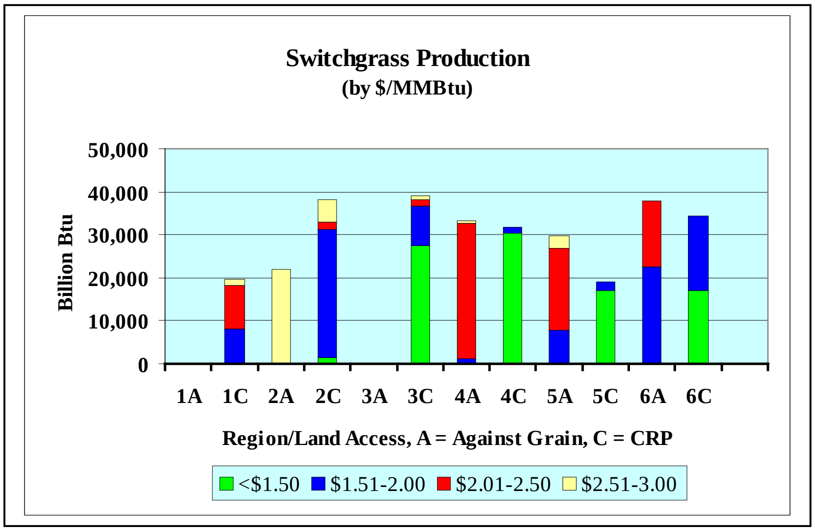

Figure 2.8.8 Switchgrass Production Volume

Figure 2.8.8 shows the estimated maximum volume of energy that could be produced under the CRP scenario and in competition with grain, by region and energy cost increment. The two land use scenarios are exclusive and can not be added. The largest volume of lower cost (<$1.50/MBtu [$1.58/MJ]) energy occurs under the CRP scenario in regions 3, 4, 5, and 6. Regions 2 and 5 are the most promising regions for switchgrass in competition with grain, with large volumes of switchgrass energy in the $1.50 – 2.00/MBtu [$1.58 – 2.11/MJ]. The volume of switchgrass energy with an edge of field cost less than $3.00/MBtu [$3.17/MJ] totals 182 trillion Btus under the CRP scenario, falling to 123 trillion Btus in competition with grain. The U.S. Department of Energy's Energy Information Administration (EIA) reports Kansas's total 1995 net energy consumption was 1,144 trillion Btus, 319 trillion of which was used for electricity generation (not including exports).

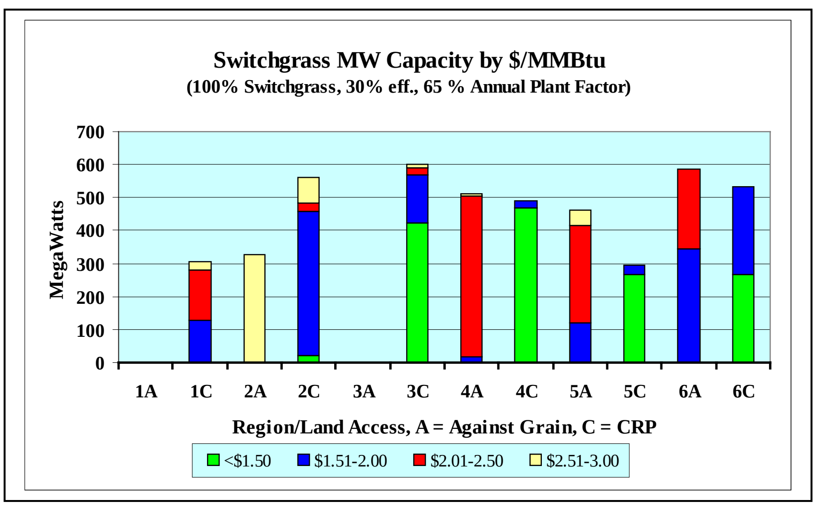

Figure 2.8.9 Switchgrass Potential Megawatts of Generation

Figure 2.8.9 shows the megaWatts of generating capacity that could be fueled by switchgrass by region and cost increment under the CRP scenario and in competition with grain, based on a plant efficiency of 30% and a 65% annual plant factor. In application, spatial diversity of land parcels at different cost increments would reduce these estimates. These estimates are also based edge of field fuel cost increments, not plant gate or boiler mouth. Table 2.8.3 below provides a detailed breakdown of estimated switchgrass energy production potential and generation that could be supported by region, county, and fuel cost increment for potentially eligible CRP acres and all potentially suitable land area, limited by using not more than 50% of the acres in any soil series or more than 10% of the land area in any county.

Table 2.8.3 Switchgrass Production Volume and Potential MW of Generation Region 1

Land Area Soil	Area (acres)		Energy, billion Btu Mbtu < $1.50	MBtu $1.51 - 2.00	MBtu $2.01 - 2.50	MBtu $2.51- 3.00	Generation (30% eff./ 65% yr.) MW @ < $1.50 MBtu	MW @ $1.51 - 2.00 MBtu	MW @ < $2.01- 2.50 MBtu	MW @ < $2.51- 3.00 MBtu
Barton County	490,602	CRP Total	0	4	575	0	0	0	9	0
		All Other Total	0	0	0	0	0	0	0	0
Ellis County	618,873	CRP Total	0	2,043	306	0	0	32	5	0
		All Other Total	0	0	0	0	0	0	0	0
Ellsworth County	566,098	CRP Total	0	0	211	0	0	0	3	0
		All Other Total	0	0	0	0	0	0	0	0
Jewell County	609,978	CRP Total	0	597	471	493	0	9	7	8
		All Other Total	0	0	0	0	0	0	0	0
Lincoln County	519,823	CRP Total	0	423	1,577	0	0	7	24	0
		All Other Total	0	0	0	0	0	0	0	0
Mitchell County	549,218	CRP Total	0	2	623	118	0	0	10	2
		All Other Total	0	0	0	0	0	0	0	0
Osborne County	789,455	CRP Total	0	1,788	1,420	0	0	28	22	0
		All Other Total	0	0	0	0	0	0	0	0
Phillips County	563,259	CRP Total	0	103	558	84	0	2	9	1
		All Other Total	0	0	0	0	0	0	0	0
Rice County	485,061	CRP Total	0	1,376	754	0	0	21	12	0
		All Other Total	0	0	0	0	0	0	0	0
Rush County	398,065	CRP Total	0	5	1,699	0	0	0	26	0
		All Other Total	0	0	0	0	0	0	0	0
Rooks County	583,789	CRP Total	0	235	925	707	0	4	14	11
		All Other Total	0	0	0	0	0	0	0	0
Russel County	497,967	CRP Total	0	458	425	0	0	7	7	0
		All Other Total	0	0	0	0	0	0	0	0
Smith County	603,931	CRP Total	0	1,194	397	204	0	18	6	3
		All Other Total	0	0	0	0	0	0	0	0
Region 1 Total	**7,276,121**	**CRP Total**	**0**	**8,226**	**9,941**	**1,605**	**0**	**127**	**154**	**25**
		All Other Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Not more than 50% of any soil series or 10% of all potentially suitable land in a county used for biomass crops.

Table 2.8.3 Switchgrass Energy Production and Potential MW of Generation Region 2

Land Area			Energy, billion Btu				Generation (30% eff./ 65% yr.)			
Soil	Area (acres)		MBtu < $1.50	MBtu $1.51 - 2.00	MBtu $2.01 - 2.50	MBtu $2.51- 3.00	MW @ < $1.50 MBtu	MW @ $1.51 - 2.00 MBtu	MW @ < $2.01- 2.50 MBtu	MW @ < $2.51- 3.00 MBtu
Cloud County	387,159	CRP Total	0	2,137	0	0	0	33	0	0
		All Other Total	0	0	0	913	0	0	0	14
Chase County	682,339	CRP Total	1,225	2,664	0	2,514	19	41	0	39
		All Other Total	0	0	0	5,647	0	0	0	87
Clay County	398,157	CRP Total	105	1,217	716	0	2	19	11	0
		All Other Total	0	0	0	1,376	0	0	0	21
Dickinson County	520,082	CRP Total	0	2,103	125	304	0	32	2	5
		All Other Total	0	0	0	0	0	0	0	0
Geary County	312,921	CRP Total	137	1,412	0	0	2	20	0	0
		All Other Total	0	0	0	2,417	0	0	0	35
Marion County	602,255	CRP Total	0	3,707	0	0	0	53	0	0
		All Other Total	0	0	0	1,503	0	0	0	22
McPherson County	582,146	CRP Total	13	3,123	0	0	0	45	0	0
		All Other Total	0	0	0	1,156	0	0	0	17
Morris County	531,858	CRP Total	0	1,601	0	1,499	0	23	0	21
		All Other Total	0	0	0	2,025	0	0	0	29
Ottawa County	509,087	CRP Total	0	3,183	0	0	0	46	0	0
		All Other Total	0	0	0	1,090	0	0	0	16
Riley County	429,743	CRP Total	0	2,008	88	878	0	29	1	13
		All Other Total	0	0	0	1,097	0	0	0	16
Republic County	441,520	CRP Total	0	282	0	45	0	4	0	1
		All Other Total	0	0	0	1,382	0	0	0	20
Saline County	506,962	CRP Total	0	3,466	0	0	0	50	0	0
		All Other Total	0	0	0	2,210	0	0	0	32
Washington County	552,767	CRP Total	0	2,840	779	80	0	41	11	1
		All Other Total	0	0	0	1,286	0	0	0	18
Region 2 Total	**6,456,996**	**CRP Total**	**1,479**	**29,743**	**1,708**	**5,320**	**23**	**435**	**25**	**79**
		All Other Total	**0**	**0**	**0**	**22,104**	**0**	**0**	**0**	**326**

Not more than 50% of any soil series or 10% of all potentially suitable land in a county used for biomass crops.

Table 2.8.3 Switchgrass Energy Production and Potential MW of Generation Region 3

Land Area Soil	Area (acres)		Energy, billion Btu: MBtu < $1.50	MBtu $1.51 - 2.00	MBtu $2.01 - 2.50	MBtu $2.51- 3.00	Generation (30% eff./ 65% yr.): MW @ < $1.50 MBtu	MW @ $1.51 - 2.00 MBtu	MW @ < $2.01- 2.50 MBtu	MW @ < $2.51- 3.00 MBtu
Atchison County	296,204	CRP Total	2,528	0	0	0	39	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Brown County	800,752	CRP Total	124	133	392	35	2	2	6	1
		All Other Total	0	0	0	0	0	0	0	0
Douglas County	253,444	CRP Total	483	0	0	0	7	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Doniphan County	241,112	CRP Total	322	912	0	0	5	14	0	0
		All Other Total	0	0	0	0	0	0	0	0
Franklin County	391,334	CRP Total	2,101	105	0	0	32	2	0	0
		All Other Total	0	0	0	0	0	0	0	0
Jackson County	440,903	CRP Total	7,089	0	0	0	109	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Jefferson County	337,434	CRP Total	115	0	0	0	2	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Johnson County	209,510	CRP Total	132	0	0	0	2	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Leavenworth County	231,054	CRP Total	1,452	0	0	0	22	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Lyon County	580,562	CRP Total	900	3,467	0	0	14	54	0	0
		All Other Total	0	0	0	0	0	0	0	0
Miami County	305,926	CRP Total	11	2,229	0	0	0	34	0	0
		All Other Total	0	0	0	0	0	0	0	0
Marshall County	568,660	CRP Total	65	427	973	676	1	7	15	10
		All Other Total	0	0	0	0	0	0	0	0
Nemaha County	493,372	CRP Total	2,178	0	0	0	34	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Osage County	454,920	CRP Total	1,268	1,834	0	0	20	28	0	0
		All Other Total	0	0	0	0	0	0	0	0
Pottawatomie County	592,226	CRP Total	4,134	157	0	0	64	2	0	0
		All Other Total	0	0	0	0	0	0	0	0
Shawnee County	279,462	CRP Total	1,902	0	0	0	29	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Wabaunsee County	626,686	CRP Total	2,516	0	0	0	39	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Wyandotte County	32,194	CRP Total	56	176	0	0	1	3	0	0
		All Other Total	0	0	0	0	0	0	0	0
Region 3 Total	**7,135,756**	**CRP Total**	**27,375**	**9,440**	**1,365**	**711**	**423**	**146**	**21**	**11**
		All Other Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Not more than 50% of any soil series or 10% of all potentially suitable land in a county used for biomass crops.

Table 2.8.3 Switchgrass Energy Production and Potential MW of Generation Region 4

Land Area Soil	Area (acres)		Energy, billion Btu Mbtu < $1.50	MBtu $1.51 - 2.00	MBtu $2.01 - 2.50	MBtu $2.51- 3.00	Generation (30% eff./ 65% yr.) MW @ < $1.50 MBtu	MW @ $1.51 - 2.00 MBtu	MW @ < $2.01- 2.50 MBtu	MW @ < $2.51- 3.00 MBtu
Allen County	291,717	CRP Total	16	0	0	0	0	0	0	0
		All Other Total	0	0	2,014	0	0	0	31	0
Anderson County	362,926	CRP Total	1,373	0	0	0	21	0	0	0
		All Other Total	0	0	1,130	223	0	0	17	3
Bourbon County	345,999	CRP Total	3,975	0	0	0	61	0	0	0
		All Other Total	0	0	3,212	0	0	0	50	0
Coffey County	417,600	CRP Total	43	0	0	0	1	0	0	0
		All Other Total	0	0	3,113	0	0	0	48	0
Cherokee County	305,576	CRP Total	5,297	0	0	0	82	0	0	0
		All Other Total	0	1,023	1,551	0	0	16	24	0
Crawford County	301,752	CRP Total	123	0	0	0	2	0	0	0
		All Other Total	0	134	2,765	0	0	2	43	0
Labette County	391,461	CRP Total	4,820	0	0	0	74	0	0	0
		All Other Total	0	0	2,037	0	0	0	31	0
Linn County	289,834	CRP Total	4,518	0	0	0	70	0	0	0
		All Other Total	0	0	1,940	318	0	0	30	5
Montgomery County	428,538	CRP Total	4,133	0	0	0	64	0	0	0
		All Other Total	0	0	3,691	0	0	0	57	0
Neosho County	350,348	CRP Total	490	1,369	100	0	8	21	2	0
		All Other Total	0	0	3,846	0	0	0	59	0
Wilson County	398,942	CRP Total	4,234	0	0	0	65	0	0	0
		All Other Total	0	0	2,698	59	0	0	42	1
Woodson County	329,169	CRP Total	1,346	0	0	0	21	0	0	0
		All Other Total	0	0	3,472	16	0	0	54	0
Region 4 Total	**4,213,861**	**CRP Total**	**30,370**	**1,369**	**100**	**0**	**469**	**21**	**2**	**0**
		All Other Total	**0**	**1,157**	**31,469**	**617**	**0**	**18**	**486**	**10**

Not more than 50% of any soil series or 10% of all potentially suitable land in a county used for biomass crops.

Table 2.8.3 Switchgrass Energy Production and Potential MW of Generation Region 5

Land Area Soil	Area (acres)		**Energy, billion Btu** MBtu < $1.50	MBtu $1.51 - 2.00	MBtu $2.01 - 2.50	MBtu $2.51- 3.00	**Generation** (30% eff./ 65% yr.) MW @ < $1.50 MBtu	MW @ $1.51 - 2.00 MBtu	MW @ < $2.01- 2.50 MBtu	MW @ < $2.51- 3.00 MBtu
Butler County	1,027,556	CRP Total	1,685	0	0	0	26	0	0	0
		All Other Total	0	0	3,605	60	0	0	56	1
Cowley County	758,352	CRP Total	6,044	0	0	0	93	0	0	0
		All Other Total	0	2,062	5,474	0	0	32	85	0
Chautauqua County	443,829	CRP Total	2,828	33	0	0	44	1	0	0
		All Other Total	0	1,757	1,668	0	0	27	26	0
Elk County	499,661	CRP Total	2,853	668	0	0	44	10	0	0
		All Other Total	0	1,116	1,449	0	0	17	22	0
Greenwood County	377,894	CRP Total	2,603	703	0	0	40	11	0	0
		All Other Total	0	998	1,580	0	0	15	24	0
Harvey County	317,762	CRP Total	777	440	0	0	12	7	0	0
		All Other Total	0	1,145	51	81	0	18	1	1
Sedgwick County	167,712	CRP Total	143	72	0	0	2	1	0	0
		All Other Total	0	622	550	489	0	10	8	8
Sumner County	745,064	CRP Total	216	0	0	0	3	0	0	0
		All Other Total	0	104	4,697	2,359	0	2	73	36
Region 5 Total	**4,337,831**	**CRP Total**	**17,149**	**1,916**	**0**	**0**	**265**	**30**	**0**	**0**
		All Other Total	**0**	**7,804**	**19,074**	**2,989**	**0**	**120**	**295**	**46**

Not more than 50% of any soil series or 10% of all potentially suitable land in a county used for biomass crops.

Table 2.8.3 Switchgrass Energy Production and Potential MW of Generation Region 6

Land Area Soil	Area (acres)		Energy, billion Btu Mbtu < $1.50	MBtu $1.51 - 2.00	MBtu $2.01 - 2.50	MBtu $2.51- 3.00	Generation (30% eff./ 65% yr.) MW @ < $1.50 MBtu	MW @ $1.51 - 2.00 MBtu	MW @ < $2.01- 2.50 MBtu	MW @ < $2.51- 3.00 MBtu
Barber County	897,822	CRP Total	7,820	118	0	0	121	2	0	0
		All Other Total	0	7,891	249	0	0	122	4	0
Comanche	645,885	CRP Total	3,172	1,296	0	0	49	20	0	0
		All Other Total	0	2,529	0	0	0	39	0	0
Edwards County	415,605	CRP Total	0	2,078	5	0	0	32	0	0
		All Other Total	0	0	2,827	0	0	0	44	0
Harper County	503,207	CRP Total	107	2,224	0	0	2	34	0	0
		All Other Total	0	1,425	965	0	0	22	15	0
Kingman County	550,024	CRP Total	1,119	1,742	0	0	17	27	0	0
		All Other Total	0	822	621	0	0	13	10	0
Kiowa County	512,259	CRP Total	494	1,880	0	0	8	29	0	0
		All Other Total	0	0	4,386	0	0	0	68	0
Pawnee County	471,135	CRP Total	0	2,188	0	0	0	34	0	0
		All Other Total	0	0	1,290	0	0	0	20	0
Pratt County	507,177	CRP Total	2,242	1,913	0	0	35	30	0	0
		All Other Total	0	4,876	1,774	0	0	75	27	0
Reno County	934,980	CRP Total	2,078	2,049	0	0	32	32	0	0
		All Other Total	0	2,481	3,330	0	0	38	51	0
Stafford County	548,100	CRP Total	112	1,820	0	0	2	28	0	0
		All Other Total	0	2,391	0	0	0	37	0	0
Region 6 Total	**5,986,194**	**CRP Total**	**17,144**	**17,309**	**5**	**0**	**265**	**267**	**0**	**0**
		All Other Total	**0**	**22,415**	**15,441**	**0**	**0**	**346**	**238**	**0**

Not more than 50% of any soil series or 10% of all potentially suitable land in a county used for biomass energy crops.

Table 2.8.3 Switchgrass Energy Production and Potential MW of Generation Regions 1-6

Land Area Soil	Area (acres)		Energy (1,000) MBtu < $1.50	(1,000) MBtu $1.51 - 2.00	(1,000) MBtu $2.01 - 2.50	(1,000) MBtu $2.51- 3.00	Generation (30%/ 65%) MW @ < $1.50 MBtu	MW @ $1.51 - 2.00 MBtu	MW @ < $2.01- 2.50 MBtu	MW @ < $2.51- 3.00 MBtu
Regions 1-6 Total	**35,406,758**	**CRP Total**	**93,517**	**68,002**	**13,120**	**7,637**	**1,444**	**1,026**	**202**	**115**
		All Other Total	**0**	**31,375**	**65,985**	**25,709**	**0**	**484**	**1,019**	**381**

2.8.3 Switchgrass Potential Contribution to Kansas Electrical Energy Consumption

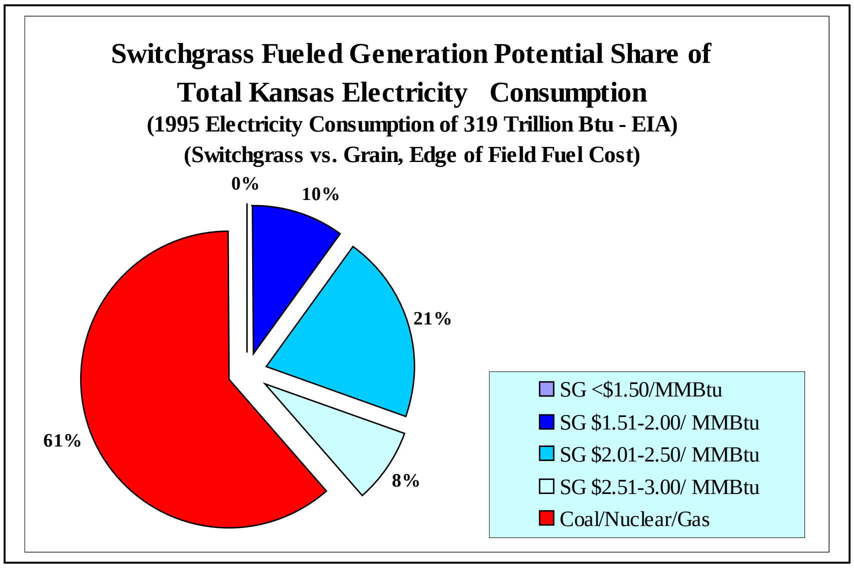

Figure 2.8.10 shows the fraction of total 1995 Kansas electricity consumption that could have been generated by switchgrass produced at average yields in competition with grain, at different cost increments. These are edge of field fuel costs, and do no include transportation to the plant gate or inside the plant gate expenses.

Figure 2.8.10 Potential Switchgrass Energy Competing with Grain

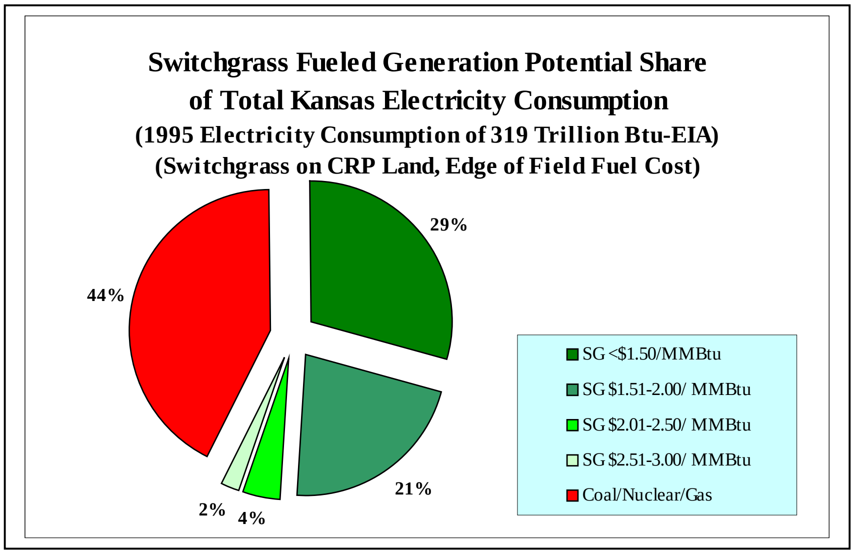

Figure 2.8.11 shows the fraction of total 1995 Kansas electricity consumption that could have been generated by switchgrass produced at average yields in on land potentially eligible for CRP with land rent equal to 40% of the federal CRP rate, at different cost increments. As with the case above, theses costs are at the field edge.

Figure 2.8.11 Potential Switchgrass Energy on CRP Land

2.8.4 Black Locust Average Yields and Cost (edge of field)

Figure 2.8.12 shows the 24 year maximum, average, and minimum yields, area weighted average for all soils within each of the six climate regions. As with switchgrass, black locust average annual yields were highest in region 4 (3.93 dry tons/acre) [8.83 Mg/ha], followed by regions 3 and 5 (2.95 dry tons/acre) [6.62 Mg/ha]. The maximum average eight year yield occurred in region 4 (4.84 dry tons/acre) [10.87 Mg/ha] and the minimum eight year average yield occurred in region 6 (1.73 dry tons/acre) [3.89 Mg/ha]. The 24 year area weighted average of all soil series provides an indication of the potential productivity within a region, however, invidual soil series average yields were evaluated to identify potentially lowest cost opportunities. Soil series with the highest average 8 year yields were; Humbarger (3.25 dry tons/acre) [7.30 Mg/ha] in region 1, Humbarger (3.93 dry tons/acre) [8.83 Mg/ha] in region 2, Marshall (4.36 dry tons/acre) [9.79 Mg/ha] in region 3, Prue (5.79 dry tons/acre) [13.00 Mg/ha] in region 4, Prue (4.37 dry tons/acre) [9.81 Mg/ha] in region 5, and Vanoss (3.69 dry tons/acre) [8.29Mg/ha] in region 6. Black locust yields were highest nearest its closest native range. Additional yield information is provided in Table 2.8.4 and Figure 2.8.15 below and Appendix B.5.

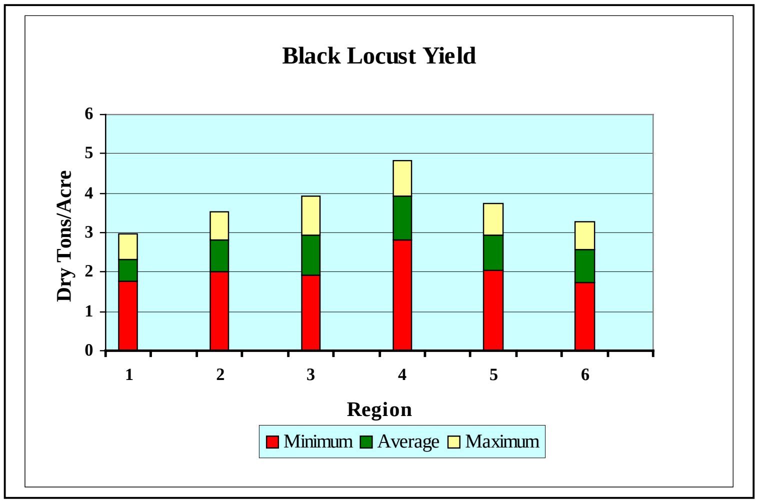

Figure 2.8.12 Black Locust Average Yield

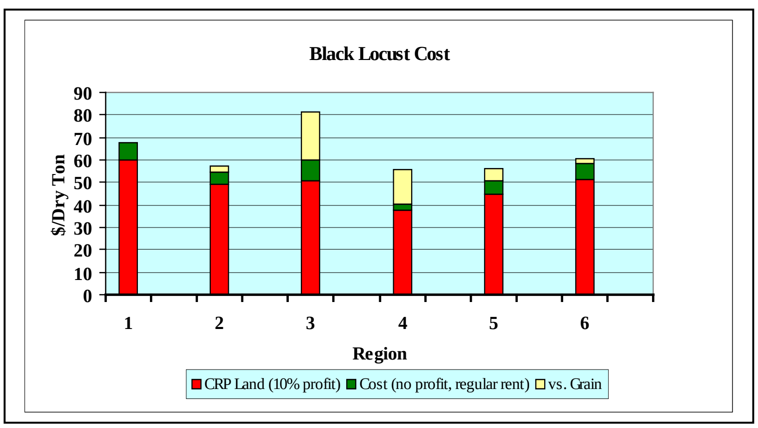

Figure 2.8.13 Black Locust Average Market Cost

Figure 2.8.13 shows black locust average 24 year production cost per dry ton in current non-discounted dollars by region. Costs are shown for the CRP case (rent at 40% of federal CRP rate plus 10% profit), the added incremental cost for full conventional rent (before profit), and the cost required to equal the average profit from the most profitable grain. For the CRP scenario the lowest average cost was region 4 at ($37.44/dry ton) [$41.28/Mg]. Regions 2, 3, 5, and 6 were within 37% with region 1 noteably higher at ($60.16/dry ton) [$135.10/Mg]. Competing with grain significantly raised black locust cost in region 3, ($81.25/dry ton) [$182.46/Mg] and region 4 ($55.76/dry ton) [$125.22/Mg]. In regions 5 and 6 black locusts yields were not particularly high, but the most profitable crop generally changed from soybeans to wheat, lessening the impact of grain competition. As with yield, the lowest cost soil series were significantly different from the average. Soil series with the lowest 24 year average edge of field cost for the CRP scenario were Smolan, ($52.47/dry ton) [$58.29/Mg] for region 1, Holder, ($42.51/dry ton) [$46.87/Mg] for region 2, Lula, ($40.15/dry ton) [$44.27/Mg] for region 3, Stephenville, ($32.39/dry ton) [$35.71/Mg] for region 4, Smolan, ($38.97/dry ton) [$42.97/Mg] for region 5, and Smolan, ($46.90/dry ton) [$51.71 /Mg] for region 6. Additional detail on edge of field cost is provided Table 2.8.2 and Figures 2.8.6 and 2.8.7 below and Appendix B.2.

Figure 2.8.14 provides a breakdown of black locust average production cost by major component by region. Black locust is a leguminous plant, and while the addition of some nitrogen fertilizer during very early development might have accelerated growth, none was applied. Table 2.8.42 below shows key yield and market cost values for soil series the lowest and highest estimated black locust edge of field cost cost. Soil series potentially eligible for CRP, based on an erosion index greater than 8, are shown in italics, followed by values for all other soils. Data on all soil series are in Appendix B.5.

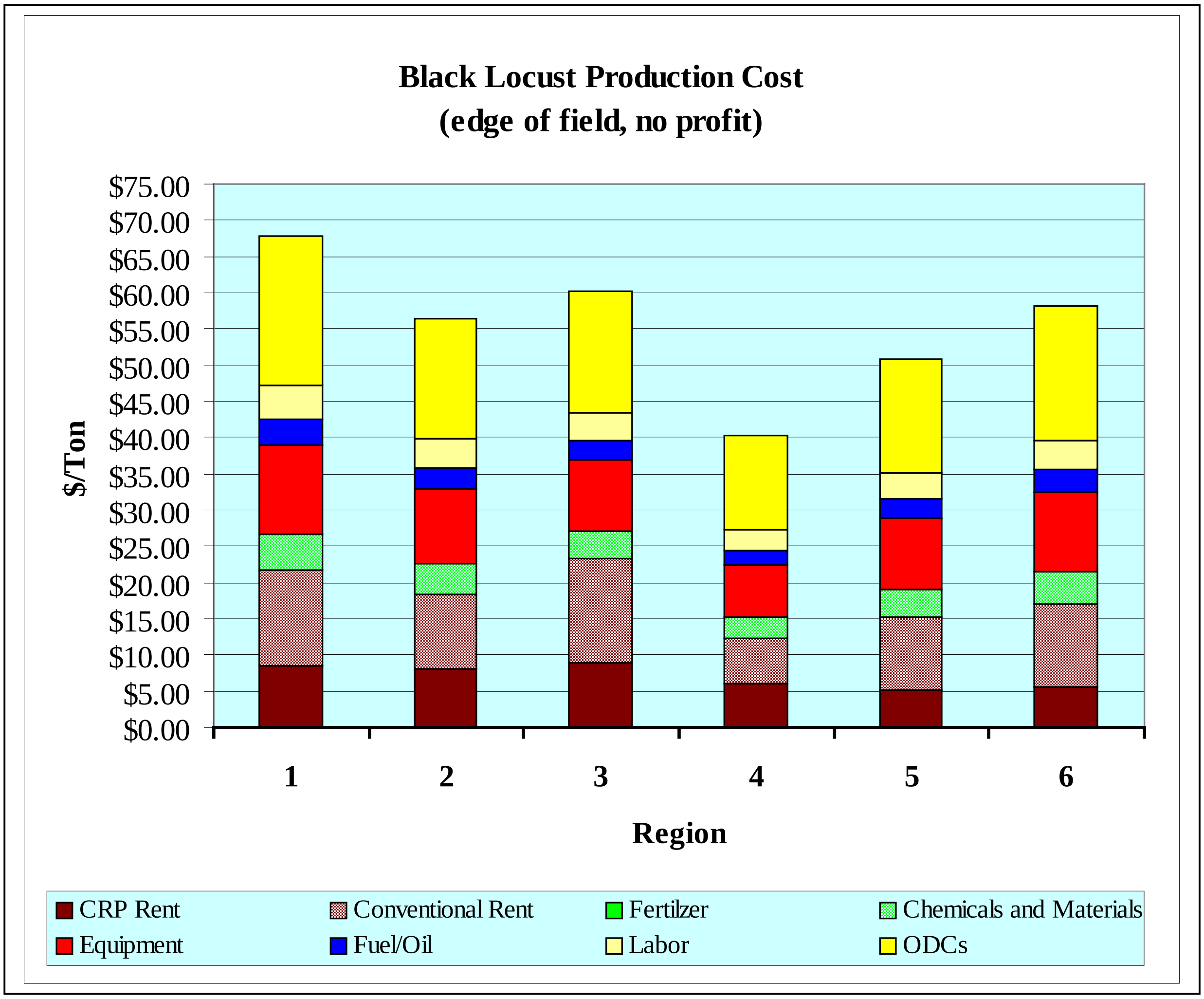

Figure 2.8.14 Black Locust Production Cost Breakdown (edge of field)

Table 2.8.4 Black Locust Yield and Market Cost ($1998) Region 1

(low and high price by soil for *CRP (in italics)* and all other soils)

Land Area & Erosion Index			**Yield**			**Nitrogen**	**Market Price**				
Soil	**Area (acres)**	**Erosion Index (EI)**	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conventional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Barton County											
TIVOLI	*7,282*	*8.56*	*2.84*	*1.72*	*2.24*	*0*	*$4.41*	*$3.74*	*$4.11*	*$4.15*	***$3.72***
HEDVILLE	*2,311*	*21.54*	*2.51*	*1.40*	*1.95*	*0*	*$5.08*	*$2.85*	*$3.39*	*$3.39*	***$4.40***
ARMO	1	7.66	3.14	1.90	2.46	0	**$4.02**	**$3.58**	$4.01	$4.04	$3.52
NEW	15,604	1.16	2.77	1.52	2.12	0	**$4.67**	**$3.38**	$3.88	$3.89	$4.15
Ellis County											
CORINTH	*15,350*	*8.04*	*3.13*	*1.85*	*2.43*	*0*	*$4.06*	*$3.39*	*$3.75*	*$3.79*	***$3.36***
BOGUE	*24,354*	*14.80*	*1.90*	*0.79*	*1.36*	*0*	*$7.27*	*$2.74*	*$3.41*	*$3.42*	***$6.02***
PENDEN	8,655	1.21	3.22	1.96	2.53	0	**$3.91**	**$3.60**	$4.02	$4.05	$3.27
NEW CAMBRIA	1,615	1.21	2.77	1.52	2.12	0	**$4.67**	**$3.38**	$3.88	$3.89	$4.15
Ellsworth County											
SMOLAN	*37*	*19.28*	*3.05*	*1.83*	*2.38*	*0*	*$4.16*	*$3.32*	*$3.77*	*$3.79*	***$3.11***
HEDVILLE	*103,656*	*24.62*	*2.51*	*1.40*	*1.95*	*0*	*$5.08*	*$2.85*	*$3.39*	*$3.39*	***$4.40***
HARNEY	119,965	6.05	3.13	1.88	2.44	0	**$4.07**	**$3.39**	$3.83	$3.86	$3.70
JANSEN	6,170	4.73	2.85	1.66	2.22	0	**$4.46**	**$3.49**	$3.99	$3.99	$4.01
Jewell County											
NIBSON	*4,166*	*40.28*	*2.77*	*1.60*	*2.16*	*0*	*$4.58*	*$2.96*	*$3.40*	*$3.40*	***$3.83***
BOGUE	*15,772*	*14.22*	*1.90*	*0.79*	*1.36*	*0*	*$7.27*	*$2.74*	*$3.41*	*$3.42*	***$6.02***
SALTINE	340	1.33	3.18	1.93	2.49	0	**$3.97**	**$3.41**	$3.83	$3.87	$3.40
NEW CAMBRIA	2,600	1.16	2.77	1.52	2.12	0	**$4.67**	**$3.38**	$3.88	$3.89	$4.15
Lincoln County											
CORINTH	*983*	*8.00*	*3.13*	*1.85*	*2.43*	*0*	*$4.06*	*$3.39*	*$3.75*	*$3.79*	***$3.36***
HEDVILLE	*39,270*	*22.31*	*2.51*	*1.40*	*1.95*	*0*	*$5.08*	*$2.85*	*$3.39*	*$3.39*	***$4.40***
SALTINE	780	1.37	3.18	1.93	2.49	0	**$3.97**	**$3.41**	$3.83	$3.87	$3.40
NEW CAMBRIA	15,518	1.20	2.77	1.52	2.12	0	**$4.67**	**$3.38**	$3.88	$3.89	$4.15
Mitchell County											
KIPSON	*154*	*24.47*	*2.76*	*1.59*	*2.15*	*0*	*$4.59*	*$2.89*	*$3.36*	*$3.37*	***$3.44***
TIMKEN	*2,659*	*45.90*	*1.81*	*0.74*	*1.29*	*0*	*$7.67*	*$2.47*	*$3.10*	*$3.10*	***$6.76***
SALTINE	143	1.33	3.18	1.93	2.49	0	**$3.97**	**$3.41**	$3.83	$3.87	$3.40
NEW CAMBRIA	5,843	1.16	2.77	1.52	2.12	0	**$4.67**	**$3.38**	$3.88	$3.89	$4.15
Osborne County											
NIBSON	*2,838*	*37.40*	*2.77*	*1.60*	*2.16*	*0*	*$4.58*	*$2.96*	*$3.40*	*$3.40*	***$3.83***
TIMKEN	*9,612*	*42.62*	*1.81*	*0.74*	*1.29*	*0*	*$7.67*	*$2.47*	*$3.10*	*$3.10*	***$6.76***
ARMO	60,978	7.12	3.14	1.90	2.46	0	**$4.02**	**$3.58**	$4.01	$4.04	$3.52
NEW CAMBRIA	5,011	1.08	2.77	1.52	2.12	0	**$4.67**	**$3.38**	$3.88	$3.89	$4.15
Phillips County											
CAMPUS	*3,297*	*40.26*	*3.10*	*1.83*	*2.41*	*0*	*$4.11*	*$3.59*	*$4.07*	*$4.08*	***$3.52***
BOGUE	*280*	*14.21*	*1.90*	*0.79*	*1.36*	*0*	*$7.27*	*$2.74*	*$3.41*	*$3.42*	***$6.02***
PENDEN	37,528	1.16	3.22	1.96	2.53	0	**$3.91**	**$3.60**	$4.02	$4.05	$3.27
VALENTINE	*638*	*8.56*	2.76	1.64	2.17	0	**$4.56**	**$3.55**	$4.01	$4.04	$3.41
Rice County											
SMOLAN	*36,469*	*19.28*	*3.05*	*1.83*	*2.38*	*0*	*$4.16*	*$3.32*	*$3.77*	*$3.79*	***$3.11***
HEDVILLE	*8,862*	*24.62*	*2.51*	*1.40*	*1.95*	*0*	*$5.08*	*$2.85*	*$3.39*	*$3.39*	***$4.40***
LESHO	2,299	1.33	3.17	1.88	2.46	0	**$4.02**	**$3.64**	$4.10	$4.12	$3.01
DILLWYN	30,878	1.74	2.70	1.58	2.12	0	**$4.67**	**$3.52**	$3.98	$3.99	$3.94
Rush County											
CORINTH	*10,464*	*8.36*	*3.13*	*1.85*	*2.43*	*0*	*$4.06*	*$3.39*	*$3.75*	*$3.79*	***$3.36***
BOGUE	*1,521*	*15.39*	*1.90*	*0.79*	*1.36*	*0*	*$7.27*	*$2.74*	*$3.41*	*$3.42*	***$6.02***
PENDEN	3,281	1.26	3.22	1.96	2.53	0	**$3.91**	**$3.60**	$4.02	$4.05	$3.27
NEW CAMBRIA	2,859	1.26	2.77	1.52	2.12	0	**$4.67**	**$3.38**	$3.88	$3.89	$4.15
Rooks County											
CAMPUS	*8,385*	*41.94*	*3.10*	*1.83*	*2.41*	*0*	*$4.11*	*$3.59*	*$4.07*	*$4.08*	***$3.52***
BOGUE	*6,948*	*14.80*	*1.90*	*0.79*	*1.36*	*0*	*$7.27*	*$2.74*	*$3.41*	*$3.42*	***$6.02***
PENDEN	24,813	1.21	3.22	1.96	2.53	0	**$3.91**	**$3.60**	$4.02	$4.05	$3.27
NEW CAMBRIA	575	1.21	2.77	1.52	2.12	0	**$4.67**	**$3.38**	$3.88	$3.89	$4.15

Table 2.8.4 Black Locust Yield and Market Cost ($1998) Region 1 (continued)

(low and high price by soil for *CRP (in italics)* and all other soils)

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	Area (acres)	Erosion Index (EI)	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conven-tional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Russel County											
EDALGO	*1,519*	*18.79*	*3.03*	*1.76*	*2.35*	*0*	*$4.22*	*$3.42*	*$3.89*	*$3.90*	***$3.59***
BOGUE	*5,584*	*14.22*	*1.90*	*0.79*	*1.36*	*0*	*$7.27*	*$2.74*	*$3.41*	*$3.42*	***$6.02***
HUMBARGER	2,163	1.16	3.25	1.98	2.56	0	**$3.94**	**$3.46**	$3.92	$3.95	$3.67
NEW CAMBRIA	49	1.16	2.77	1.52	2.12	0	**$4.67**	**$3.38**	$3.88	$3.89	$4.15
Smith County											
CAMPUS	*4,172*	*37.40*	*3.10*	*1.83*	*2.41*	*0*	*$4.11*	*$3.59*	*$4.07*	*$4.08*	***$3.52***
BOGUE	*3,188*	*13.20*	*1.90*	*0.79*	*1.36*	*0*	*$7.27*	*$2.74*	*$3.41*	*$3.42*	***$6.02***
PENDEN	6,148	1.08	3.22	1.96	2.53	0	**$3.91**	**$3.60**	$4.02	$4.05	$3.27
NEW CAMBRIA	1,452	1.08	2.77	1.52	2.12	0	**$4.67**	**$3.38**	$3.88	$3.89	$4.15
Region Total	**7,276,121**										

Table 2.8.4 Black Locust Yield and Market Cost ($1998) Region 2

(low and high price by soil for *CRP (in italics)* and all other soils)

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	Area (acres)	Erosion Index (EI)	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conven-tional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Cloud County											
LONGFORD	*29,956*	*11.30*	*3.71*	*2.17*	*2.96*	*0*	*$3.28*	*$3.97*	*$4.47*	*$4.47*	***$2.89***
HEDVILLE	*16,143*	*23.85*	*2.88*	*1.55*	*2.27*	*0*	*$4.29*	*$2.94*	*$3.37*	*$3.40*	***$3.83***
HUMBARGER	5,089	1.28	3.93	2.28	3.13	0	**$3.20**	**$4.40**	$4.73	$4.73	$3.02
SARPY	2,731	5.13	3.07	1.73	2.44	0	**$4.18**	**$3.15**	$3.73	$3.73	$4.07
Chase County											
SMOLAN	*3,993*	*20.71*	*3.71*	*2.15*	*2.95*	*0*	*$3.28*	*$3.82*	*$4.29*	*$4.30*	***$2.81***
SOGN	*149,416*	*30.04*	*2.94*	*1.54*	*2.30*	*0*	*$4.21*	*$2.70*	*$2.97*	*$3.03*	***$3.62***
CHASE	8,246	4.08	3.85	2.28	3.08	0	**$3.21**	**$4.11**	$4.58	$4.58	$2.97
ZAAR	7,394	4.30	3.29	1.82	2.60	0	**$3.72**	**$3.74**	$4.31	$4.31	$3.19
Clay County											
HOLDER	*2,811*	*9.34*	*3.60*	*2.06*	*2.86*	*0*	*$3.38*	*$3.75*	*$4.26*	*$4.26*	***$2.51***
HEDVILLE	*22,117*	*22.98*	*2.88*	*1.55*	*2.27*	*0*	*$4.29*	*$2.94*	*$3.37*	*$3.40*	***$3.83***
CALCO	451	1.24	3.87	2.28	3.11	0	**$3.14**	**$4.63**	$5.05	$5.05	$2.83
SARPY	2,155	4.94	3.07	1.73	2.44	0	**$4.18**	**$3.15**	$3.73	$3.73	$4.07
Dickinson County											
WELLS	*11,748*	*8.92*	*3.82*	*2.21*	*3.04*	*0*	*$3.28*	*$4.18*	*$4.56*	*$4.56*	***$3.07***
VALENTINE	*5,326*	*9.96*	*1.37*	*0.89*	*1.13*	*6*	*$8.80*	*$8.33*	*$9.35*	*$9.36*	***$7.56***
GEARY	23,827	4.66	3.73	2.18	2.98	0	**$3.25**	**$4.07**	$4.53	$4.53	$2.41
ELSMERE	668	3.48	3.29	1.86	2.60	0	**$3.86**	**$3.51**	$4.04	$4.06	$3.66
Geary County											
HOLDER	*3,673*	*10.48*	*3.60*	*2.06*	*2.86*	*0*	*$3.38*	*$3.75*	*$4.26*	*$4.26*	***$2.51***
VALENTINE	*472*	*10.24*	*1.37*	*0.89*	*1.13*	*6*	*$8.80*	*$8.33*	*$9.35*	*$9.36*	***$7.56***
GEARY	7,561	4.79	3.73	2.18	2.98	0	**$3.25**	**$4.07**	$4.53	$4.53	$2.41
SARPY	884	5.54	3.07	1.73	2.44	0	**$4.18**	**$3.15**	$3.73	$3.73	$4.07
Marion County											
EDALGO	*2,071*	*22.47*	*3.66*	*2.05*	*2.88*	*0*	*$3.36*	*$3.76*	*$4.24*	*$4.25*	***$2.95***
HEDVILLE	*6,828*	*25.77*	*2.88*	*1.55*	*2.27*	*0*	*$4.29*	*$2.94*	*$3.37*	*$3.40*	***$3.83***
VERDIGRIS	40,532	3.44	3.92	2.29	3.13	0	**$3.10**	**$4.68**	$5.09	$5.10	$2.64
ROSEHILL	19,069	6.99	3.18	1.71	2.49	0	**$3.94**	**$3.38**	$3.92	$3.94	$3.57

Table 2.8.4 Black Locust Yield and Market Cost ($1998) Region 2 (continued)

(low and high price by soil for *CRP (in italics)* and all other soils)

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	**Area (acres)**	**Erosion Index (EI)**	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conven-tional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
McPherson County											
PRATT	*355*	*8.34*	*3.55*	*2.02*	*2.81*	*0*	*$3.44*	*$3.93*	*$4.35*	*$4.37*	***$2.55***
HEDVILLE	*59,205*	*26.93*	*2.88*	*1.55*	*2.27*	*0*	*$4.29*	*$2.94*	*$3.37*	*$3.40*	***$3.83***
NESS	681	1.45	3.82	2.16	3.01	0	**$3.21**	**$4.04**	$4.53	$4.53	$2.38
ELSMERE	425	3.74	3.29	1.86	2.60	0	**$3.86**	**$3.51**	$4.04	$4.06	$3.66
Morris County											
SMOLAN	*2,626*	*20.72*	*3.71*	*2.15*	*2.95*	*0*	*$3.28*	*$3.82*	*$4.29*	*$4.30*	***$2.81***
SOGN	*37,493*	*30.06*	*2.94*	*1.54*	*2.30*	*0*	*$4.21*	*$2.70*	*$2.97*	*$3.03*	***$3.62***
CHASE	2,505	4.08	3.85	2.28	3.08	0	**$3.21**	**$4.11**	$4.58	$4.58	$2.97
OSAGE	330	3.53	3.45	1.94	2.74	0	**$3.61**	**$3.46**	$4.02	$4.02	$3.34
Ottawa County											
ARMO	*3,409*	*8.76*	*3.82*	*2.20*	*3.04*	*0*	*$3.22*	*$4.30*	*$4.68*	*$4.69*	***$2.90***
HEDVILLE	*86,667*	*24.62*	*2.88*	*1.55*	*2.27*	*0*	*$4.29*	*$2.94*	*$3.37*	*$3.40*	***$3.83***
HORD	29,079	3.28	3.74	2.19	2.99	0	**$3.23**	**$4.31**	$4.72	$4.72	$2.40
ELS	984	2.05	3.00	1.67	2.38	0	**$4.11**	**$3.51**	$4.03	$4.04	$3.69
Riley County											
SMOLAN	*4,734*	*19.63*	*3.71*	*2.15*	*2.95*	*0*	*$3.28*	*$3.82*	*$4.29*	*$4.30*	***$2.81***
SOGN	*69,085*	*28.48*	*2.94*	*1.54*	*2.30*	*0*	*$4.21*	*$2.70*	*$2.97*	*$3.03*	***$3.62***
CHASE	3,115	3.86	3.85	2.28	3.08	0	**$3.21**	**$4.11**	$4.58	$4.58	$2.97
SARPY	2,919	5.39	3.07	1.73	2.44	0	**$4.18**	**$3.15**	$3.73	$3.73	$4.07
Republic County											
LONGFORD	*252*	*10.57*	*3.71*	*2.17*	*2.96*	*0*	*$3.28*	*$3.97*	*$4.47*	*$4.47*	***$2.89***
HEDVILLE	*4,162*	*22.31*	*2.88*	*1.55*	*2.27*	*0*	*$4.29*	*$2.94*	*$3.37*	*$3.40*	***$3.83***
HUMBARGE	8,427	1.20	3.93	2.28	3.13	0	**$3.20**	**$4.40**	$4.73	$4.73	$3.02
SARPY	2,650	4.80	3.07	1.73	2.44	0	**$4.18**	**$3.15**	$3.73	$3.73	$4.07
Saline County											
SMOLAN	*1,177*	*19.88*	*3.71*	*2.15*	*2.95*	*0*	*$3.28*	*$3.82*	*$4.29*	*$4.30*	***$2.81***
HEDVILLE	*86,300*	*25.39*	*2.88*	*1.55*	*2.27*	*0*	*$4.29*	*$2.94*	*$3.37*	*$3.40*	***$3.83***
COZAD	5,293	3.39	3.77	2.18	3.01	0	**$3.22**	**$4.09**	$4.46	$4.46	$2.81
SUTPHEN	16,344	1.81	3.43	1.89	2.71	0	**$3.71**	**$3.32**	$3.90	$3.91	$3.53
Washington County											
LONGFORD	*31,570*	*10.55*	*3.71*	*2.17*	*2.96*	*0*	*$3.28*	*$3.97*	*$4.47*	*$4.47*	***$2.89***
HEDVILLE	*42,578*	*22.28*	*2.88*	*1.55*	*2.27*	*0*	*$4.29*	*$2.94*	*$3.37*	*$3.40*	***$3.83***
COLO	493	2.60	3.74	2.20	3.00	0	**$3.23**	**$4.47**	$4.91	$4.91	$2.39
SARPY	7	4.79	3.07	1.73	2.44	0	**$4.18**	**$3.15**	$3.73	$3.73	$4.07
Region Total	**6,456,996**										

Table 2.8.4 Black Locust Yield and Market Cost ($1998) Region 3

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	Area (acres)	Erosion Index (EI)	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conventional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Atchison County											
KNOX	15,022	32.19	4.24	2.05	3.17	0	$3.49	$6.32	$6.52	$6.68	**$2.98**
VINLAND	4,417	46.37	3.32	1.63	2.51	0	$4.38	$3.84	$4.05	$4.09	**$3.68**
KENNEBEC	19,993	2.89	4.30	2.09	3.22	0	**$3.52**	**$6.71**	$7.16	$7.30	$3.10
SARPY	553	5.33	3.28	1.61	2.49	0	**$4.50**	**$4.14**	$4.52	$4.54	$3.91
Brown County											
BURCHARD	2,786	16.55	4.13	1.96	3.08	0	$3.57	$6.61	$6.81	$6.93	**$3.00**
VINLAND	3,726	45.12	3.32	1.63	2.51	0	$4.38	$3.84	$4.05	$4.09	**$3.68**
KENNEBEC	132,433	2.82	4.30	2.09	3.22	0	**$3.52**	**$6.71**	$7.16	$7.30	$3.10
WYMORE	125,638	6.33	3.83	1.88	2.89	0	**$3.98**	**$4.32**	$4.69	$4.70	$3.59
Douglas County											
LULA	369	9.37	4.03	1.94	3.02	0	$3.58	$5.58	$5.82	$5.92	**$2.38**
COLLINSVILLE	226	61.09	2.81	1.31	2.09	0	$5.17	$2.75	$3.24	$3.24	**$4.01**
VERDIGRIS	780	3.49	4.20	2.00	3.13	0	**$3.47**	**$7.34**	$7.61	$7.78	$2.77
SARPY	1,446	5.62	3.28	1.61	2.49	0	**$4.50**	**$4.14**	$4.52	$4.54	$3.91
Doniphan County											
KNOX	20,138	32.19	4.24	2.05	3.17	0	$3.49	$6.32	$6.52	$6.68	**$2.98**
VINLAND	3,903	46.37	3.32	1.63	2.51	0	$4.38	$3.84	$4.05	$4.09	**$3.68**
KENNEBEC	13,218	2.89	4.30	2.09	3.22	0	**$3.52**	**$6.71**	$7.16	$7.30	$3.10
SARPY	1,579	5.33	3.28	1.61	2.49	0	**$4.50**	**$4.14**	$4.52	$4.54	$3.91
Franklin County											
LULA	54,940	9.57	4.03	1.94	3.02	0	$3.58	$5.58	$5.82	$5.92	**$2.38**
COLLINSVILLE	13,022	62.42	2.81	1.31	2.09	0	$5.17	$2.75	$3.24	$3.24	**$4.01**
KENOMA	54,338	7.97	3.88	1.96	2.95	0	**$3.81**	**$4.21**	$4.66	$4.69	$3.33
VERDIGRIS	24,812	3.56	4.20	2.00	3.13	0	**$3.47**	**$7.34**	$7.61	$7.78	$2.77
Jackson County											
BURCHARD	32,715	17.00	4.13	1.96	3.08	0	$3.57	$6.61	$6.81	$6.93	**$3.00**
SIBLEYVILLE	6	14.70	3.56	1.71	2.68	0	$4.27	$4.26	$4.51	$4.52	**$3.82**
KENNEBEC	32,084	2.89	4.30	2.09	3.22	0	**$3.52**	**$6.71**	$7.16	$7.30	$3.10
WYMORE	30,058	6.50	3.83	1.88	2.89	0	**$3.98**	**$4.32**	$4.69	$4.70	$3.59
Jefferson County											
STEINAUER	10	24.06	4.26	2.03	3.17	0	$3.50	$6.62	$6.80	$6.96	**$3.01**
SIBLEYVILLE	3,173	15.10	3.56	1.71	2.68	0	$4.27	$4.26	$4.51	$4.52	**$3.82**
KENNEBEC	16,988	2.97	4.30	2.09	3.22	0	**$3.52**	**$6.71**	$7.16	$7.30	$3.10
SARPY	1,404	5.48	3.28	1.61	2.49	0	**$4.50**	**$4.14**	$4.52	$4.54	$3.91
Johnson County											
CLARESON	115	27.50	3.64	1.74	2.73	0	$3.96	$4.47	$4.80	$4.81	**$3.07**
SIBLEYVILLE	5,256	15.44	3.56	1.71	2.68	0	$4.27	$4.26	$4.51	$4.52	**$3.82**
VERDIGRIS	519	3.47	4.20	2.00	3.13	0	**$3.47**	**$7.34**	$7.61	$7.78	$2.77
OSAGE	13	3.47	3.59	1.73	2.69	0	**$4.04**	**$5.09**	$5.51	$5.56	$3.30
Leavenworth County											
KNOX	6,937	33.06	4.24	2.05	3.17	0	$3.49	$6.32	$6.52	$6.68	**$2.98**
SIBLEYVILLE	7,563	15.10	3.56	1.71	2.68	0	$4.27	$4.26	$4.51	$4.52	**$3.82**
KENNEBEC	9,289	2.97	4.30	2.09	3.22	0	**$3.52**	**$6.71**	$7.16	$7.30	$3.10
SARPY	353	5.48	3.28	1.61	2.49	0	**$4.50**	**$4.14**	$4.52	$4.54	$3.91
Lyon County											
LULA	143	9.48	4.03	1.94	3.02	0	$3.58	$5.58	$5.82	$5.92	**$2.38**
COLLINSVILLE	1,775	61.81	2.81	1.31	2.09	0	$5.17	$2.75	$3.24	$3.24	**$4.01**
IVAN	36,679	3.53	4.29	2.10	3.22	0	**$3.36**	**$6.56**	$6.90	$7.05	$2.23
ZAAR	3,028	4.30	3.49	1.74	2.66	0	**$4.15**	**$4.55**	$5.06	$5.10	$3.53
Miami County											
LULA	281	9.81	4.03	1.94	3.02	0	$3.58	$5.58	$5.82	$5.92	**$2.38**
WOODSON	19,600	8.17	3.78	1.84	2.85	0	$3.94	$4.41	$4.78	$4.80	**$3.43**
VERDIGRIS	13,891	3.65	4.20	2.00	3.13	0	**$3.47**	**$7.34**	$7.61	$7.78	$2.77
OSAGE	8,497	3.65	3.59	1.73	2.69	0	**$4.04**	**$5.09**	$5.51	$5.56	$3.30

Table 2.8.4 Black Locust Yield and Market Cost ($1998) Region 3 (continued)

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	Area (acres)	Erosion Index (EI)	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conventional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Marshall County											
BURCHARD	*925*	*16.24*	*4.13*	*1.96*	*3.08*	*0*	*$3.57*	*$6.61*	*$6.81*	*$6.93*	***$3.00***
KIPSON	*45,174*	*26.89*	*3.41*	*1.67*	*2.58*	*0*	*$4.27*	*$3.83*	*$4.05*	*$4.08*	***$3.59***
TULLY	23,706	6.73	4.17	2.01	3.12	0	**$3.46**	**$5.66**	$6.03	$6.09	$2.30
WYMORE	182,591	6.21	3.83	1.88	2.89	0	**$3.98**	**$4.32**	$4.69	$4.70	$3.59
Nemaha County											
BURCHARD	*89,704*	*16.55*	*4.13*	*1.96*	*3.08*	*0*	*$3.57*	*$6.61*	*$6.81*	*$6.93*	***$3.00***
SIBLEYVILLE	*353*	*14.31*	*3.56*	*1.71*	*2.68*	*0*	*$4.27*	*$4.26*	*$4.51*	*$4.52*	***$3.82***
CALCO	263	1.30	4.36	2.10	3.24	0	**$3.34**	**$7.01**	$7.44	$7.60	$2.68
WYMORE	66,101	6.33	3.83	1.88	2.89	0	**$3.98**	**$4.32**	$4.69	$4.70	$3.59
Osage County											
LULA	*30,257*	*9.33*	*4.03*	*1.94*	*3.02*	*0*	*$3.58*	*$5.58*	*$5.82*	*$5.92*	***$2.38***
SIBLEYVILLE	*401*	*15.44*	*3.56*	*1.71*	*2.68*	*0*	*$4.27*	*$4.26*	*$4.51*	*$4.52*	***$3.82***
VERDIGRIS	27,727	3.47	4.20	2.00	3.13	0	**$3.47**	**$7.34**	$7.61	$7.78	$2.77
OSAGE	9,560	3.47	3.59	1.73	2.69	0	**$4.04**	**$5.09**	$5.51	$5.56	$3.30
Pottawatomie County											
BURCHARD	*42*	*17.19*	*4.13*	*1.96*	*3.08*	*0*	*$3.57*	*$6.61*	*$6.81*	*$6.93*	***$3.00***
KIPSON	*251*	*28.48*	*3.41*	*1.67*	*2.58*	*0*	*$4.27*	*$3.83*	*$4.05*	*$4.08*	***$3.59***
TULLY	56,191	7.12	4.17	2.01	3.12	0	**$3.46**	**$5.66**	$6.03	$6.09	$2.30
SARPY	3,107	5.39	3.28	1.61	2.49	0	**$4.50**	**$4.14**	$4.52	$4.54	$3.91
Shawnee County											
DWIGHT	*4,430*	*11.41*	*3.85*	*1.87*	*2.89*	*0*	*$3.73*	*$4.47*	*$4.83*	*$4.88*	***$2.48***
SIBLEYVILLE	*888*	*15.10*	*3.56*	*1.71*	*2.68*	*0*	*$4.27*	*$4.26*	*$4.51*	*$4.52*	***$3.82***
IVAN	57	3.40	4.29	2.10	3.22	0	**$3.36**	**$6.56**	$6.90	$7.05	$2.23
SARPY	2,180	5.48	3.28	1.61	2.49	0	**$4.50**	**$4.14**	$4.52	$4.54	$3.91
Wabaunsee County											
FLORENCE	*57,568*	*51.41*	*3.19*	*1.49*	*2.37*	*0*	*$4.55*	*$4.33*	*$4.83*	*$4.83*	***$3.03***
VINLAND	*59*	*49.48*	*3.32*	*1.63*	*2.51*	*0*	*$4.38*	*$3.84*	*$4.05*	*$4.09*	***$3.68***
IVAN	20,920	3.53	4.29	2.10	3.22	0	**$3.36**	**$6.56**	$6.90	$7.05	$2.23
SARPY	1,346	5.69	3.28	1.61	2.49	0	**$4.50**	**$4.14**	$4.52	$4.54	$3.91
Wyandotte County											
KNOX	*3,863*	*33.06*	*4.24*	*2.05*	*3.17*	*0*	*$3.49*	*$6.32*	*$6.52*	*$6.68*	***$2.98***
SIBLEYVILLE	*406*	*15.10*	*3.56*	*1.71*	*2.68*	*0*	*$4.27*	*$4.26*	*$4.51*	*$4.52*	***$3.82***
KENNEBEC	597	2.97	4.30	2.09	3.22	0	**$3.52**	**$6.71**	$7.16	$7.30	$3.10
SARPY	255	5.48	3.28	1.61	2.49	0	**$4.50**	**$4.14**	$4.52	$4.54	$3.91
Region Total	**7,135,756**										

Table 2.8.4 Black Locust Yield and Market Cost ($1998) — Region 4

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	**Area (acres)**	**Erosion Index (EI)**	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conventional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Allen County											
SUMMIT	246	8.35	5.13	2.93	4.13	1	$2.41	$4.19	$4.44	$4.46	**$2.17**
COLLINSVILLE	3,216	68.66	3.44	1.94	2.80	0	$3.54	$2.07	$2.36	$2.39	**$3.18**
VERDIGRIS	23,735	3.92	5.66	3.23	4.54	0	**$2.24**	**$5.09**	$5.23	$5.31	$2.22
ZAAR	30,528	4.78	4.59	2.59	3.72	0	**$2.67**	**$3.36**	$3.66	$3.67	$2.48
Anderson County											
SUMMIT	20,570	8.16	5.13	2.93	4.13	1	$2.41	$4.19	$4.44	$4.46	**$2.17**
COLLINSVILLE	3,296	67.10	3.44	1.94	2.80	0	$3.54	$2.07	$2.36	$2.39	**$3.18**
VERDIGRIS	26,359	3.83	5.66	3.23	4.54	0	**$2.24**	**$5.09**	$5.23	$5.31	$2.22
OSAGE	3,890	3.83	4.79	2.72	3.88	0	**$2.56**	**$3.56**	$3.82	$3.83	$2.36
Bourbon County											
SUMMIT	1,509	8.35	5.13	2.93	4.13	1	$2.41	$4.19	$4.44	$4.46	**$2.17**
COLLINSVILLE	3,857	68.66	3.44	1.94	2.80	0	$3.54	$2.07	$2.36	$2.39	**$3.18**
VERDIGRIS	12,566	3.92	5.66	3.23	4.54	0	**$2.24**	**$5.09**	$5.23	$5.31	$2.22
ZAAR	48,273	4.78	4.59	2.59	3.72	0	**$2.67**	**$3.36**	$3.66	$3.67	$2.48
Coffey County											
DWIGHT	852	12.56	4.91	2.79	3.96	0	$2.51	$3.54	$3.76	$3.78	**$1.93**
COLLINSVILLE	9,161	65.54	3.44	1.94	2.80	0	$3.54	$2.07	$2.36	$2.39	**$3.18**
VERDIGRIS	29,101	3.74	5.66	3.23	4.54	0	**$2.24**	**$5.09**	$5.23	$5.31	$2.22
OSAGE	17,065	3.74	4.79	2.72	3.88	0	**$2.56**	**$3.56**	$3.82	$3.83	$2.36
Cherokee County											
DENNIS	81,870	8.01	5.14	3.00	4.17	0	$2.39	$3.28	$3.43	$3.47	**$2.20**
COLLINSVILLE	3,575	74.90	3.44	1.94	2.80	0	$3.54	$2.07	$2.36	$2.39	**$3.18**
VERDIGRIS	1,353	4.27	5.66	3.23	4.54	0	**$2.24**	**$5.09**	$5.23	$5.31	$2.22
ZAAR	4,778	5.21	4.59	2.59	3.72	0	**$2.67**	**$3.36**	$3.66	$3.67	$2.48
Crawford County											
PARSONS	132,004	10.68	5.24	3.03	4.25	0	$2.35	$3.74	$3.91	$3.96	**$2.23**
COLLINSVILLE	22	73.34	3.44	1.94	2.80	0	$3.54	$2.07	$2.36	$2.39	**$3.18**
HEPLER	11,060	2.23	5.58	3.18	4.48	0	**$2.25**	**$2.41**	$2.58	$2.62	$2.19
VERDIGRIS	1,652	4.18	5.66	3.23	4.54	0	**$2.24**	**$5.09**	$5.23	$5.31	$2.22
Labette County											
DENNIS	38,879	8.01	5.14	3.00	4.17	0	$2.39	$3.28	$3.43	$3.47	**$2.20**
COLLINSVILLE	5,229	74.90	3.44	1.94	2.80	0	$3.54	$2.07	$2.36	$2.39	**$3.18**
VERDIGRIS	16,590	4.27	5.66	3.23	4.54	0	**$2.24**	**$5.09**	$5.23	$5.31	$2.22
ZAAR	31,227	5.21	4.59	2.59	3.72	0	**$2.67**	**$3.36**	$3.66	$3.67	$2.48
Linn County											
SUMMIT	29,319	8.16	5.13	2.93	4.13	1	$2.41	$4.19	$4.44	$4.46	**$2.17**
COLLINSVILLE	683	67.10	3.44	1.94	2.80	0	$3.54	$2.07	$2.36	$2.39	**$3.18**
VERDIGRIS	13,380	3.83	5.66	3.23	4.54	0	**$2.24**	**$5.09**	$5.23	$5.31	$2.22
OSAGE	14,308	3.83	4.79	2.72	3.88	0	**$2.56**	**$3.56**	$3.82	$3.83	$2.36
Montgomery County											
STEPHENVILLE	5,822	9.64	4.85	2.91	3.97	0	$2.50	$2.55	$2.70	$2.73	**$1.92**
COLLINSVILLE	43,822	73.34	3.44	1.94	2.80	0	$3.54	$2.07	$2.36	$2.39	**$3.18**
VERDIGRIS	21,286	4.18	5.66	3.23	4.54	0	**$2.24**	**$5.09**	$5.23	$5.31	$2.22
ZAAR	19,242	5.11	4.59	2.59	3.72	0	**$2.67**	**$3.36**	$3.66	$3.67	$2.48
Neosho County											
STEPHENVILLE	3,536	9.43	4.85	2.91	3.97	0	$2.50	$2.55	$2.70	$2.73	**$1.92**
COLLINSVILLE	4,860	71.78	3.44	1.94	2.80	0	$3.54	$2.07	$2.36	$2.39	**$3.18**
VERDIGRIS	20,020	4.09	5.66	3.23	4.54	0	**$2.24**	**$5.09**	$5.23	$5.31	$2.22
ZAAR	28,069	5.00	4.59	2.59	3.72	0	**$2.67**	**$3.36**	$3.66	$3.67	$2.48
Wilson County											
STEPHENVILLE	2,850	9.23	4.85	2.91	3.97	0	$2.50	$2.55	$2.70	$2.73	**$1.92**
COLLINSVILLE	24,427	70.22	3.44	1.94	2.80	0	$3.54	$2.07	$2.36	$2.39	**$3.18**
VERDIGRIS	23,776	4.01	5.66	3.23	4.54	0	**$2.24**	**$5.09**	$5.23	$5.31	$2.22
ZAAR	20,417	4.89	4.59	2.59	3.72	0	**$2.67**	**$3.36**	$3.66	$3.67	$2.48

Table 2.8.4 Black Locust Yield and Market Cost ($1998) Region 4 (continued)

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	Area (acres)	Erosion Index (EI)	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conven-tional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Woodson County											
STEPHENVILLE	*3,739*	*8.82*	*4.85*	*2.91*	*3.97*	*0*	*$2.50*	*$2.55*	*$2.70*	*$2.73*	***$1.92***
COLLINSVILLE	*28,293*	*67.10*	*3.44*	*1.94*	*2.80*	*0*	*$3.54*	*$2.07*	*$2.36*	*$2.39*	***$3.18***
VERDIGRIS	18,922	3.83	5.66	3.23	4.54	0	**$2.24**	**$5.09**	$5.23	$5.31	$2.22
ZAAR	787	4.67	4.59	2.59	3.72	0	**$2.67**	**$3.36**	$3.66	$3.67	$2.48
Region Total	4,213,861										

Table 2.8.4 Black Locust Yield and Market Cost ($1998) Region 5

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	Area (acres)	Erosion Index (EI)	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conven-tional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Butler County											
MARTIN	*2,035*	*16.74*	4.03	2.29	3.20	0.0000	$2.95	$3.86	$4.06	$4.07	**$2.67**
FLORENCE	*54,384*	*55.33*	3.34	1.63	2.54	0.0000	$3.72	$3.26	$3.78	$3.78	**$3.38**
VERDIGRIS	71,438	3.80	4.25	2.40	3.37	0.0000	**$2.85**	**$4.67**	$4.87	$4.91	$2.72
ROSEHILL	12,224	7.72	3.42	1.75	2.64	0.0000	**$3.58**	**$3.10**	$3.55	$3.55	$3.20
Cowley County											
SMOLAN	*38,623*	*22.84*	*3.98*	*2.24*	*3.15*	*0.0000*	*$3.00*	*$3.75*	*$3.92*	*$3.94*	***$2.31***
TIVOLI	*2,892*	*11.59*	*1.37*	*0.89*	*1.12*	*5.5781*	*$8.64*	*$9.01*	*$9.88*	*$9.88*	***$6.74***
VERDIGRIS	32,863	3.89	4.25	2.40	3.37	0.0000	**$2.85**	**$4.67**	$4.87	$4.91	$2.72
ROSEHILL	8,101	7.91	3.42	1.75	2.64	0.0000	**$3.58**	**$3.10**	$3.55	$3.55	$3.20
Chautauqua County											
SMOLAN	*52*	*24.43*	*3.98*	*2.24*	*3.15*	*0.0000*	*$3.00*	*$3.75*	*$3.92*	*$3.94*	***$2.31***
COLLINSVILLE	*10,037*	*72.90*	*2.97*	*1.44*	*2.25*	*0.0000*	*$4.19*	*$2.06*	*$2.53*	*$2.53*	***$3.78***
VERDIGRIS	6,549	4.16	4.25	2.40	3.37	0.0000	**$2.85**	**$4.67**	$4.87	$4.91	$2.72
OSAGE	10,439	4.16	3.73	1.98	2.91	0.0000	**$3.25**	**$3.49**	$3.91	$3.91	$2.86
Elk County											
MARTIN	*29,226*	*17.53*	*4.03*	*2.29*	*3.20*	*0.0000*	*$2.95*	*$3.86*	*$4.06*	*$4.07*	***$2.67***
COLLINSVILLE	*2,495*	*69.73*	*2.97*	*1.44*	*2.25*	*0.0000*	*$4.19*	*$2.06*	*$2.53*	*$2.53*	***$3.78***
PRUE	1,412	7.95	4.37	2.46	3.46	0.0000	**$2.76**	**$4.30**	$4.41	$4.47	$2.59
OSAGE	433	3.98	3.73	1.98	2.91	0.0000	**$3.25**	**$3.49**	$3.91	$3.91	$2.86
Greenwood County											
LULA	*855*	*10.45*	*3.88*	*2.12*	*3.05*	*0.0000*	*$3.09*	*$3.80*	*$3.90*	*$3.94*	***$2.39***
COLLINSVILLE	*12*	*68.15*	*2.97*	*1.44*	*2.25*	*0.0000*	*$4.19*	*$2.06*	*$2.53*	*$2.53*	***$3.78***
VERDIGRIS	120	3.89	4.25	2.40	3.37	0.0000	**$2.85**	**$4.67**	$4.87	$4.91	$2.72
ZAAR	472	4.74	3.53	1.87	2.75	0.0000	**$3.46**	**$3.37**	$3.87	$3.87	$3.21
Harvey County											
SMOLAN	*9,355*	*19.65*	*3.98*	*2.24*	*3.15*	*0.0000*	*$3.00*	*$3.75*	*$3.92*	*$3.94*	***$2.31***
TIVOLI	*8,695*	*9.97*	*1.37*	*0.89*	*1.12*	*5.5781*	*$8.64*	*$9.01*	*$9.88*	*$9.88*	***$6.74***
VERDIGRIS	0	3.35	4.25	2.40	3.37	0.0000	**$2.85**	**$4.67**	$4.87	$4.91	$2.72
PRATT	10,326	7.77	1.75	1.07	1.41	5.5781	**$6.89**	**$7.66**	$8.28	$8.28	$5.37
Sedgwick County											
SMOLAN	*231*	*20.18*	*3.98*	*2.24*	*3.15*	*0.0000*	*$3.00*	*$3.75*	*$3.92*	*$3.94*	***$2.31***
TIVOLI	*888*	*10.24*	*1.37*	*0.89*	*1.12*	*5.5781*	*$8.64*	*$9.01*	*$9.88*	*$9.88*	***$6.74***
ELANDCO	10,180	2.13	4.15	2.36	3.30	0.0000	**$2.86**	**$4.55**	$4.65	$4.70	$2.21
PRATT	2,829	7.98	1.75	1.07	1.41	5.5781	**$6.89**	**$7.66**	$8.28	$8.28	$5.37
Sumner County											
PRATT	*1,830*	*8.40*	*1.75*	*1.07*	*1.41*	*5.5781*	*$6.89*	*$7.66*	*$8.28*	*$8.28*	***$5.37***
TIVOLI	*3,347*	*10.78*	*1.37*	*0.89*	*1.12*	*5.5781*	*$8.64*	*$9.01*	*$9.88*	*$9.88*	***$6.74***
VERDIGRIS	43	3.62	4.25	2.40	3.37	0.0000	**$2.85**	**$4.67**	$4.87	$4.91	$2.72
ROSEHILL	22,987	7.36	3.42	1.75	2.64	0.0000	**$3.58**	**$3.10**	$3.55	$3.55	$3.20
Region Total	4,337,831										

Table 2.8.4 Black Locust Yield and Market Cost ($1998) Region 6

Land Area & Erosion Index			Yield			Nitrogen	Market Price				
Soil	Area (acres)	Erosion Index (EI)	Max (tons/ acre)	Min (tons/ acre)	Ave (tons/ acre)	Average (lbs/ acre)	Conventional Land Rent Average ($/MBtu)	To Equal Profit on 10 Yr. Average Grain Price $/MBtu	To Equal Profit on 10 Yr. 75th Percentile Grain Price $/MBtu	To Equal Profit on 10 Yr. 95th Percentile Grain Price $/MBtu	CRP Land 40% of Rent Production Cost + 10% Profit $/MBtu
Barber County											
CLAIREMONT	46,451	163.32	3.61	1.88	2.82	0	$3.40	$4.04	$4.38	$4.40	$2.95
QUINLAN	100,888	14.66	2.88	1.48	2.26	0	$4.24	$3.48	$3.92	$3.92	$3.71
PORT	21,090	1.94	3.57	1.84	2.78	0	$3.46	$3.94	$4.31	$4.31	$3.15
YAHOLA	7,929	2.27	1.83	1.14	1.49	6	$6.61	$6.53	$7.06	$7.11	$5.92
Comanche County											
CLAIREMONT	7,353	138.58	3.61	1.88	2.82	0	$3.40	$4.04	$4.38	$4.40	$2.95
HEDVILLE	3,129	23.15	2.54	1.30	2.00	0	$4.80	$2.98	$3.36	$3.39	$4.12
ABILENE	16,904	1.65	3.64	1.93	2.85	0	$3.36	$4.07	$4.41	$4.44	$3.00
YAHOLA	1,903	1.93	1.83	1.14	1.49	6	$6.61	$6.53	$7.06	$7.11	$5.92
Edwards County											
CAMPUS	308	45.29	3.40	1.75	2.64	0	$3.64	$4.06	$4.44	$4.49	$3.18
CANLON	308	45.29	2.58	1.33	2.03	0	$4.72	$2.81	$3.12	$3.14	$4.13
LUBBOCK	9,576	1.49	3.64	1.90	2.84	0	$3.39	$3.99	$4.33	$4.36	$3.12
PLATTE	4,519	0.93	2.94	1.53	2.30	0	$4.17	$3.80	$4.18	$4.23	$3.24
Harper County											
CASE	255	8.91	3.62	1.91	2.84	0	$3.38	$4.14	$4.47	$4.50	$2.96
QUINLAN	28,219	13.49	2.88	1.48	2.26	0	$4.24	$3.48	$3.92	$3.92	$3.71
ELANDCO	379	2.08	3.58	1.86	2.80	0	$3.43	$4.12	$4.49	$4.50	$3.09
DILLWYN	544	1.78	2.92	1.53	2.29	0	$4.18	$3.77	$4.14	$4.20	$3.74
Kingman County											
CASE	10,705	8.43	3.62	1.91	2.84	0	$3.38	$4.14	$4.47	$4.50	$2.96
QUINLAN	25,750	12.76	2.88	1.48	2.26	0	$4.24	$3.48	$3.92	$3.92	$3.71
MCLAIN	1,853	1.96	3.57	1.87	2.79	0	$3.44	$3.89	$4.24	$4.26	$2.98
DILLWYN	20,743	1.68	2.92	1.53	2.29	0	$4.18	$3.77	$4.14	$4.20	$3.74
Kiowa County											
CLAIREMONT	10	138.58	3.61	1.88	2.82	0	$3.40	$4.04	$4.38	$4.40	$2.95
CANLON	3,971	43.28	2.58	1.33	2.03	0	$4.72	$2.81	$3.12	$3.14	$4.13
ABILENE	1,315	1.65	3.64	1.93	2.85	0	$3.36	$4.07	$4.41	$4.44	$3.00
PLATTE	4	0.89	2.94	1.53	2.30	0	$4.17	$3.80	$4.18	$4.23	$3.24
Pawnee County											
TIVOLI	8,926	9.62	3.15	1.66	2.48	0	$3.87	$4.08	$4.36	$4.43	$3.37
NIBSON	3,635	45.29	2.94	1.53	2.31	0	$4.16	$3.19	$3.51	$3.55	$3.74
LUBBOCK	6,493	1.49	3.64	1.90	2.84	0	$3.39	$3.99	$4.33	$4.36	$3.12
PLATTE	7,527	0.93	2.94	1.53	2.30	0	$4.17	$3.80	$4.18	$4.23	$3.24
Pratt County											
CASE	17,669	9.40	3.62	1.91	2.84	0	$3.38	$4.14	$4.47	$4.50	$2.96
TIVOLI	29,394	10.51	3.15	1.66	2.48	0	$3.87	$4.08	$4.36	$4.43	$3.37
FARNUM	53,305	1.02	3.53	1.84	2.76	0	$3.50	$3.92	$4.26	$4.30	$3.23
DILLWYN	337	1.87	2.92	1.53	2.29	0	$4.18	$3.77	$4.14	$4.20	$3.74
Reno County											
SMOLAN	2,052	18.06	3.40	1.80	2.68	0	$3.58	$3.46	$3.82	$3.84	$2.78
TIVOLI	45,674	9.16	3.15	1.66	2.48	0	$3.87	$4.08	$4.36	$4.43	$3.37
VANOSS	49,175	1.64	3.69	1.92	2.87	0	$3.42	$3.68	$4.03	$4.06	$3.29
DILLWYN	3,559	1.63	2.92	1.53	2.29	0	$4.18	$3.77	$4.14	$4.20	$3.74
Stafford County											
CLARK	2,633	8.81	3.54	1.88	2.78	0	$3.45	$4.19	$4.53	$4.56	$3.02
TIVOLI	45,676	9.85	3.15	1.66	2.48	0	$3.87	$4.08	$4.36	$4.43	$3.37
FARNUM	33,621	0.95	3.53	1.84	2.76	0	$3.50	$3.92	$4.26	$4.30	$3.23
DILLWYN	20,964	1.76	2.92	1.53	2.29	0	$4.18	$3.77	$4.14	$4.20	$3.74
Region Total	**5,986,194**										

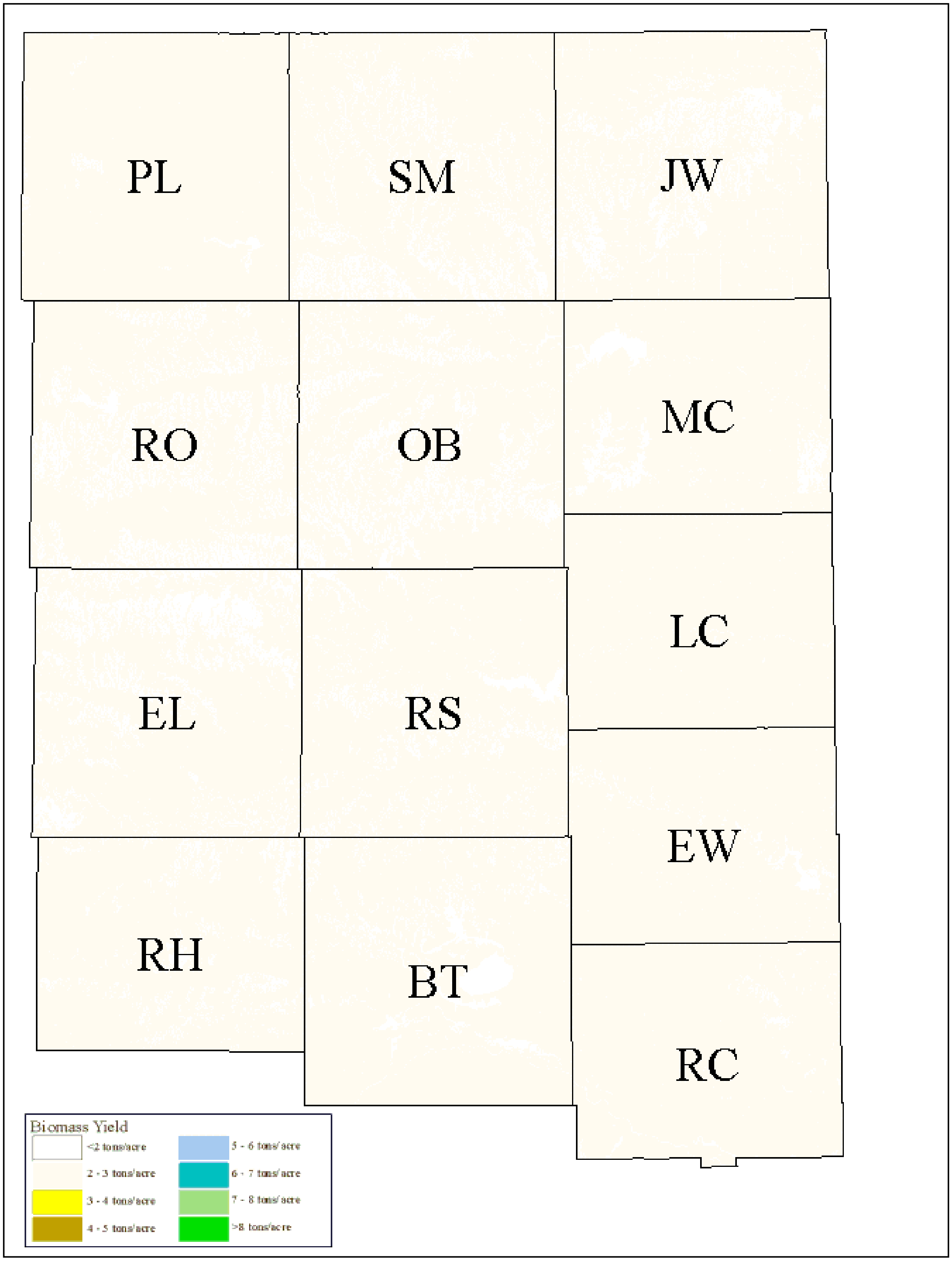

Figure 2.8.15 Map of Black Locust Average Yield (tons per acre) by Soil Series Region 1
Average region 1 black locust yields were the lowest of any region/crop investigated, ranging from 2-3 tons/acre or less [4.5 – 6.7 Mg/ha].

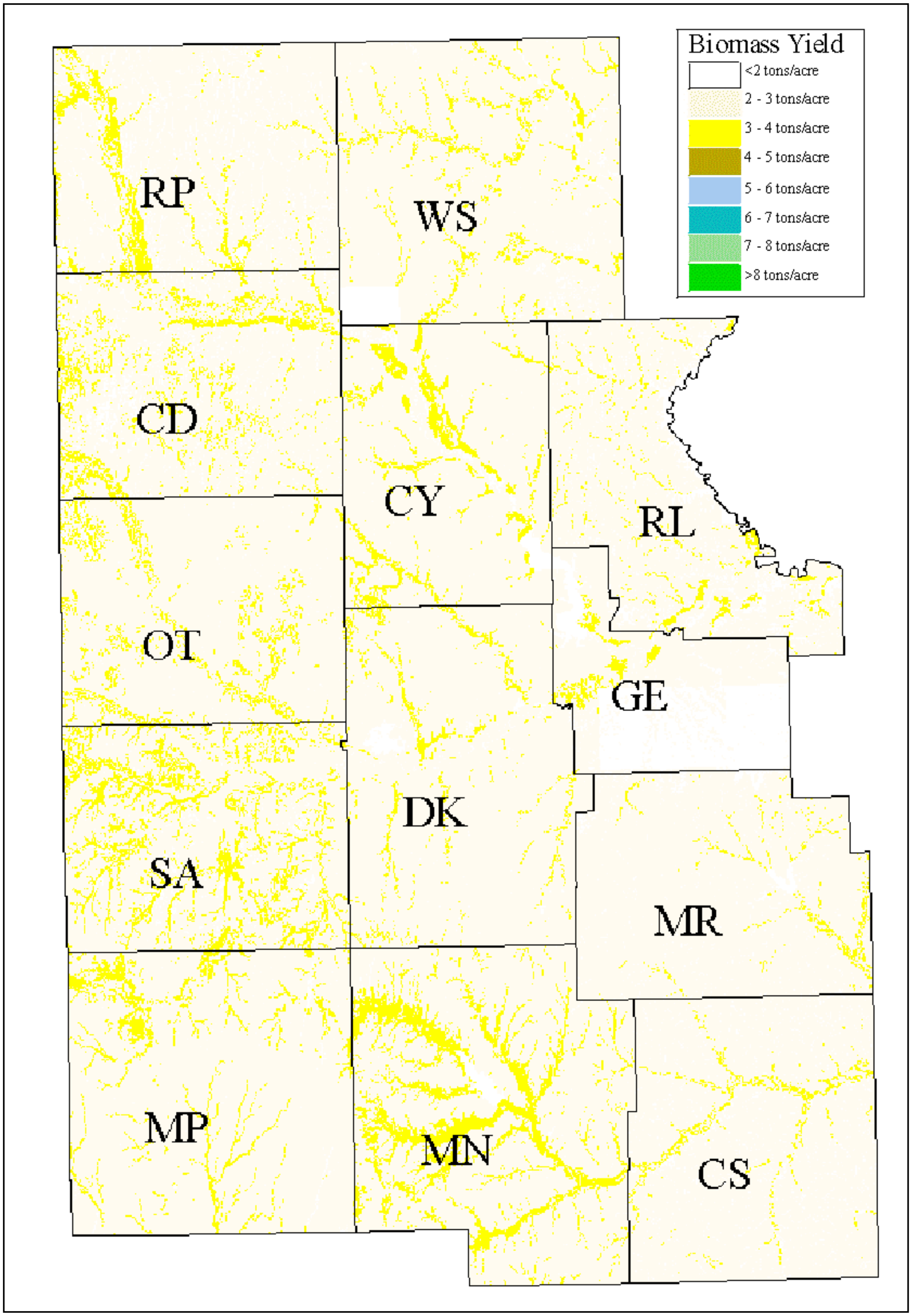

Figure 2.8.15 Map of Black Locust Average Yield (tons per acre) by Soil Series Region 2
Much of region 2 average black locust yields were like region 1, falling in the 2-3 tons/acre or less [4.5 – 6.7 Mg/ha]. Significant areas of soil series with higher moisture in drainage systems had higher yields, ranging from 3 – 4 tons per acre [6.7 – 9.0 Mg/ha].

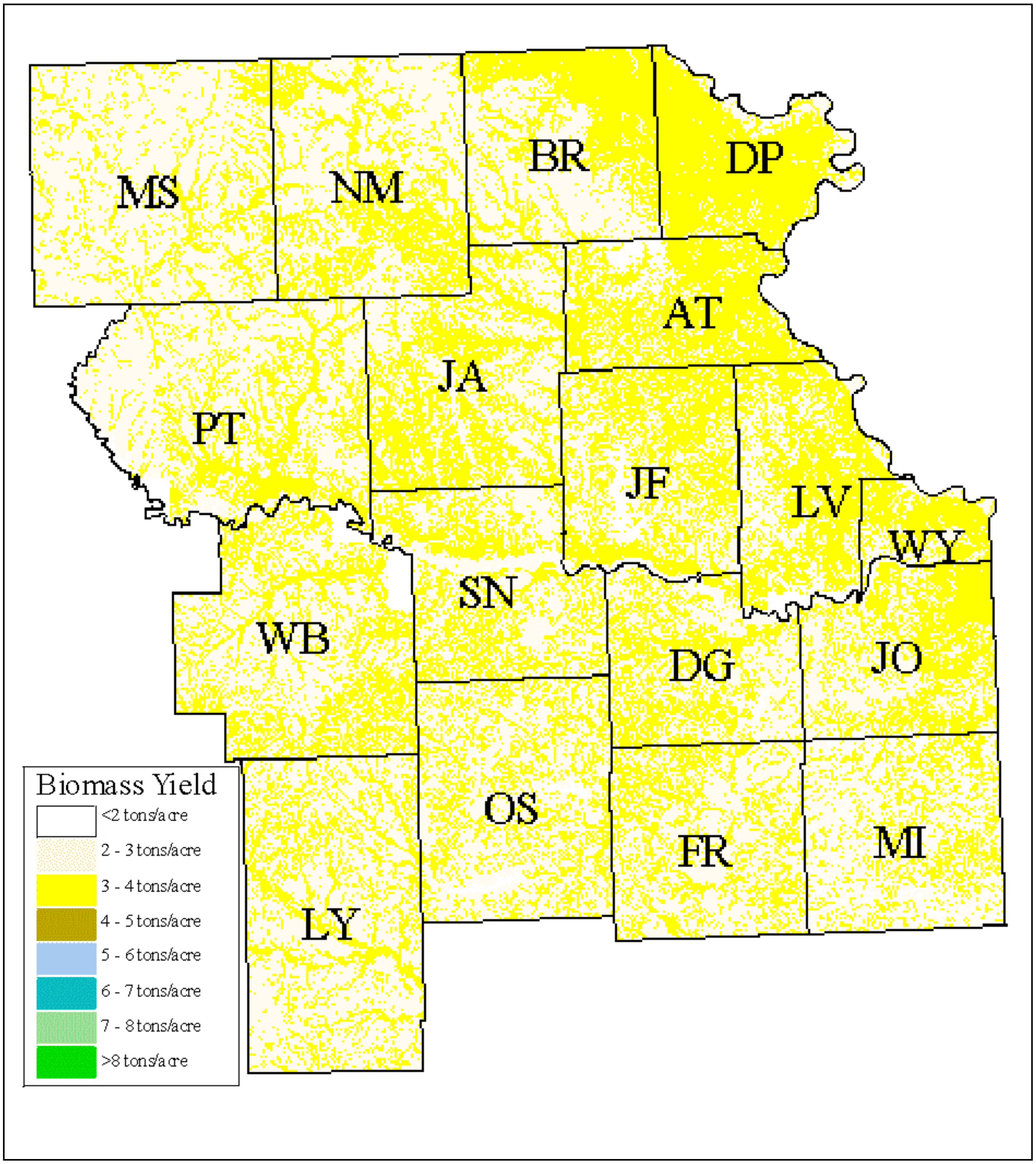

Figure 2.8.15 Map of Black Locust Average Yield (tons per acre) by Soil Series Region 3 Large areas of northest Kansas had average black locust yields in the 3 – 4 tons/acre [6.7 – 9.0 Mg/ha] range, but none higher.

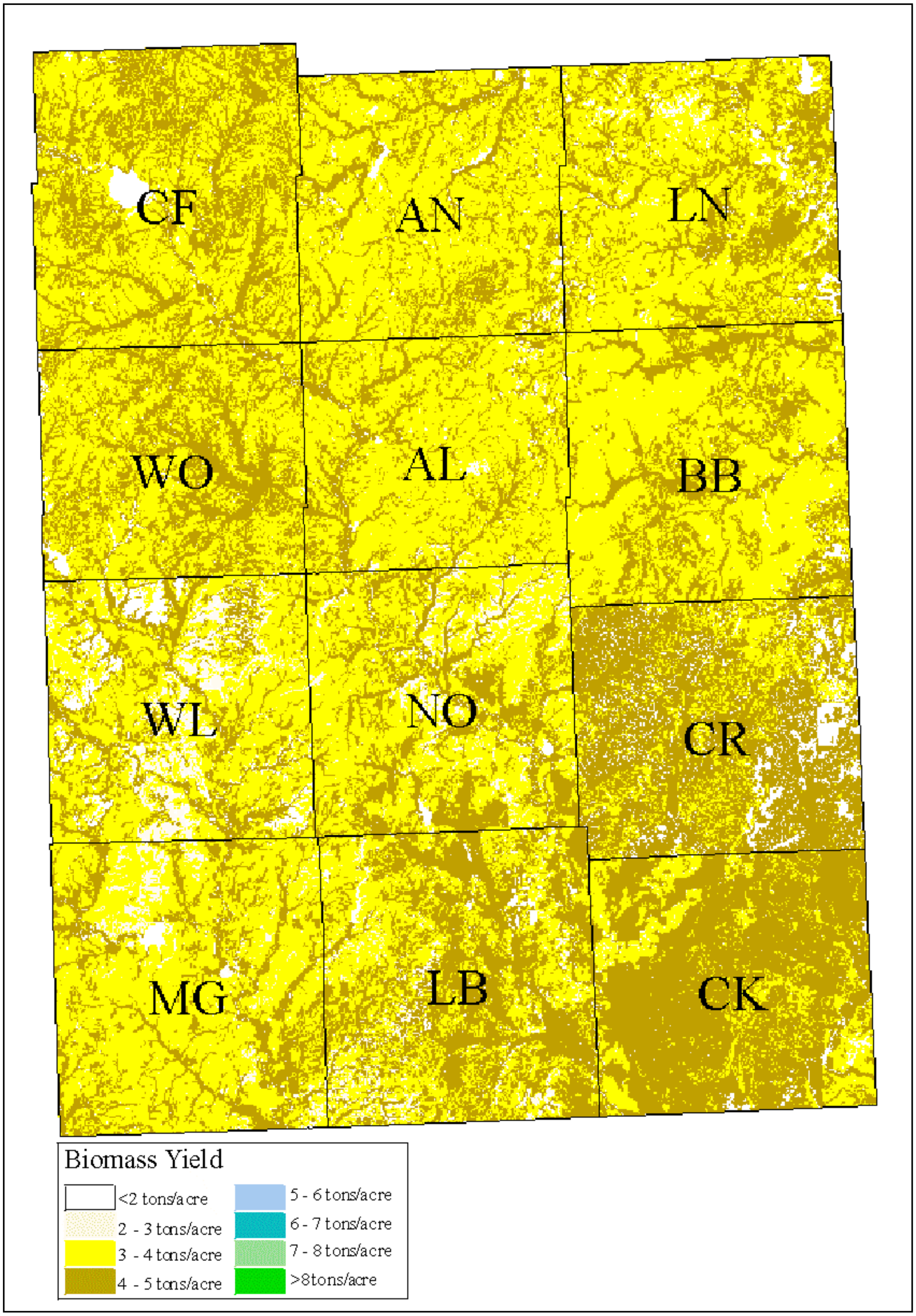

Figure 2.8.15 Map of Black Locust Average Yield (tons per acre) by Soil Series Region 4
Warmer and wetter, region 4 has significant areas with average black locust yields in the 4 – 5 tons/acre [9.0 – 11.2 Mg/ha] range and most of the remainder of the region in the 3 – 4 tons/acre [6.7 – 9.0 Mg/ha] range.

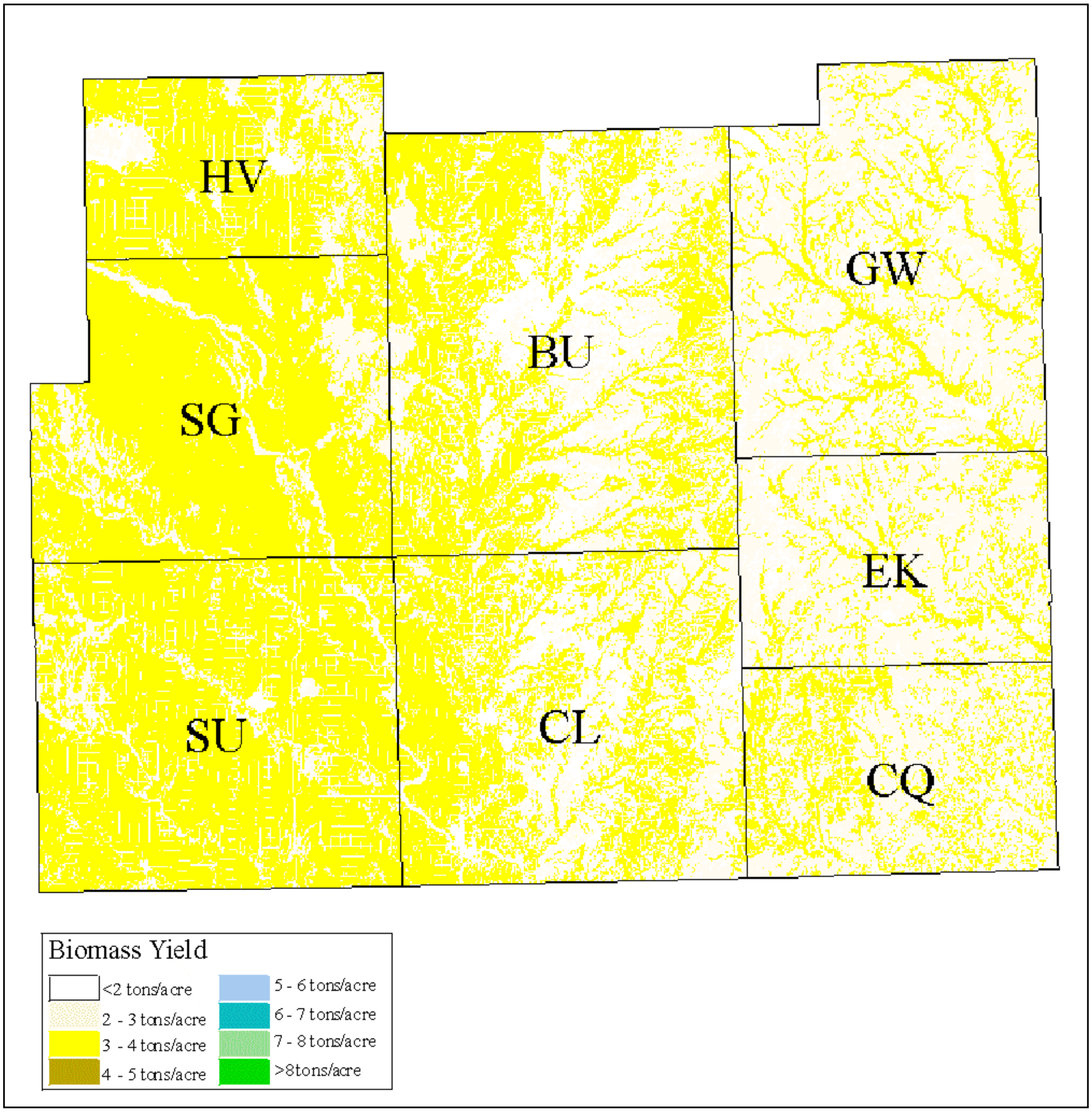

Figure 2.8.15 Map of Black Locust Average Yield (tons per acre) by Soil Series Region 5
The rich lowlands of Harvey, Sedgwick, and Sumner county have average black locust yields comparable to extreme northeast Kansas, raning from 3 – 4 tons/acre [6.7 – 9. 0 Mg/ha].

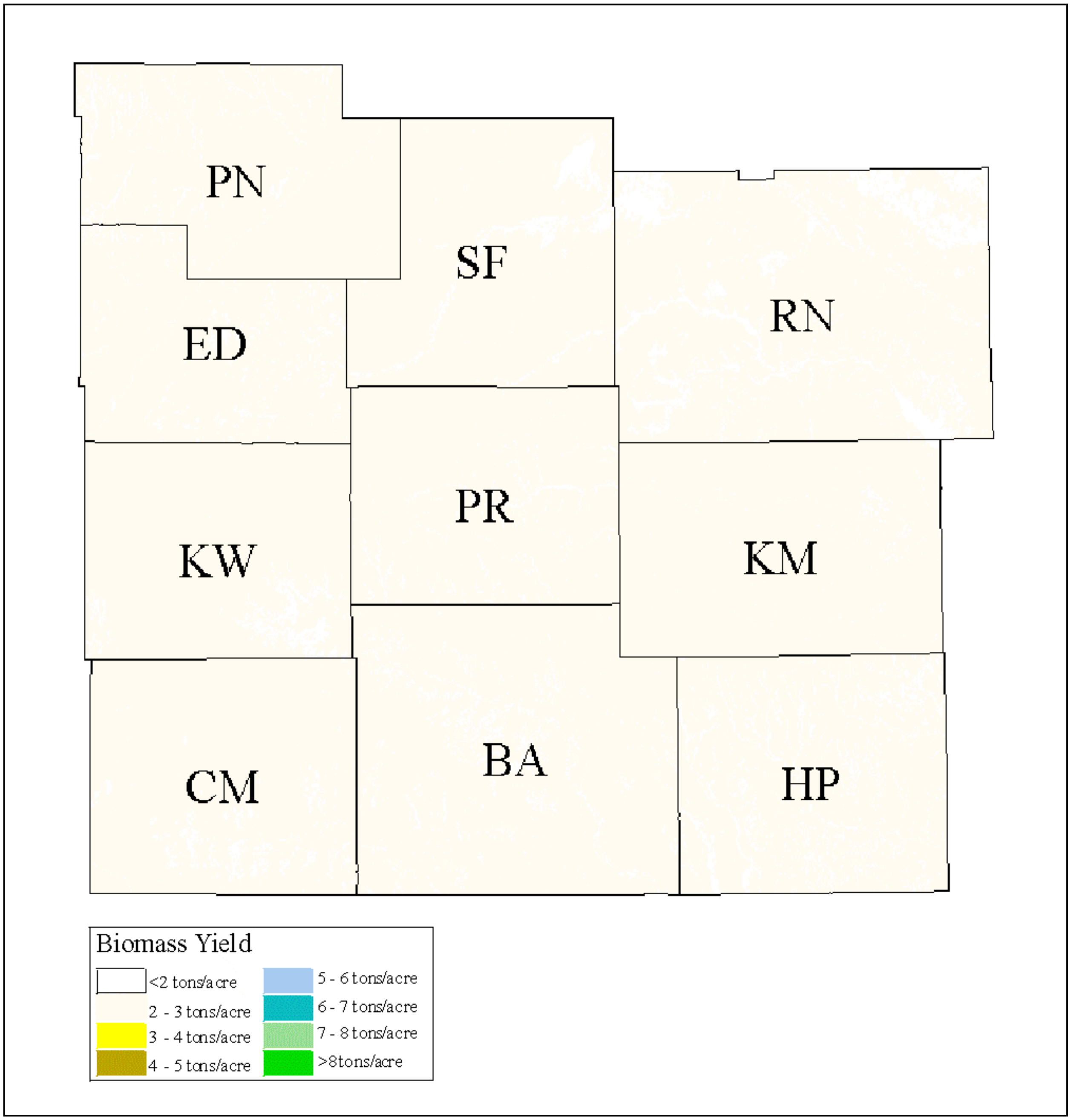

Figure 2.8.15 Map of Black Locust Average Yield (tons per acre) by Soil Series Region 6
Average black locust yields in region 6 resemble region 1, never rising above 2 –3 tons/acre [4.5 – 6.7 Mg/ha].

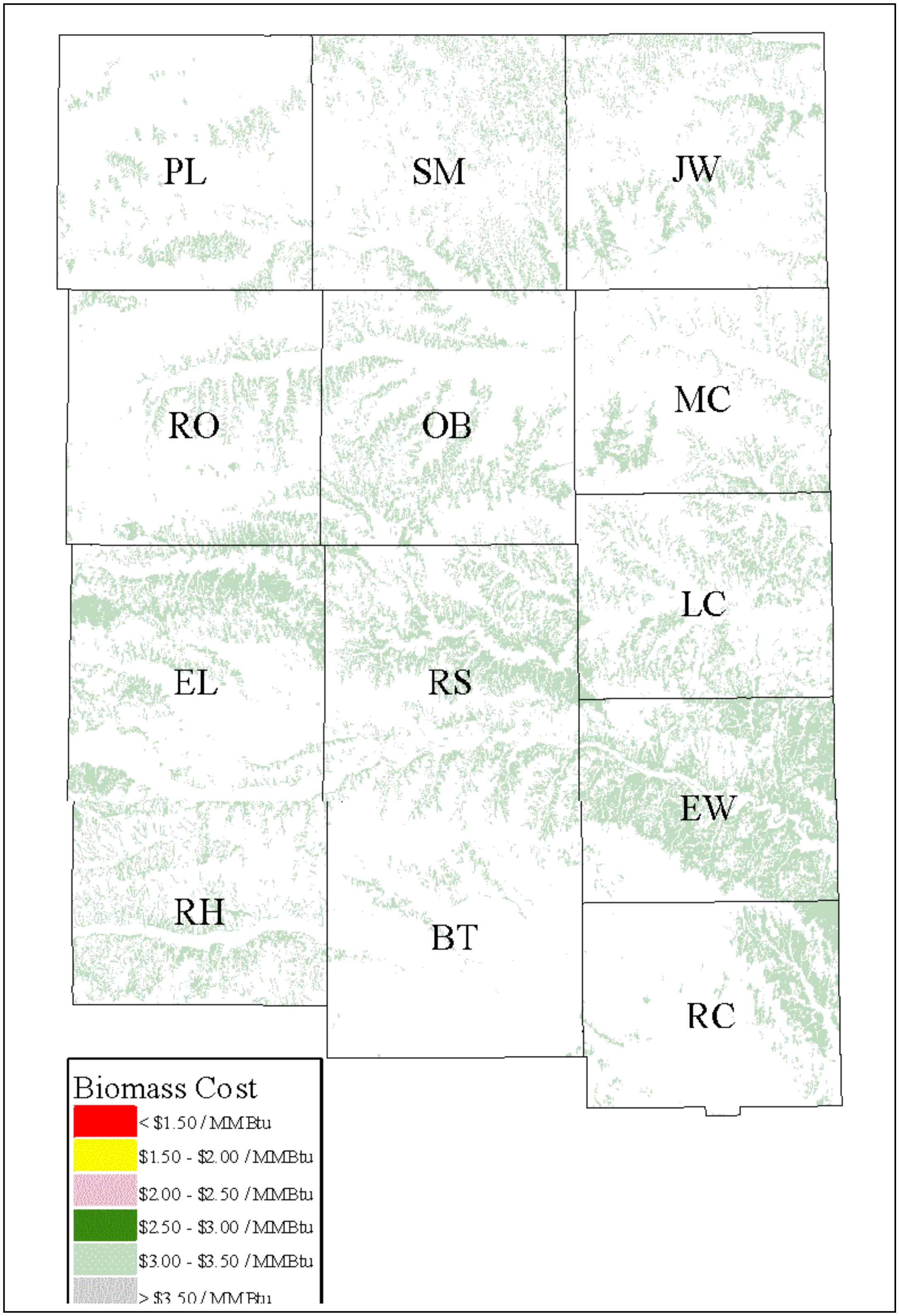

Figure 2.8.16 Map of Black Locust Edge of Field Cost, $/MBtu (40% of CRP Land Rent) **Region 1** Large areas (white on map) of region 1 have an erosion index <8 and therefore were not considered potentially eligible for CRP. In areas that are low yields push edge of field cost to the $3.00 – 3.50 range [$3.17 – 3.69 MJ].

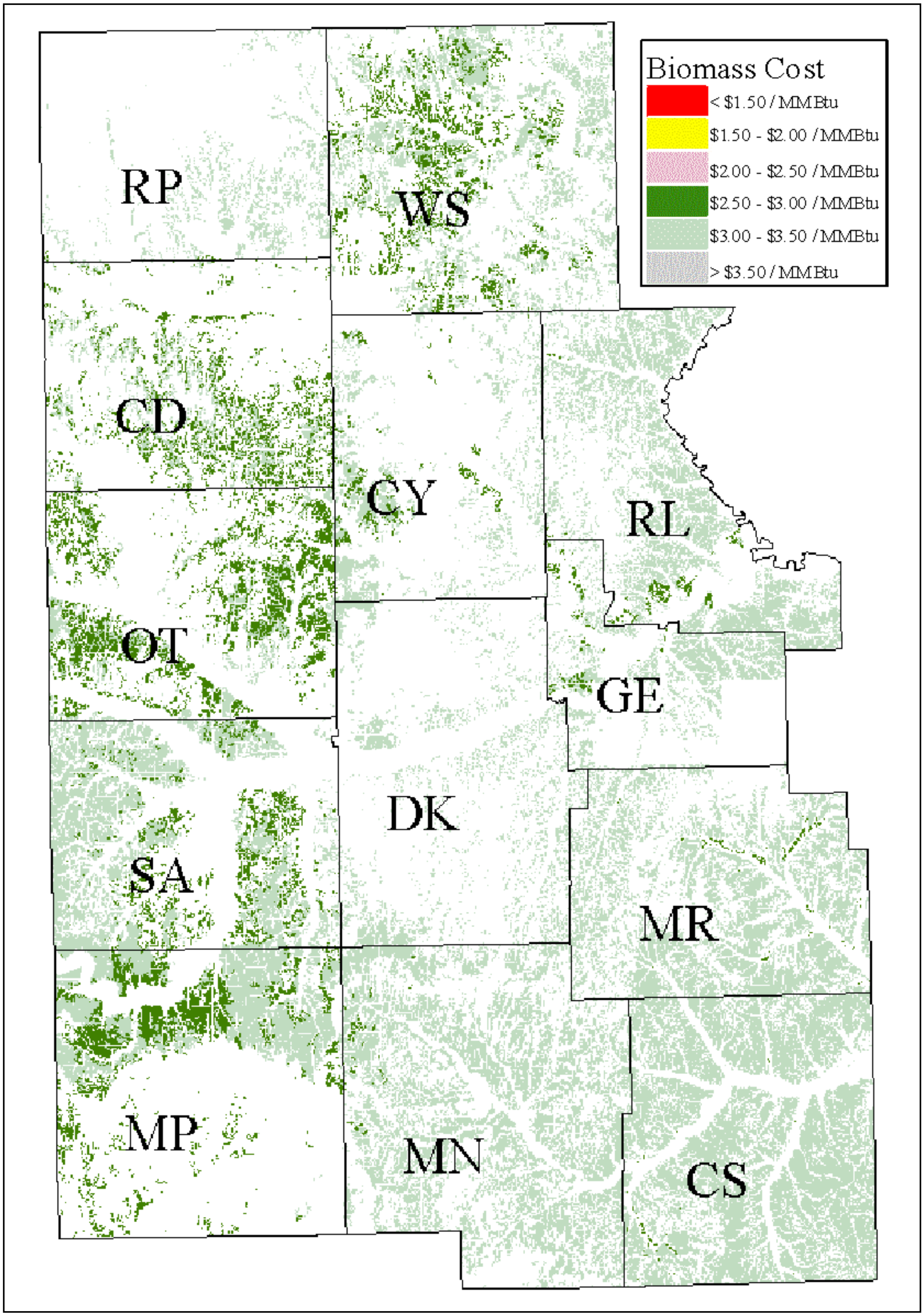

Figure 2.8.16 Map of Black Locust Edge of Field Cost, $/MBtu (40% of CRP Land Rent) **Region 2** Like region 1, much of region 2 is not potentially eligible for CRP. Most that might qualify for CRP could produce black locust at an edge of field cost at $3.00 – 3.50/MBtu [$3.17 – 3.69 MJ] with significant areas in the $2.50 – 3.00/MBtu [$2.64 - 3.17/MJ] range.

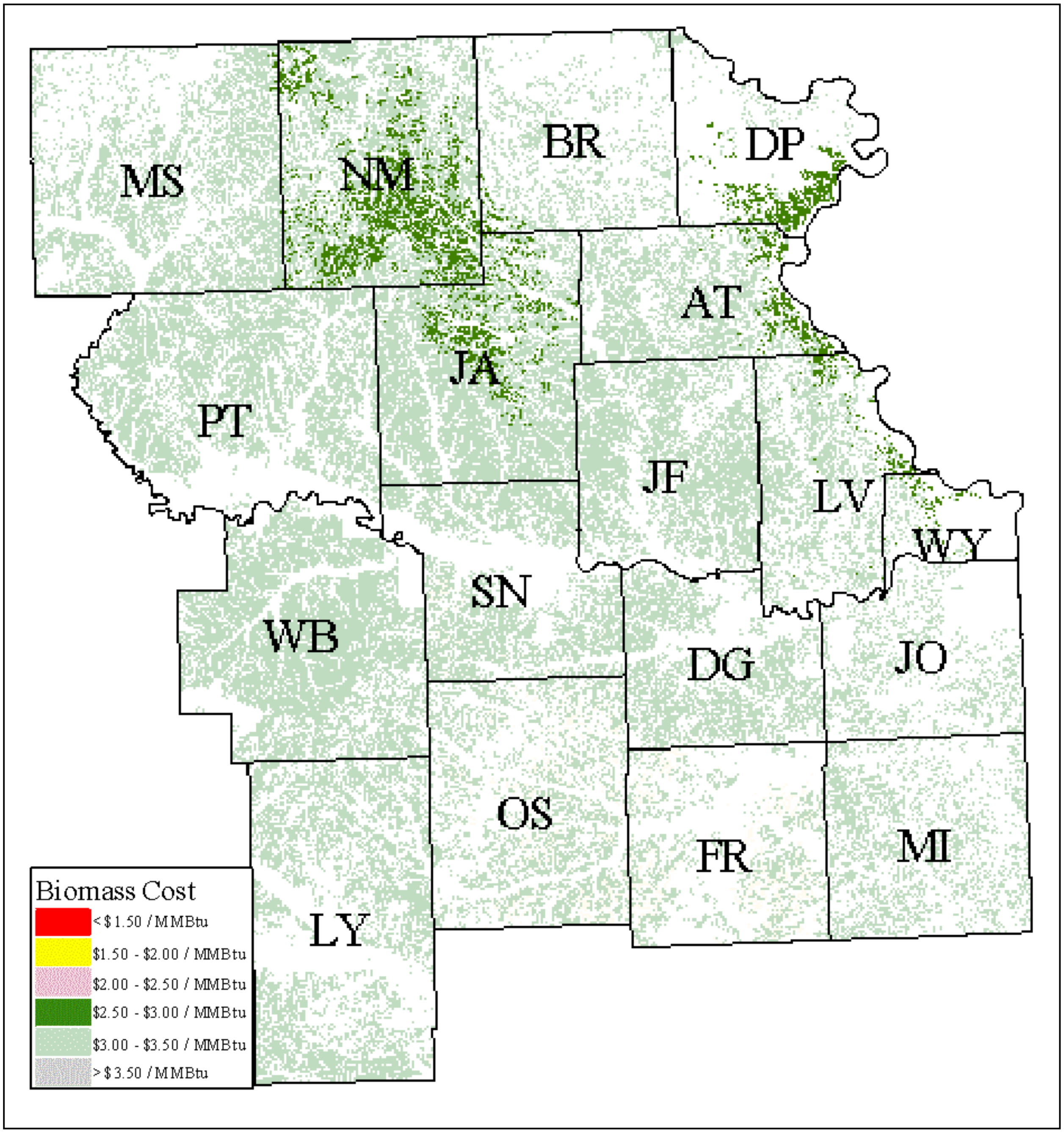

Figure 2.8.16 Map of Black Locust Edge of Field Cost, $/MBtu (40% of CRP Land Rent) **Region 3** Much of region 3 is potentially eligible for CRP, but the cost of black locust is very similar to region 2 with large areas in the $3.00 – 3.50 [$3.17 – 3.69/MJ] range and significant areas in the $2.50 – 3.00/MBtu [$2.64 - 3.17/MJ] range.

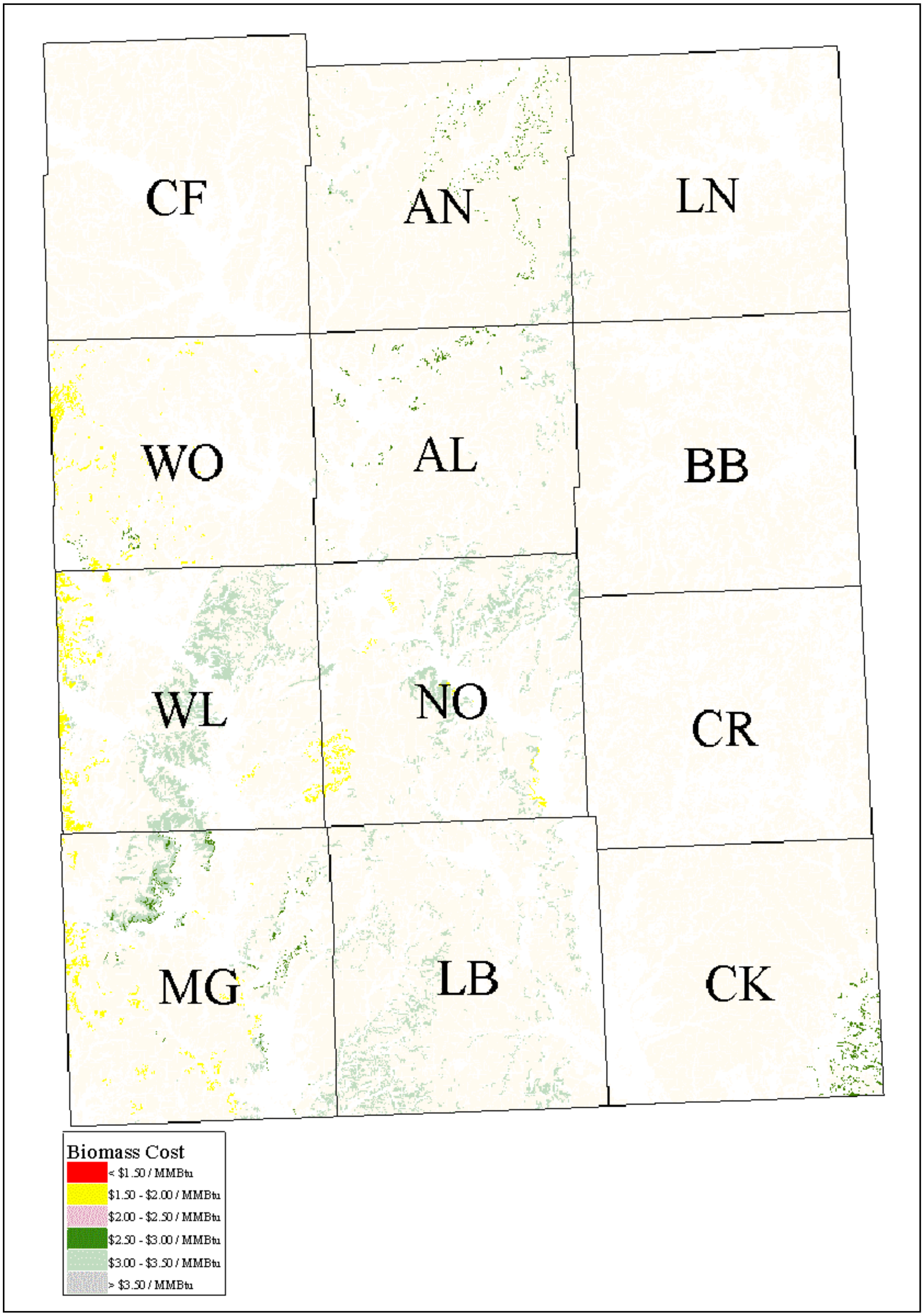

Figure 2.8.16 Map of Black Locust Edge of Field Cost, $/MBtu (40% of CRP Land Rent) **Region 4**
Region 4 had the areas of highest average black locust yields, resulting in areas of lowest cost in the $1.50 – 2.00/MBtu [$1.58 – 2.11 /MJ] at the field edge, with addition areas with costs in the $2.00 – 2.50/MBtu [$2.11 – 2.64/MJ] range.

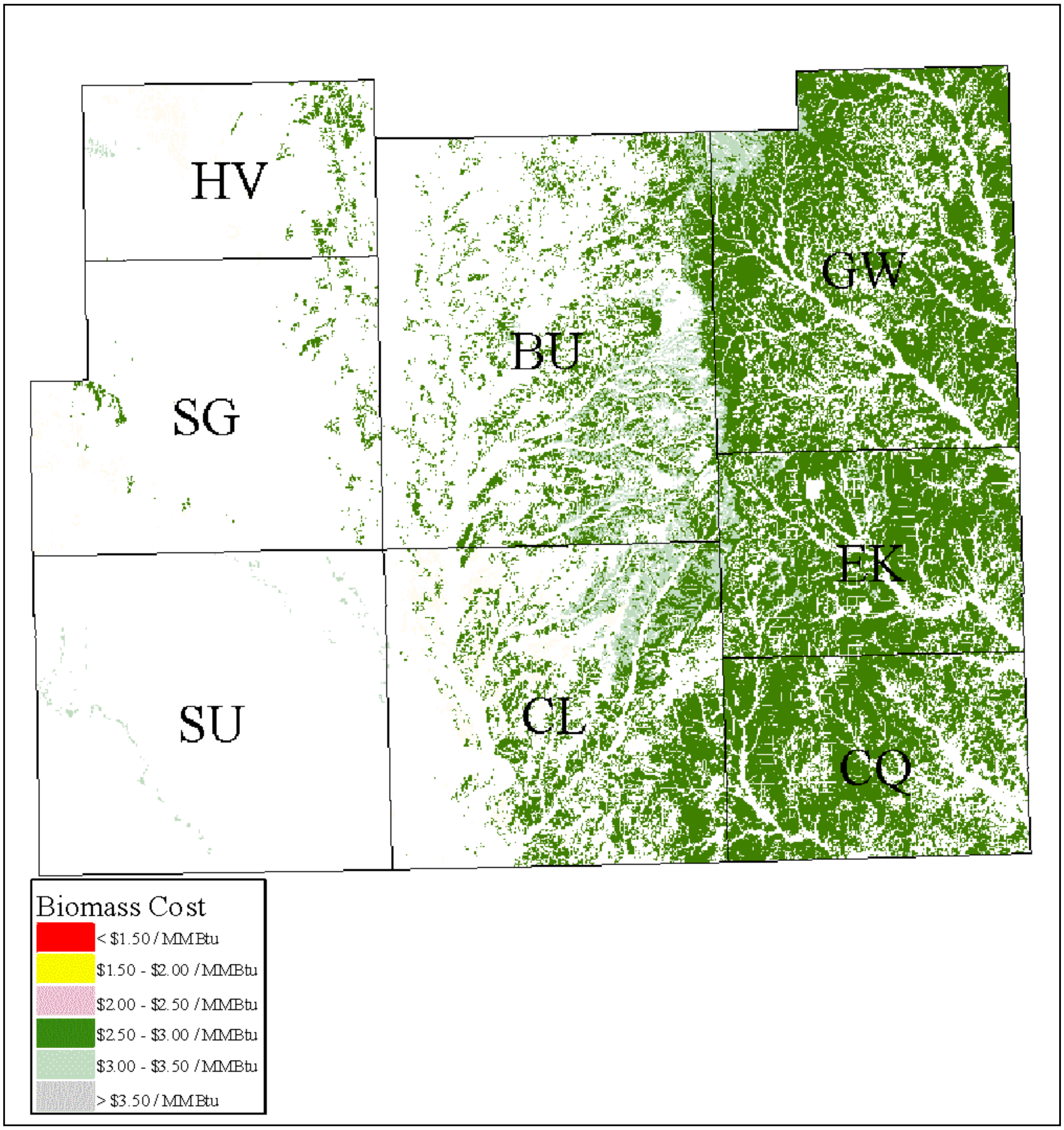

Figure 2.8.16 Map of Black Locust Edge of Field Cost, $/MBtu (40% of CRP Land Rent) **Region 5**
Region 5 had large portions of the eastern tier of counties with average edge of field black locust cost in the $2.50 – 3.00 [$2.64 - 3.17/MJ] range. The flat productive soils of the western tier of counties seldom have an erosion index >8 and are therfore not potentially eligible for CRP.

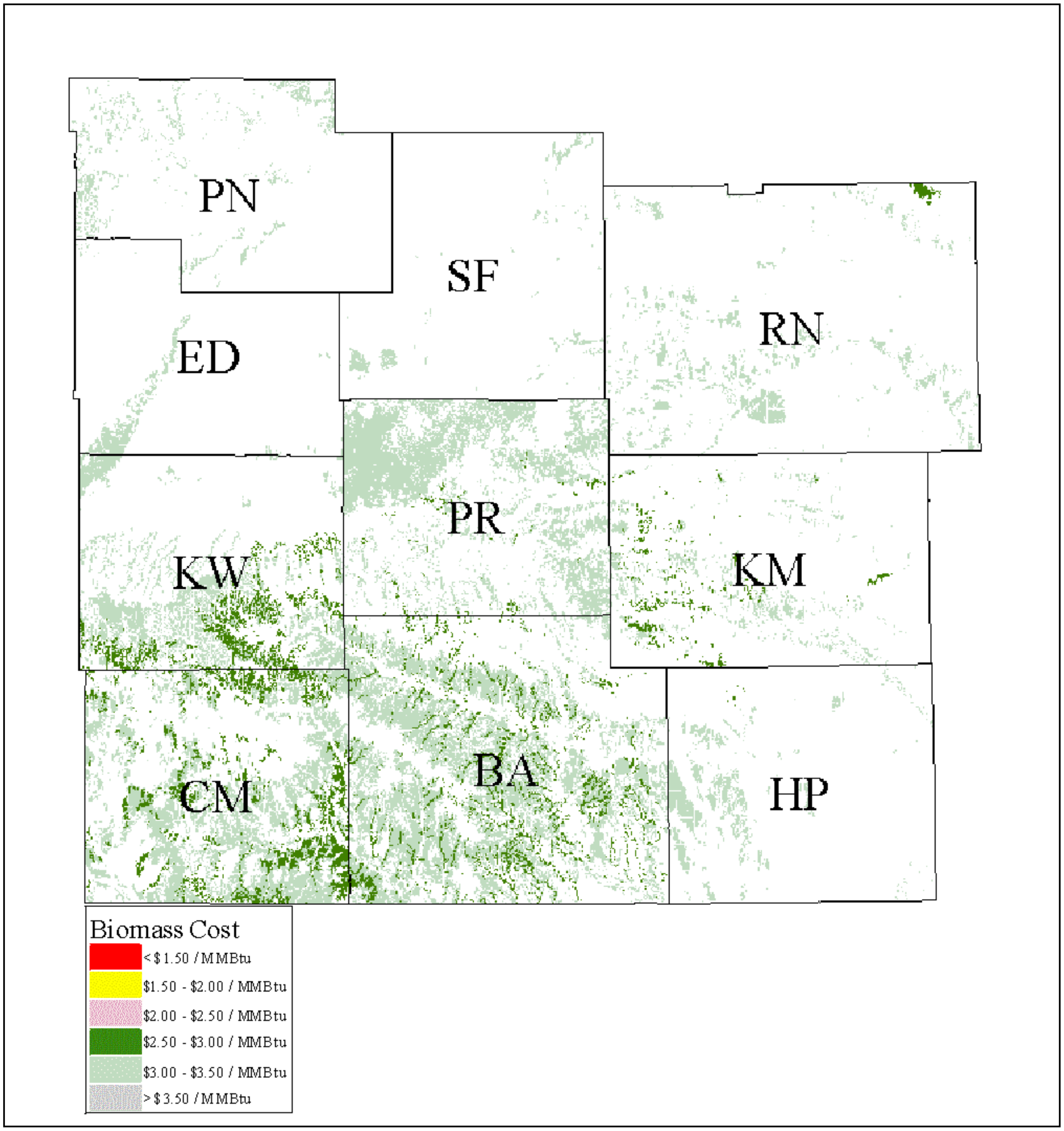

Figure 2.8.16 Map of Black Locust Edge of Field Cost, $/MBtu (40% of CRP Land Rent) **Region 6** Significant areas in the southwest portion of region 6 had edge of field black locust yields in the $3.00 – 3.50/MBtu [$3.17 – 3.69/MJ] range with modest portions in the $2.50 – 3.00/MBtu [$2.64 – 3.17/MJ] range.

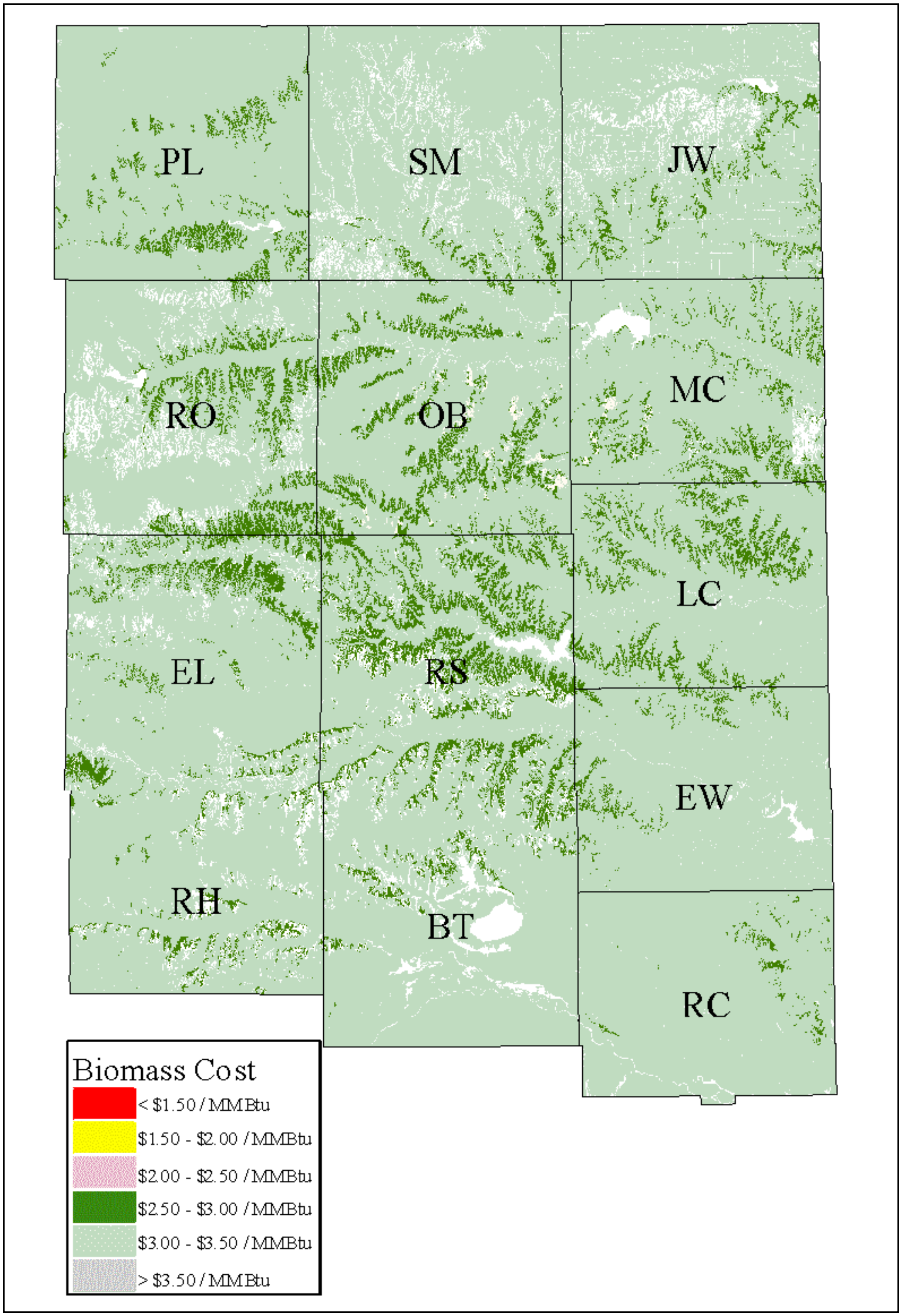

Figure 2.8.17 Map of Black Locust Edge of Field Cost, $/MBtu (Competing with Grain) **Region 1** Comparatively low grain profits in region 1 resulted in large areas with black locust edge of field costs of $3.00 – 3.50/MBtu [$3.17 – 3.69/MJ] for most of the region with significant areas in the $2.50 – 3.00/MBtu [$2.64 – 3.17/MJ] range.

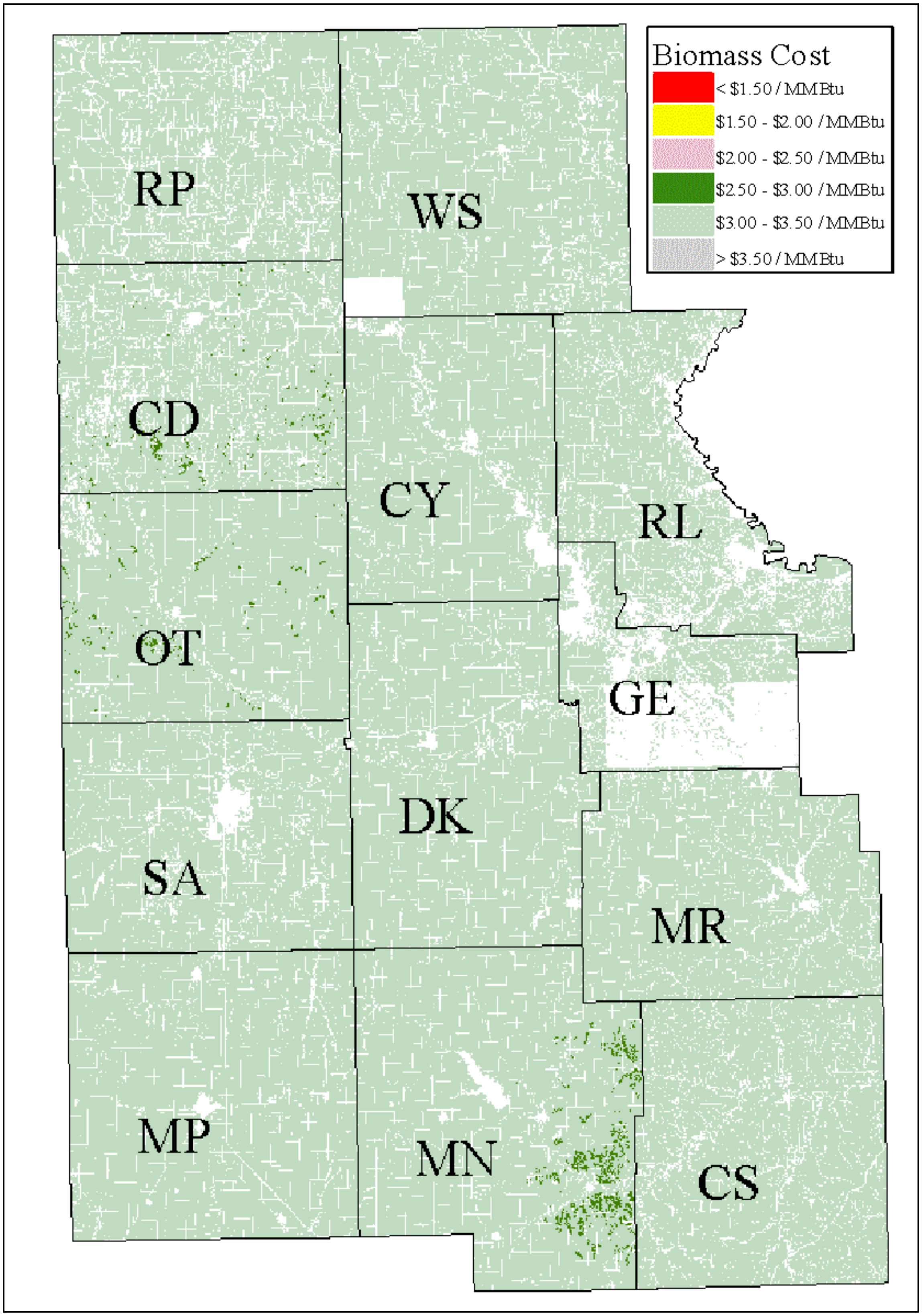

Figure 2.8.17 Map of Black Locust Edge of Field Cost, $/MBtu **(Competing with Grain)** Region 2
Most of region 2 has an edge of field black locust cost in the $3.00 – 3.50/MBtu [$3.17 – 3.69 /MJ] range with relatively small areas in the $2.50 – 3.00/MBtu [$2.64 – 3.17/MJ] range.

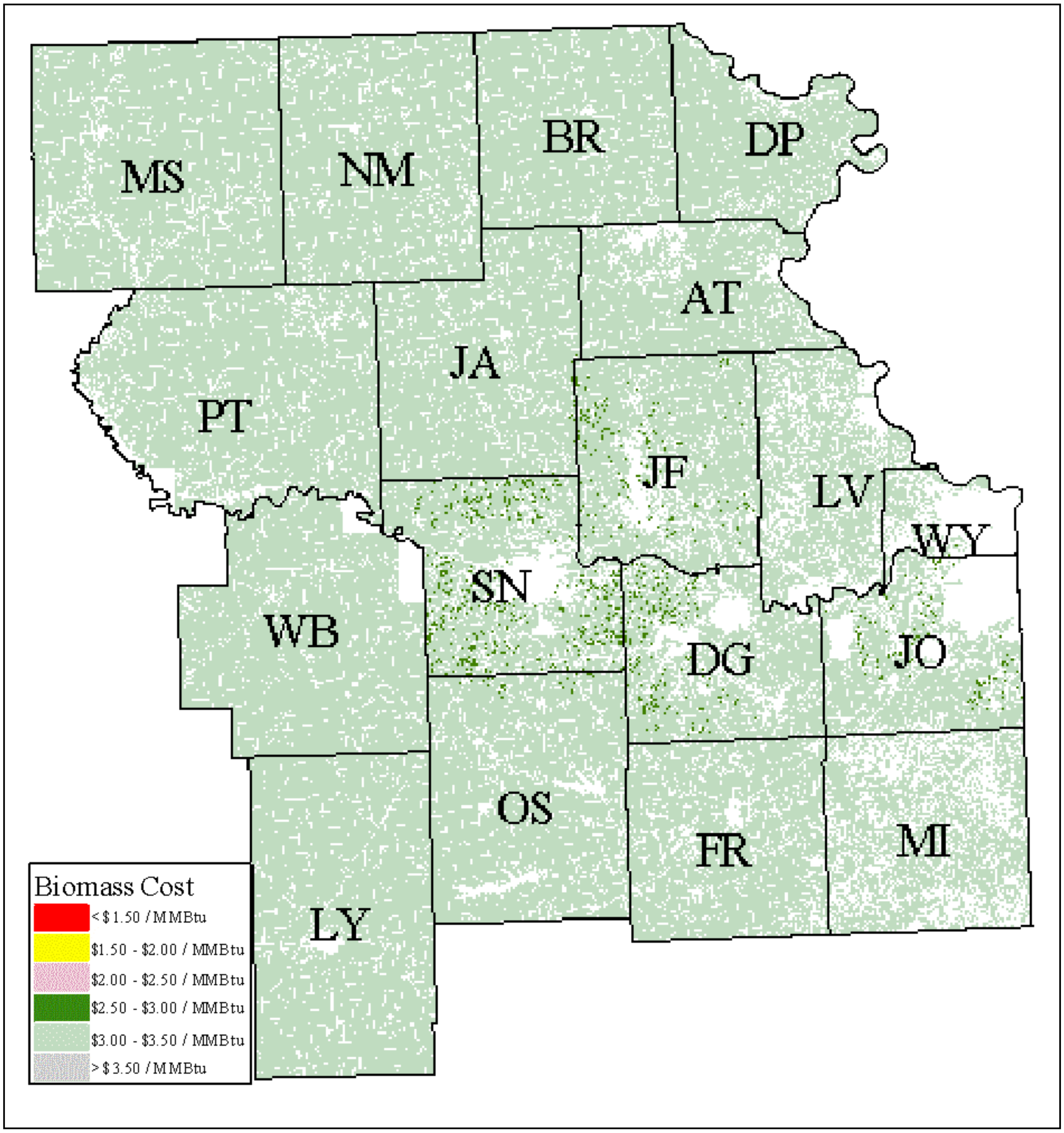

Figure 2.8.17 Map of Black Locust Edge of Field Cost, $/MBtu (Competing with Grain) **Region 3** Like region 2, most of region 3 has an edge of field black locust cost in the $3.00 – 3.50/MBtu [$3.17 – 3.69/MJ] range with relatively small areas in the $2.50 – 3.00/MBtu [$2.64 – 3.17/MJ] range.

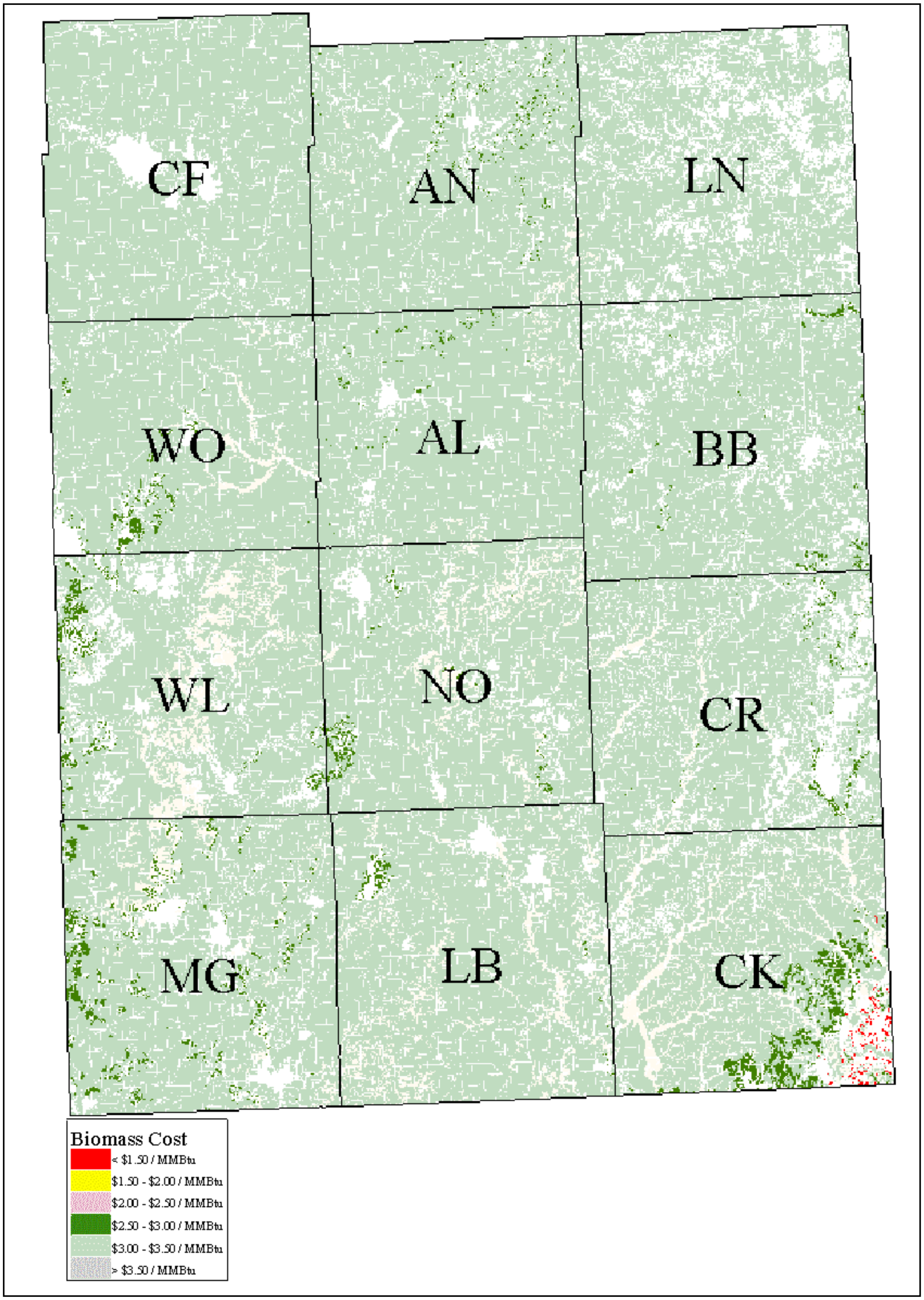

Figure 2.8.17 Map of Black Locust Edge of Field Cost, $/MBtu (Competing with Grain) **Region 4**
Like regions 2 and 3 most of region 3 has an edge of field black locust cost in the $3.00 – 3.50/MBtu [$3.17 – 3.69 /MJ] range with relatively small areas in the $2.50 – 3.00/MBtu [$2.64 – 3.17/MJ] range and small areas with the cost below $1.50/MBtu [$1.58/MJ].

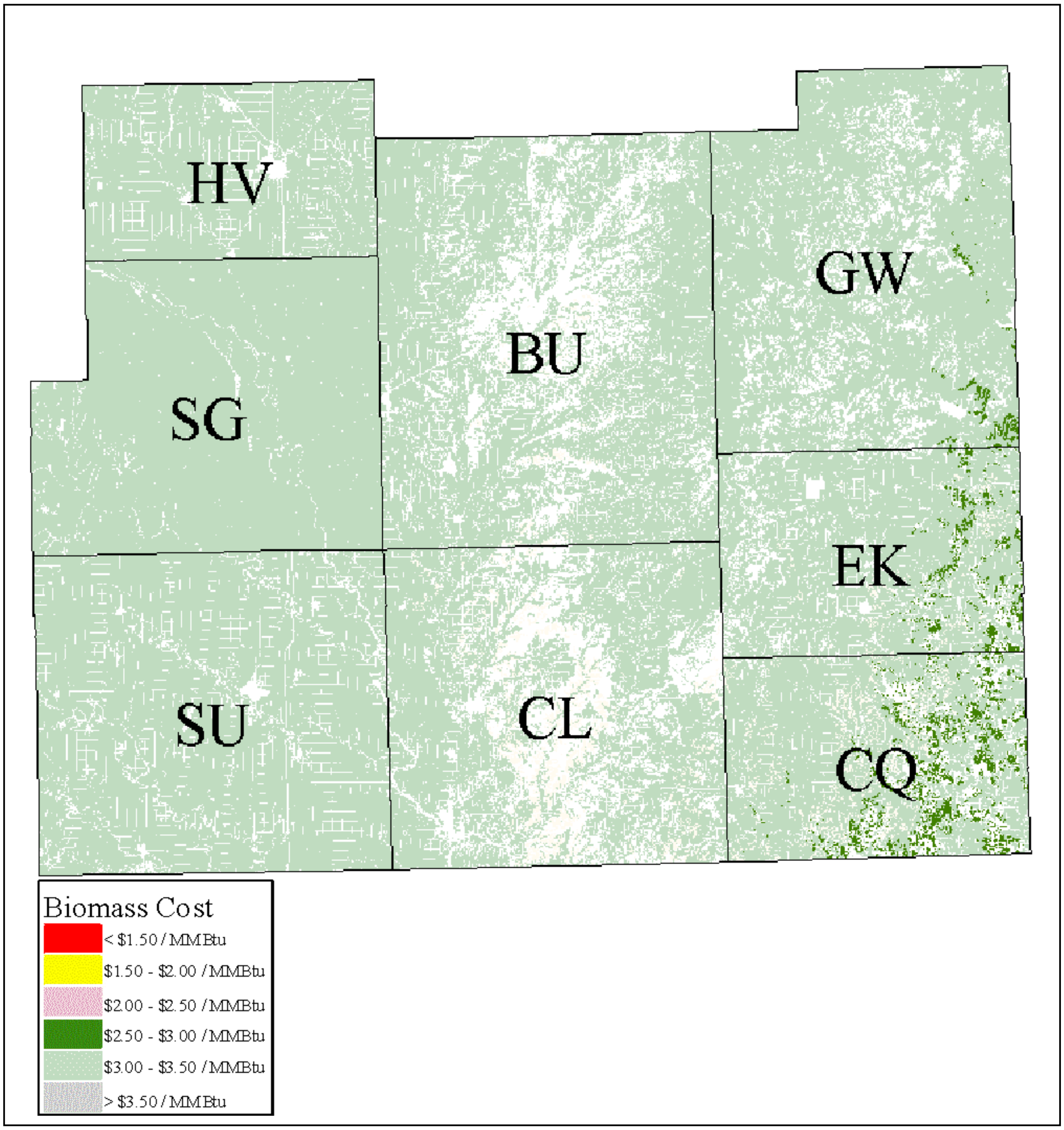

Figure 2.8.17 Map of Black Locust Edge of Field Cost, $/MBtu (Competing with Grain) **Region 5** Like region 1- 4, most of region 5 has an edge of field black locust cost in the $3.00 – 3.50/MBtu [$3.17 – 3.69 /MJ] range with relatively small areas in the $2.50 – 3.00/MBtu [$2.64 – 3.17/MJ] range.

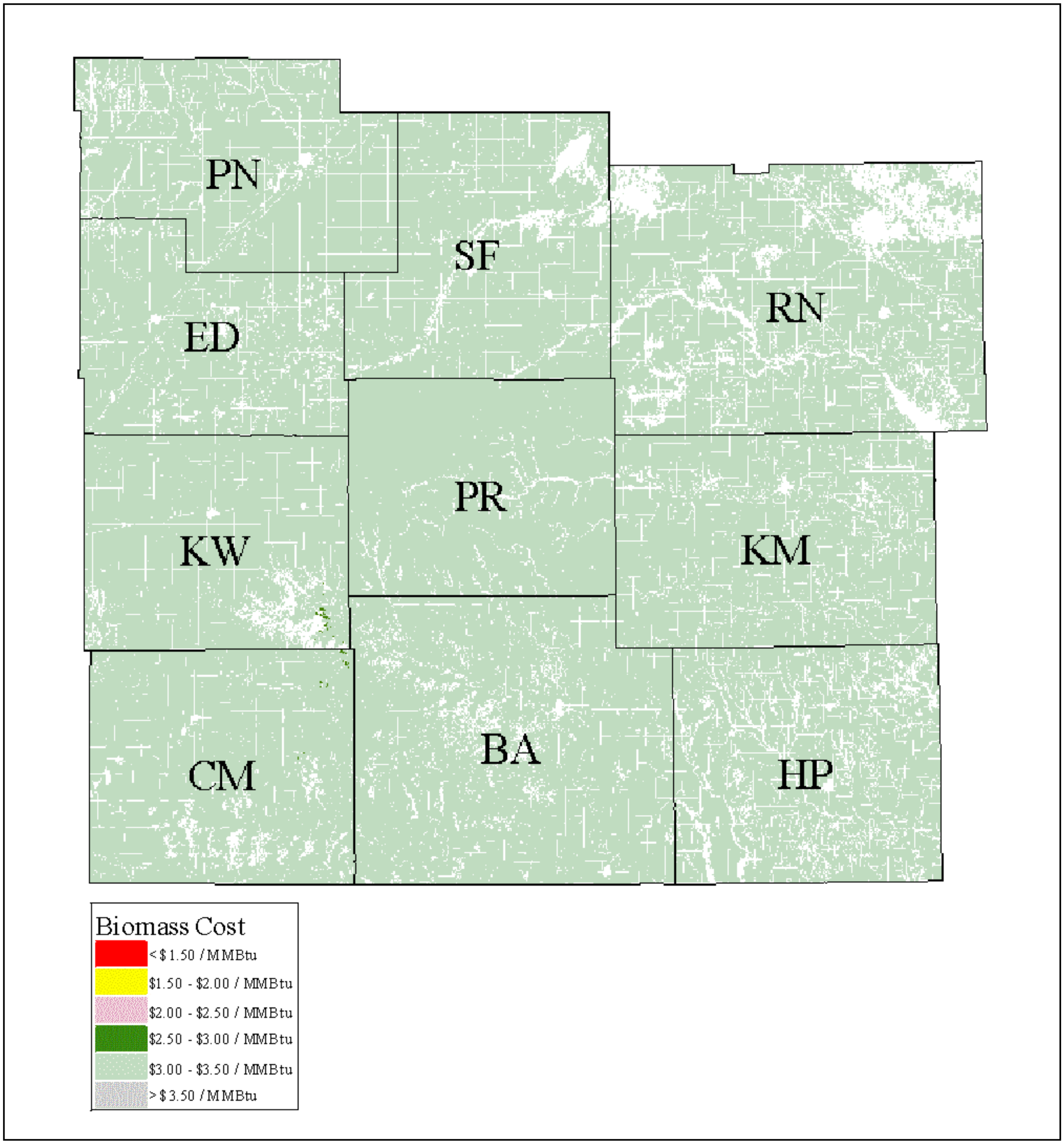

Figure 2.8.17 Map of Black Locust Edge of Field Cost, $/MBtu (Competing with Grain) **Region 6** Most of region 6 had edge of field black locust cost in the $3.00 – 3.50/MBtu [$3.17 – 3.69/MJ] range.

2.8.5 Black Locust Production Volume and Potential MW of Generation

Figure 2.8.18 shows the estimated maximum volume of energy that could be produced under the CRP scenario and in competition with grain, by region and energy cost increment. The two land use scenarios are exclusive and can not be added. The only lower cost (<$1.50/MBtu [$1.58/MJ]) energy occurs under the CRP scenario in region 2. The most promising regions for black locust in competition with grain is also region 2, with significant volumes of black locust in the $2.50 – 3.00/MBtu [$2.64 – 3.17/MJ] range. The volume of black locust energy with an edge of field cost less than $3.00/MBtu [$3.17/MJ] totals 73 trillion Btus under the CRP scenario, falling to 30 trillion Btus in competition with grain.

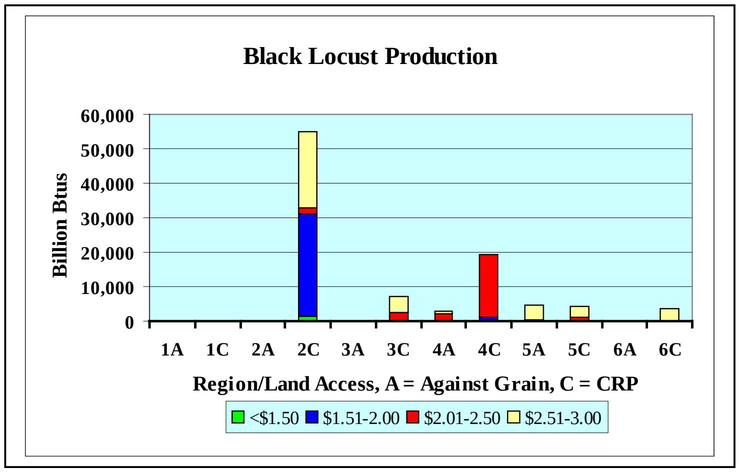

Figure 2.8.18 Black Locust Production Volume

Figure 2.8.19 shows the megaWatts of generating capacity that could be fueled with black locust by region and cost increment under the CRP scenario and in competition with grain, based on a plant efficiency of 30% and a 65% annual plant factor. In application spatial diversity of land parcels at different cost increments would reduce these estimates. These are also based edge of field fuel cost increments, not plant gate or boiler mouth. Table 2.8.5 below provides a detailed breakdown of estimated switchgrass energy production potential and generation that could be supported by region, county, and fuel cost increment for potentially eligible CRP acres and all potentially suitable land area, limited by using not more than 50% of the acres in any soil series or more than 10% of the land area in any county.

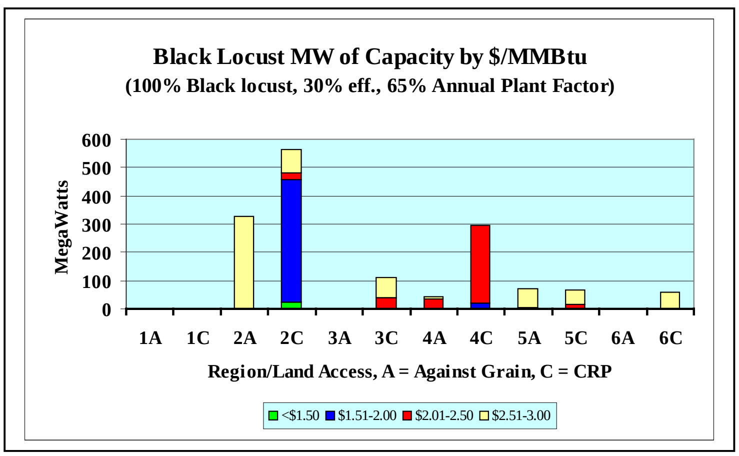

Figure 2.8.19 Black Locust Potential MWs of Generation

Table 2.8.5 Black Locust Energy Production and Potential MW of Generation Region 1

Land Area			Energy, billion Btu				Generation (30% eff./ 65% yr)			
Soil	Area (acres)		MBtu < $1.50	MBtu $1.51 - 2.00	MBtu $2.01 - 2.50	MBtu $2.51- 3.00	MW @ < $1.50 MBtu	MW @ $1.51 - 2.00 MBtu	MW @ $2.01- 2.50 MBtu	MW @ $2.51- 3.00 MBtu
Barton County	490,602	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Ellis County	618,873	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Ellsworth County	566,098	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Jewell County	609,978	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Lincoln County	519,823	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Mitchell County	549,218	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Osborne County	789,455	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Phillips County	563,259	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Rice County	485,061	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Rush County	398,065	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Rooks County	583,789	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Russel County	497,967	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Smith County	603,931	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Region 1 Total	**7,276,121**	**CRP Total**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
		All Other Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Not more than 50% of any soil series or 10% of all potentially suitable land in a county used for biomass crops.

Table 2.8.5 Black Locust Energy Production and Potential MW of Generation Region 2

Land Area Soil	Area (acres)		Energy, billion Btu MBtu < $1.50	MBtu $1.51 - 2.00	MBtu $2.01 - 2.50	MBtu $2.51- 3.00	Generation (30% eff./ 65% yr) MW @ < $1.50 MBtu	MW @ $1.51 - 2.00 MBtu	MW @ $2.01- 2.50 MBtu	MW @ $2.51- 3.00 MBtu
Cloud County	387,159	CRP Total	0	2,137	0	0	0	33	0	0
		All Other Total	0	0	0	913	0	0	0	14
Chase County	682,339	CRP Total	1,225	2,664	0	2,514	19	41	0	39
		All Other Total	0	0	0	5,647	0	0	0	87
Clay County	398,157	CRP Total	105	1,217	716	0	2	19	11	0
		All Other Total	0	0	0	1,376	0	0	0	21
Dickinson County	520,082	CRP Total	0	2,103	125	304	0	32	2	5
		All Other Total	0	0	0	0	0	0	0	0
Geary County	312,921	CRP Total	137	1,412	0	0	2	20	0	0
		All Other Total	0	0	0	2,417	0	0	0	35
Marion County	602,255	CRP Total	0	3,707	0	0	0	53	0	0
		All Other Total	0	0	0	1,503	0	0	0	22
McPherson County	582,146	CRP Total	13	3,123	0	0	0	45	0	0
		All Other Total	0	0	0	1,156	0	0	0	17
Morris County	531,858	CRP Total	0	1,601	0	1,499	0	23	0	21
		All Other Total	0	0	0	2,025	0	0	0	29
Ottawa County	509,087	CRP Total	0	3,183	0	0	0	46	0	0
		All Other Total	0	0	0	1,090	0	0	0	16
Riley County	429,743	CRP Total	0	2,008	88	878	0	29	1	13
		All Other Total	0	0	0	1,097	0	0	0	16
Republic County	441,520	CRP Total	0	282	0	45	0	4	0	1
		All Other Total	0	0	0	1,382	0	0	0	20
Saline County	506,962	CRP Total	0	3,466	0	0	0	50	0	0
		All Other Total	0	0	0	2,210	0	0	0	32
Washington County	552,767	CRP Total	0	2,840	779	80	0	41	11	1
		All Other Total	0	0	0	1,286	0	0	0	18
Region 2 Total	**6,456,996**	**CRP Total**	**1,479**	**29,743**	**1,708**	**5,320**	**23**	**435**	**25**	**79**
		All Other Total	**0**	**0**	**0**	**22,104**	**0**	**0**	**0**	**326**

Not more than 50% of any soil series or 10% of all potentially suitable land in a county used for biomass crops.

Table 2.8.5 Black Locust Energy Production and Potential MW of Generation Region 3

Land Area Soil	Area (acres)		Energy, billion Btu MBtu < $1.50	MBtu $1.51 - 2.00	MBtu $2.01 - 2.50	MBtu $2.51- 3.00	Generation (30% eff./ 65% yr) MW @ < $1.50 MBtu	MW @ $1.51 - 2.00 MBtu	MW @ $2.01- 2.50 MBtu	MW @ $2.51- 3.00 MBtu
Atchison County	296,204	CRP Total	0	0	0	535	0	0	0	8
		All Other Total	0	0	0	0	0	0	0	0
Brown County	800,752	CRP Total	0	0	0	138	0	0	0	2
		All Other Total	0	0	0	0	0	0	0	0
Douglas County	253,444	CRP Total	0	0	9	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Doniphan County	241,112	CRP Total	0	0	0	506	0	0	0	8
		All Other Total	0	0	0	0	0	0	0	0
Franklin County	391,334	CRP Total	0	0	1,312	0	0	0	20	0
		All Other Total	0	0	0	0	0	0	0	0
Jackson County	440,903	CRP Total	0	0	0	838	0	0	0	13
		All Other Total	0	0	0	0	0	0	0	0
Jefferson County	337,434	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Johnson County	209,510	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Leavenworth County	231,054	CRP Total	0	0	0	174	0	0	0	3
		All Other Total	0	0	0	0	0	0	0	0
Lyon County	580,562	CRP Total	0	0	305	0	0	0	5	0
		All Other Total	0	0	0	0	0	0	0	0
Miami County	305,926	CRP Total	0	0	7	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Marshall County	568,660	CRP Total	0	0	0	206	0	0	0	3
		All Other Total	0	0	0	0	0	0	0	0
Nemaha County	493,372	CRP Total	0	0	0	2,191	0	0	0	34
		All Other Total	0	0	0	0	0	0	0	0
Osage County	454,920	CRP Total	0	0	786	0	0	0	12	0
		All Other Total	0	0	0	0	0	0	0	0
Pottawatomie County	592,226	CRP Total	0	0	0	4	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Shawnee County	279,462	CRP Total	0	0	102	0	0	0	2	0
		All Other Total	0	0	0	0	0	0	0	0
Wabaunsee County	626,686	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Wyandotte County	32,194	CRP Total	0	0	0	97	0	0	0	1
		All Other Total	0	0	0	0	0	0	0	0
Region 3 Total	**7,135,756**	**CRP Total**	**0**	**0**	**2,520**	**4,690**	**0**	**0**	**39**	**72**
		All Other Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Not more than 50% of any soil series or 10% of all potentially suitable land in a county used for biomass crops.

Table 2.8.5 Black Locust Energy Production and Potential MW of Generation Region 4

Land Area Soil	Area (acres)		Energy, billion Btu MBtu < $1.50	MBtu $1.51 - 2.00	MBtu $2.01 - 2.50	MBtu $2.51- 3.00	Generation (30% eff./ 65% yr) MW @ < $1.50 MBtu	MW @ $1.51 - 2.00 MBtu	MW @ $2.01- 2.50 MBtu	MW @ $2.51- 3.00 MBtu
Allen County	291,717	CRP Total	0	0	26	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Anderson County	362,926	CRP Total	0	0	1,467	0	0	0	23	0
		All Other Total	0	0	0	0	0	0	0	0
Bourbon County	345,999	CRP Total	0	0	649	0	0	0	10	0
		All Other Total	0	0	0	0	0	0	0	0
Coffey County	417,600	CRP Total	0	27	701	0	0	0	11	0
		All Other Total	0	0	0	0	0	0	0	0
Cherokee County	305,576	CRP Total	0	0	2,704	0	0	0	42	0
		All Other Total	0	0	1,299	558	0	0	20	9
Crawford County	301,752	CRP Total	0	0	4,443	0	0	0	69	0
		All Other Total	0	0	392	71	0	0	6	1
Labette County	391,461	CRP Total	0	0	1,284	0	0	0	20	0
		All Other Total	0	0	324	0	0	0	5	0
Linn County	289,834	CRP Total	0	0	1,888	0	0	0	29	0
		All Other Total	0	0	9	0	0	0	0	0
Montgomery County	428,538	CRP Total	0	184	2,486	0	0	3	38	0
		All Other Total	0	0	0	0	0	0	0	0
Neosho County	350,348	CRP Total	0	111	885	0	0	2	14	0
		All Other Total	0	0	0	0	0	0	0	0
Wilson County	398,942	CRP Total	0	463	697	0	0	7	11	0
		All Other Total	0	0	0	0	0	0	0	0
Woodson County	329,169	CRP Total	0	352	900	0	0	5	14	0
		All Other Total	0	0	270	0	0	0	4	0
Region 4 Total	**4,213,861**	**CRP Total**	**0**	**1,137**	**18,130**	**0**	**0**	**18**	**280**	**0**
		All Other Total	**0**	**0**	**2,294**	**629**	**0**	**0**	**35**	**10**

Not more than 50% of any soil series or 10% of all potentially suitable land in a county used for biomass crops.

Table 2.8.5 Black Locust Energy Production and Potential MW of Generation Region 5

Land Area			Energy, billion Btu				Generation (30% eff./ 65% yr)			
Soil	Area (acres)		MBtu < $1.50	MBtu $1.51 - 2.00	MBtu $2.01 - 2.50	MBtu $2.51- 3.00	MW @ < $1.50 MMBtu	MW @ $1.51 - 2.00 MBtu	MW @ $2.01- 2.50 MBtu	MW @ $2.51- 3.00 MBtu
Butler County	1,027,556	CRP Total	0	0	0	52	0	0	0	1
		All Other Total	0	0	0	0	0	0	0	0
Cowley County	758,352	CRP Total	0	0	963	2,140	0	0	15	33
		All Other Total	0	0	0	0	0	0	0	0
Chautauqua County	443,829	CRP Total	0	0	160	1,147	0	0	2	18
		All Other Total	0	0	0	0	0	0	0	0
Elk County	499,661	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	2,327	0	0	0	36
Greenwood County	377,894	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	21	1,548	0	0	0	24
Harvey County	317,762	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	233	333	0	0	4	5
Sedgwick County	167,712	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	53	54	0	0	1	1
Sumner County	745,064	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Region 5 Total	**4,337,831**	**CRP Total**	**0**	**0**	**1,123**	**3,339**	**0**	**0**	**17**	**52**
		All Other Total	**0**	**0**	**307**	**4,263**	**0**	**0**	**5**	**66**

Not more than 50% of any soil series or 10% of all potentially suitable land in a county used for biomass crops.

Table 2.8.5 Black Locust Energy Production and Potential MW of Generation Region 6

Land Area Soil	Area (acres)		Energy, billion Btu: MBtu < $1.50	MBtu $1.51 - 2.00	MBtu $2.01 - 2.50	MBtu $2.51- 3.00	Generation (30% eff./ 65% yr): MW @ < $1.50 MBtu	MW @ $1.51 - 2.00 MBtu	MW @ $2.01- 2.50 MBtu	MW @ $2.51- 3.00 MBtu
Barber County	897,822	CRP Total	0	0	0	1,157	0	0	0	18
		All Other Total	0	0	0	0	0	0	0	0
Comanche	645,885	CRP Total	0	0	0	1,229	0	0	0	19
		All Other Total	0	0	0	0	0	0	0	0
Edwards County	415,605	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Harper County	503,207	CRP Total	0	0	0	6	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Kingman County	550,024	CRP Total	0	0	0	241	0	0	0	4
		All Other Total	0	0	0	0	0	0	0	0
Kiowa County	512,259	CRP Total	0	0	0	675	0	0	0	10
		All Other Total	0	0	0	0	0	0	0	0
Pawnee County	471,135	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Pratt County	507,177	CRP Total	0	0	0	397	0	0	0	6
		All Other Total	0	0	0	0	0	0	0	0
Reno County	934,980	CRP Total	0	0	0	44	0	0	0	1
		All Other Total	0	0	0	0	0	0	0	0
Stafford County	548,100	CRP Total	0	0	0	0	0	0	0	0
		All Other Total	0	0	0	0	0	0	0	0
Region 6 Total	**5,986,194**	**CRP Total**	**0**	**0**	**0**	**3,749**	**0**	**0**	**0**	**58**
		All Other Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Not more than 50% of any soil series or 10% of all potentially suitable land in a county used for biomass crops.

Table 2.8.5 Black Locust Energy Production and Potential MW of Generation Regions 1-6

Land Area Soil	Area (acres)		Energy, Billion Btu: (1,000) MBtu < $1.50	(1,000) MBtu $1.51 - 2.00	(1,000) MBtu $2.01 - 2.50	(1,000) MBtu $2.51- 3.00	Generation (30%/ 65%): MW @ < $1.50 MBtu	MW @ $1.51 - 2.00 MBtu	MW @ < $2.01- 2.50 MBtu	MW @ < $2.51- 3.00 MBtu
Regions 1-6 Total	**35,406,758**	**CRP Total**	**1,479**	**30,879**	**23,481**	**17,097**	**23**	**453**	**362**	**261**
		All Other Total	**0**	**0**	**2,601**	**26,995**	**0**	**0**	**40**	**401**

2.8.6 Black Locust Potential Contribution to Kansas Electricity Consumption

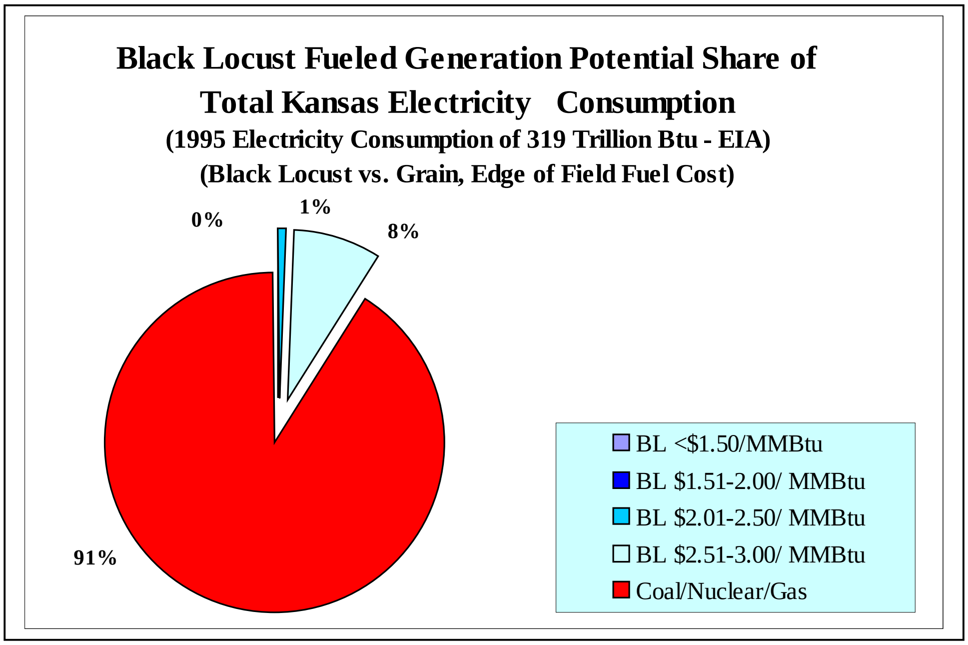

Figure 2.8.20 Black Locust vs. Grain Generation Potential Share of Total Kansas Electricity Consumption

Figure 2.8.20 shows the fraction of total 1995 Kansas electricity consump-tion that could have been generated by black locust produced at average yields in competition with grain, at different cost increments. These are edge of field fuel costs, and do not include transportation to the plant gate or inside the plant gate expenses.

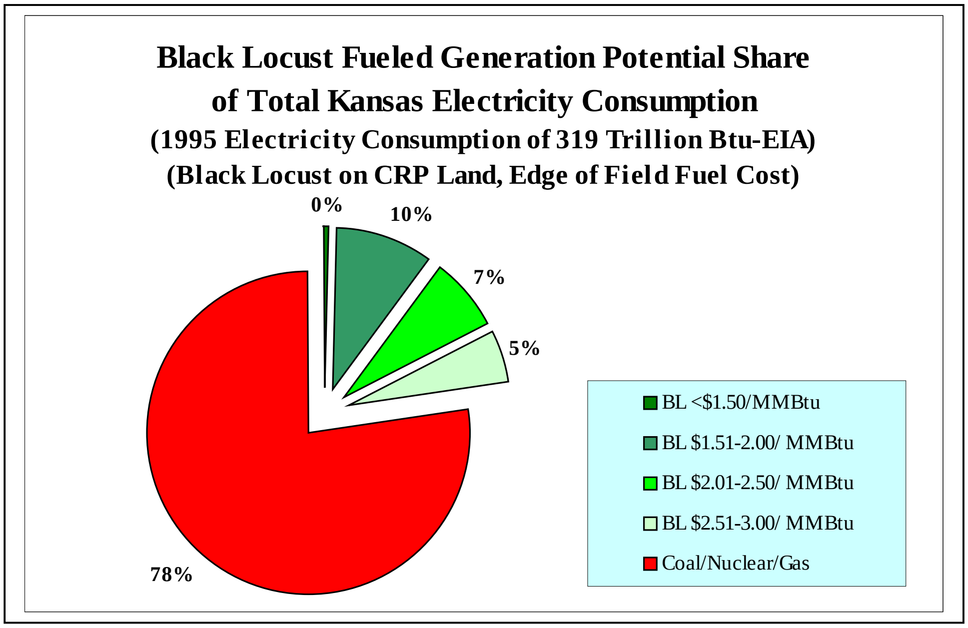

Figure 2.8.21 Black Locust Fueled Generation Potential Share of Total Kansas Electricity Consumption

Figure 2.8.21 shows the fraction of total 1995 Kansas electricity consump-tion that could have been generated with black locust produced at average yields on land potentially eligible for CRP with land rent equal to 40% of the federal CRP rate, at different cost increments. As with the case above, theses costs are at the field edge.

2.8.7 Switchgrass or Black Locust?

When competing for land use with conventional grain crops, switchgrass is clearly more economical than black locust. The eight year deferral, with interest, of establishment costs, land rents, and profits that would have been gained from annual grain sales, is too significant to overcome the savings from reduced annual field operations. Use of CRP lands at lower rents and without the loss of grain crop profits narrows the gap between switchgrass and black locust. Black locust does have several advantages over switchgrass, including the following:

1) Switchgrass yield can vary substantially in direct response to seasonal weather variation. Without covered storage at added expense, the availability of fuel in a dry year could become a problem, particularly for a plant fully dedicated to biomass. Black locust, with an eight year harvest cycle, levels out annual variation in growth.

2) The principal motivation for considering biomass for electric power generation is the aggregate environmental benefits, particularly reduced carbon emissions. For the entire fuel cycle, from planting to the boiler door, black locust has average energy profit ratio (EPR) of 30 - 41, while the switchgrass EPR is 13.4 – 15.[63] Growing a leguminous tree with occasional harvesting converts more net solar energy than growing a grass requiring substantial fertilzer derived from fossil fuels and annual harvest cost.

3) While the energy impact of fertilizer use is reflected in the EPR discussed above, use of nitrogen fertilizer has other consequences, including ground water contamination, eutrophication of surface water, and increased atmospheric nitrous oxide.[64]

---

[63] Based on 5% co-firing at Jeffrey and LaCygne for both CRP and competing with grain scenarios.
[64] Smil, V., ***Global Population and the Nitrogen Cycle***, Scientific American, July, 1997.

2.9 The Environmental Impact of Biomass Production

The motivation for considering biomass as an energy source is almost entirely environmental, although in some circumstance cost savings may occur. Some environmental benefits, such as reduced emissions, may occur regardless of the source of biomass, while others may be highly dependent on prior land use. Land considered for biomass production for this project was limited to existing agricultural tilled land. This limitation excludes existing forest land. Only about 0.6 million acres, some 1.1 % of Kansas is considered forested, and although this area has increased in the past 15 years, much of it is on isolated riparian strips, steep bluffs, or other land forms or soil conditions unsuitable for mechanized bioenergy crop production (otherwise it would likely be tilled now). Such diverse woodlands also represent important ecosystems and large scale conversion to mono-crops for energy production was considered environmentally unjustifiable without further site specific research. Existing pastureland totaling an estimated 13.8 million acres statewide was also considered. Pasture, whether unbroken prairie or land permanently returned to grass is likely not tilled because shallow soil depth, slope, or available moisture make in unsuitable for tillage. These conditions often result in insufficient biomass yields to achieve acceptable production costs. Lands eligible for, and perhaps already in, CRP are included. Use of CRP lands for biomass energy production is a key recommendation of this report and to the extent that tilled land would have been already converted to grass or trees as part of CRP and irregardless of biomass energy, many of the environmental benefits, such as reduced erosion and runoff, improved ground water and wildlife habitat, would already occur.

1) Reduced environmental emissions

Substituting biomass fuels for conventional fuels can reduce emissions in several ways. First, by capturing and storing solar energy greater than the fossil fuel inputs required to produce, deliver, and process them, second, by impacting the combustion process in a manner that reduces stack emissions, and finally by sequestering the carbon from combustion emissions occuring elsewhere in their extensive root systems.

2) Reduced soil erosion

Soil erosion is an important issue, globally, nationally, and in Kansas. Erosion of the soil occurs due to rainfall (water) and/or wind forces. Rainfall erosion occurs when rain directly strikes the soil dislodging particles in the top layer of soil. When soil becomes saturated, particles are moved down the slope of the field. Soil erosion due to wind occurs in much the same manner as rainfall with wind forces dislodging soil particles and carrying them along the field surface (creep and saltation) or suspending them above the field. The eastern one-third of Kansas (regions 2, 3, 4, and 5) is predominately affected by rainfall erosion while the central third of Kansas (regions 1 and 6) can be affected by both forces.

It has been estimated that soil is formed naturally at the rate of approximately 0.44 tons/acre/year (t/ac/yr). The average amount of soil lost to rainfall and wind erosion on cultivated cropland in the United States was 3.5 t/ac/yr and 2.9 t/ac/yr respectively (NRI, 1992), while in Kansas the values are 2.3 and 2.1 t/ac/yr. Soil erosion due to rainfall on non-cultivated cropland was 0.9 and 0.4 t/ac/yr for the US and Kansas respectively, and was 0.4 and 0.7 t/ac/yr subject to wind erosion (NRI, 1992). Table 2.9.1 contains water (rainfall) and wind erosion rates (tons per acre per year) derived from the National Resources Inventory (NRI) for corn, sorghum, soybeans, and winter wheat grown in Kansas in each of the 6 regions analyzed in this study. Each soil loss value within a region is an irrigated and dryland acreage-weighted value given in the 1992 NRI.

Table 2.9.1 Water and Wind Erosion by Kansas Climate Region (1992 NRI)

Erosion from Water and Wind			**tons per acre per year**	
KS region	**NRI crop code**	**crop**	**rainfall erosion**	**wind erosion**
1	11	corn	2.09	2.08
1	12	sorghum	2.78	2.30
1	13	soybeans	1.11	5.79
1	111	wheat	2.32	2.47
1	141	hay	0.28	0.08
1	142	hay	0.24	0.25
1	143	hay	0.16	0.08
1	410	CRP	0.37	0.03
KS region	**NRI crop code**	**crop**	**rainfall erosion**	**wind erosion**
2	11	corn	2.92	0.34
2	12	sorghum	3.48	0.23
2	13	soybeans	3.98	0.46
2	111	wheat	3.14	1.01
2	141	hay	0.46	0.01
2	142	hay	0.42	0.07
2	143	hay	0.24	0.00
2	410	CRP	0.69	0.02
KS region	**NRI crop code**	**crop**	**rainfall erosion**	**wind erosion**
3	11	corn	6.20	0.00
3	12	sorghum	4.84	0.00
3	13	soybeans	5.83	0.00
3	111	wheat	4.92	0.00
3	141	hay	0.44	0.00
3	142	hay	1.19	0.00
3	143	hay	0.43	0.00
3	410	CRP	1.23	0.00
KS region	**NRI crop code**	**crop**	**rainfall erosion**	**wind erosion**
4	11	corn	3.34	0.00
4	12	sorghum	3.78	0.00
4	13	soybeans	4.03	0.00
4	111	wheat	3.79	0.00
4	141	hay	0.39	0.00
4	142	hay	0.58	0.00
4	143	hay	0.37	0.00
4	410	CRP	0.56	0.00
KS region	**NRI crop code**	**crop**	**rainfall erosion**	**wind erosion**
5	11	corn	1.62	2.46
5	12	sorghum	2.72	1.02
5	13	soybeans	3.70	0.70
5	111	wheat	2.78	1.41
5	141	hay	0.38	0.12
5	142	hay	0.31	0.26
5	143	hay	0.16	0.00
5	410	CRP	0.58	0.09
KS region	**NRI crop code**	**crop**	**rainfall erosion**	**wind erosion**
6	11	corn	1.81	1.81
6	12	sorghum	1.77	2.43
6	13	soybeans	1.59	2.12
6	111	wheat	1.74	3.67
6	141	hay	0.29	0.36
6	142	hay	0.24	1.65
6	410	CRP	0.38	0.39

Table 2.9.1 Water and Wind Erosion by Climate Region (cont'd)

United States and Kansas Totals				
Cultivated Cropland				
USLE	3.50	t/ac/year	US	
	2.30	t/ac/year	KS	
WEQ	2.90	t/ac/year	US	
	2.10	t/ac/year	KS	
Non-cultivated Cropland				
USLE	0.90	t/ac/year	US	
	0.40	t/ac/year	KS	
WEQ	0.40	t/ac/year	US	
	0.70	t/ac/year	KS	
1987 Cultivated Cropland			US	
USLE	**9.20**	**metric tonnes/hectare/year**		

The amount of soil actually eroded is a function of the amount and intensity of the rainfall and/or wind, soil type, slope of the field, type of crop planted, and cropping management. While eroded soil does not disappear, the erosion process moves soil particles to other locations in the field (either downslope or downwind) where they are eventually transferred into waterways or onto non-croplands.

Soil quality and its productivity are directly affected by the soil erosion process. Loss of topsoil to water and/or wind erosion depletes the cropland of vital nutrients and organic matter leaving behind subsoils to support plant growth. These subsoils are often much lower in nutrients and organic matter and are typically more dense than topsoil, thereby reducing their ability to retain nutrients and water. A consequence associated with nutrient depletion is the need to use additional fertilizers to enhance production at an additional cost to the landowner. While fertilizers offer a short-term fix to soil productivity, they can not replace other minerals and organic matter required for long-term soil health. Runoff of these fertilizers has been shown to have an adverse impact on the water quality of streams, rivers, lakes, and reservoirs.

The dense subsoil layer has other implications associated with soil erosion as these sublayers tend to form a crust which limits water infiltration. Because this water is not absorbed by the soil structure, it is moved to other fields and onto other lands, streams, rivers, and reservoirs. Washed and/or blown sediment due to soil erosion contaminates and decreases water supplies as well as the storage capacity of reservoirs, thereby shortening the useful lives of dams. In addition, an increase of sediment due to soil erosion above which a reservoir was designed for can cause severe damage to a hydroelectric generating facility.

Biomass energy crops could help significantly or have little impact on efforts to reduce soil erosion, depending on where they would be planted and what current land cover they would displace. Biomass energy crops produce continuous cover which shields the soil surface from the impact of rainfall.

In addition, bioenergy crops have extensive root systems which hold soil, retarding both wind and water induced erosion in contrast with conventional grain crops. Another important aspect associated with bioenergy crop production is that their establishment, growth, and harvesting, whether annually (switchgrass) or every eight years (black locust), require minimal field operations that disturb the soil versus those field operations reuired to plant, maintain, and harvest the four conventional commodity crops, even under the conservation tillage scenarios employed in this study. Disruption of the soil surface contributes to increased soil erosion by compacting the soil, thereby reducing the soil's ability to allow for infiltration, which in turn increases the potential for runoff. Limited field trials have shown annual rainfall erosion rates on land planted to perennial energy crops averaging 0.71 tons per acre per year. This is a significant reduction from the average annual rainfall erosion rate on cultivated cropland of 3.5 tons per acre per year.

Tables 2.9.1 present the ALMANAC calculated water and wind soil erosion (ALMANAC variables USLE and YW) for the 24 year average for each soil series for switchgrass and black locust compared to the most profitable of the four conventional grain crops, for each of the six climate regions. Actual runoff reduction achieved by a specific biomass plantation intended to provide fuel for a particular generating facility would depend on many variables, including current land use (cropping rotations), site slope and soil properties.

Wind erosion was not considered in this analysis because the wind erosion component of the ALMANAC (and EPIC) model was in the process of being updated from the WEQ (Wind Erosion eQuation) model, established in 1965, to the RWEQ (Revised Wind Erosion eQuation) which was completed in 1996. However, it is known that the amount of wind erosion that occurs on lands planted to either switchgrass or black locust results in significant reductions of soil loss (Benson, 1998) primarily due to the following factors:

- mature switchgrass (stand after the establishment year) provides excellent cover over the surface of the land and there are no field operations that leave the soil surface exposed to wind forces at any time(s) during the 24 year period,

- tree species such as black locust provide a wind break, thereby reducing the wind velocity at the ground level which is a primary driver for wind induced erosion to occur.

By contrast, conventional commodity crops such as those considered in this study are subject to field operations which leave the field exposed to wind forces during various times of the year. For those areas in which high rates of wind erosion occur, the National Resource Conservation Service recommends a practice of installing cover crops such as grasses or wind breaks along the field edges.

For each soil type within each county in each of the 6 regions, percent reductions in rainfall induced (water) erosion due to switchgrass and black locust production versus the most profitable grain crop are presented. Percent reductions are shown for soils with EI's greater than 8 and those with an EI less than 8. Each EI partion within a particular county is the arithmatic average of all EI's for all soils within that partion. The percent reduction in water erosion attributable to each bioenergy crop is calculated as the difference between water erosion that occurs for the most profitable grain crop and water erosion for each bioenergy crop divided by the water erosion that occurs for the most profitable grain crop. For all counties within each of the 6 regions, and for each EI case considered, average percent reductions in rainfall induced erosion exceeded 96% for switchgrass and 91% for black locust versus the most profitable grain crop. Average values in percent reductions were nearly 99%.

Reductions in rainfall induced erosion for both energy crops is attributable to the fact that they both provide superior cover either above the ground (canopy of black locust) or on the ground (switchgrass) thereby decreasing the intensity of the rainfall (energy contained in the individual raindrops) striking the soil surface and hence, its ability to dislodge soil particles.

Table 2.9.1 Wind and Water Erosion Reduction, 24 Year Total, Tons/Acre **Region 1**

Note: The grain crop values are for the particular grain having the highest profit at average grain prices the greatest number of years in the 24 year evaluation period.

			Most Profitable Grain			Switchgrass			Black Locust		
Soil	Acres	Erosion Index (average)	Crop	Water (average)	Wind (average)	Water (average)	Wind (average)	Total Reduction	Water (average)	Wind (average)	Total Reduction
Barton County											
Soils w/ EI > 8.0	31,443	21.3	Wheat	17.86	0.00	0.33	0.00	98.2%	0.21	0.00	98.8%
Soils w/ EI < 8.0	459,159	2.8	Wheat	8.13	0.00	0.12	0.00	98.6%	0.06	0.00	99.3%
Ellis County											
Soils w/ EI > 8.0	182,582	49.7	Wheat	23.83	0.00	0.32	0.00	98.7%	0.22	0.00	99.1%
Soils w/ EI < 8.0	436,291	3.7	Wheat	9.44	0.00	0.15	0.00	98.4%	0.08	0.00	99.2%
Ellsworth County											
Soils w/ EI > 8.0	339,885	22.1	Wheat	16.05	0.00	0.26	0.00	98.4%	0.16	0.00	99.0%
Soils w/ EI < 8.0	226,213	4.0	Wheat	5.81	0.00	0.14	0.00	97.6%	0.07	0.00	98.8%
Jewell County											
Soils w/ EI > 8.0	85,649	55.2	Wheat	18.83	0.00	0.39	0.00	97.9%	0.27	0.00	98.6%
Soils w/ EI < 8.0	524,329	3.8	Wheat	9.67	0.00	0.14	0.00	98.6%	0.07	0.00	99.3%
Lincoln County											
Soils w/ EI > 8.0	183,196	22.8	Wheat	18.52	0.00	0.29	0.00	98.4%	0.18	0.00	99.0%
Soils w/ EI < 8.0	336,626	3.8	Wheat	9.32	0.00	0.14	0.00	98.5%	0.07	0.00	99.3%
Mitchell County											
Soils w/ EI > 8.0	47,284	26.0	Wheat	26.33	0.00	0.48	0.00	98.2%	0.37	0.00	98.6%
Soils w/ EI < 8.0	501,934	3.6	Wheat	11.07	0.00	0.16	0.00	98.6%	0.08	0.00	99.2%
Osborne County											
Soils w/ EI > 8.0	286,402	56.2	Wheat	31.94	0.00	0.54	0.00	98.3%	0.44	0.00	98.6%
Soils w/ EI < 8.0	503,052	3.9	Wheat	10.73	0.00	0.13	0.00	98.8%	0.07	0.00	99.4%
Phillips County											
Soils w/ EI > 8.0	45,251	47.9	Wheat	21.64	0.00	0.33	0.00	98.5%	0.23	0.00	98.9%
Soils w/ EI < 8.0	518,008	4.0	Wheat	9.94	0.00	0.15	0.00	98.5%	0.08	0.00	99.2%
Rice County											
Soils w/ EI > 8.0	110,698	20.4	Wheat	17.58	0.00	0.27	0.00	98.5%	0.17	0.00	99.0%
Soils w/ EI < 8.0	374,364	2.6	Wheat	7.71	0.00	0.11	0.00	98.5%	0.06	0.00	99.3%
Rush County											
Soils w/ EI > 8.0	89,153	22.7	Wheat	23.03	0.00	0.29	0.00	98.7%	0.20	0.00	99.1%
Soils w/ EI < 8.0	308,913	3.4	Wheat	7.80	0.00	0.15	0.00	98.1%	0.08	0.00	99.0%
Rooks County											
Soils w/ EI > 8.0	114,923	54.3	Wheat	21.03	0.00	0.34	0.00	98.4%	0.23	0.00	98.9%
Soils w/ EI < 8.0	468,867	3.8	Wheat	9.77	0.00	0.14	0.00	98.6%	0.07	0.00	99.2%
Russel County											
Soils w/ EI > 8.0	165,849	47.4	Wheat	15.16	0.00	0.31	0.00	98.0%	0.22	0.00	98.6%
Soils w/ EI < 8.0	332,119	4.1	Wheat	11.62	0.00	0.15	0.00	98.7%	0.08	0.00	99.3%
Smith County											
Soils w/ EI > 8.0	84,978	52.8	Wheat	23.33	0.00	0.37	0.00	98.4%	0.26	0.00	98.9%
Soils w/ EI < 8.0	518,953	3.8	Wheat	10.83	0.00	0.15	0.00	98.6%	0.08	0.00	99.3%

Table 2.9.1 Wind and Water Erosion Reduction, 24 Years, Tons per Acre Region 2

			Most Profitable Grain Crop			Switchgrass			Black Locust		
Soil	**Acres**	**Erosion Index** (average)	**Crop**	**Water** (average)	**Wind** (average)	**Water** (average)	**Wind** (average)	**Total Reduction**	**Water** (average)	**Wind** (average)	**Total Reduction**
Cloud County											
Soils w/ EI > 8.0	98,990	21.29	Wheat	34.16	0.00	0.39	0.00	98.9%	0.28	0.00	99.2%
Soils w/ EI < 8.0	288,169	3.61	Wheat	5.64	0.00	0.13	0.00	97.7%	0.08	0.00	98.6%
Chase County											
Soils w/ EI > 8.0	540,044	34.70	Wheat	11.99	0.00	0.26	0.00	97.8%	0.19	0.00	98.4%
Soils w/ EI < 8.0	142,295	4.12	Wheat	4.84	0.00	0.17	0.00	96.4%	0.11	0.00	97.7%
Clay County											
Soils w/ EI > 8.0	90,921	23.94	Wheat	26.83	0.00	0.34	0.00	98.7%	0.25	0.00	99.1%
Soils w/ EI < 8.0	307,235	3.63	Wheat	6.60	0.00	0.15	0.00	97.8%	0.09	0.00	98.6%
Dickinson County											
Soils w/ EI > 8.0	98,035	21.90	Soybeans	35.88	0.00	0.36	0.00	99.0%	0.27	0.00	99.3%
Soils w/ EI < 8.0	422,046	3.44	Wheat	6.86	0.00	0.14	0.00	97.9%	0.09	0.00	98.7%
Geary County											
Soils w/ EI > 8.0	199,951	28.18	Wheat	16.01	0.00	0.27	0.00	98.3%	0.20	0.00	98.8%
Soils w/ EI < 8.0	112,970	4.03	Wheat	7.80	0.00	0.17	0.00	97.8%	0.11	0.00	98.6%
Marion County											
Soils w/ EI > 8.0	293,715	30.73	Wheat	26.42	0.00	0.32	0.00	98.8%	0.24	0.00	99.1%
Soils w/ EI < 8.0	308,540	3.67	Wheat	5.17	0.00	0.16	0.00	96.9%	0.10	0.00	98.0%
McPherson County											
Soils w/ EI > 8.0	214,828	17.87	Soybeans	20.29	0.00	0.28	0.00	98.6%	0.20	0.00	99.0%
Soils w/ EI < 8.0	367,318	2.84	Wheat	5.54	0.00	0.13	0.00	97.7%	0.08	0.00	98.6%
Morris County											
Soils w/ EI > 8.0	295,334	41.11	Wheat	21.58	0.00	0.30	0.00	98.6%	0.23	0.00	99.0%
Soils w/ EI < 8.0	236,524	3.93	Wheat	5.51	0.00	0.17	0.00	96.9%	0.11	0.00	98.0%
Ottawa County											
Soils w/ EI > 8.0	205,490	23.18	Soybeans	34.81	0.00	0.33	0.00	99.1%	0.25	0.00	99.3%
Soils w/ EI < 8.0	303,598	59.68	0	104.98	0.00	2.32	0.00	97.8%	1.41	0.00	98.7%
Riley County											
Soils w/ EI > 8.0	227,890	30.14	Wheat	24.99	0.00	0.33	0.00	98.7%	0.24	0.00	99.0%
Soils w/ EI < 8.0	201,854	4.14	Wheat	6.41	0.00	0.16	0.00	97.5%	0.10	0.00	98.4%
Republic County											
Soils w/ EI > 8.0	37,160	20.82	Soybeans	39.81	0.00	0.44	0.00	98.9%	0.31	0.00	99.2%
Soils w/ EI < 8.0	404,360	3.75	Wheat	7.61	0.00	0.14	0.00	98.1%	0.09	0.00	98.9%
Saline County											
Soils w/ EI > 8.0	286,286	21.30	Soybeans	25.60	0.00	0.32	0.00	98.8%	0.23	0.00	99.1%
Soils w/ EI < 8.0	220,676	3.23	Wheat	6.10	0.00	0.14	0.00	97.7%	0.08	0.00	98.7%
Washington County											
Soils w/ EI > 8.0	217,255	23.38	Soybeans	25.75	0.00	0.31	0.00	98.8%	0.23	0.00	99.1%
Soils w/ EI < 8.0	335,512	4.62	Wheat	9.73	0.00	0.17	0.00	98.3%	0.11	0.00	98.9%

Table 2.9.1 Wind and Water Erosion Reduction, 24 Years, Tons per Acre Region 3

			Most Profitable Grain			Switchgrass			Black Locust		
Soil	**Acres**	**Erosion Index** (average)	**Crop**	**Water** (average)	**Wind** (average)	**Water** (average)	**Wind** (average)	**Total Reduction**	**Water** (average)	**Wind** (average)	**Total Reduction**
Atchison County											
Soils w/ EI >	175,796	26.94	Soybeans	68.61	0.00	0.81	0.00	98.8%	4.60	0.00	93.3%
Soils w/ EI < 8.0	120,408	4.34	Soybeans	23.15	0.00	0.24	0.00	99.0%	1.40	0.00	93.9%
Brown County											
Soils w/ EI >	317,805	19.66	Soybeans	60.85	0.00	0.62	0.00	99.0%	3.29	0.00	94.6%
Soils w/ EI < 8.0	482,947	3.87	Soybeans	30.24	0.00	0.32	0.00	98.9%	1.84	0.00	93.9%
Douglas County											
Soils w/ EI >	163,607	22.04	Soybeans	38.94	0.00	0.41	0.00	99.0%	2.18	0.00	94.4%
Soils w/ EI < 8.0	89,836	5.22	Soybeans	25.30	0.00	0.27	0.00	99.0%	1.54	0.00	93.9%
Doniphan County											
Soils w/ EI >	60,649	0.00	0	0.00	0.00	0.00	0.00	98.8%	0.00	0.00	93.3%
Soils w/ EI < 8.0	180,463	4.16	Soybeans	28.20	0.00	0.30	0.00	99.0%	1.72	0.00	93.9%
Franklin County											
Soils w/ EI >	194,768	24.14	Soybeans	36.15	0.00	0.39	0.00	98.9%	2.27	0.00	93.7%
Soils w/ EI < 8.0	196,566	5.48	Soybeans	17.27	0.00	0.18	0.00	98.9%	1.05	0.00	93.9%
Jackson County											
Soils w/ EI >	353,775	21.12	Soybeans	65.73	0.00	0.67	0.00	99.0%	3.61	0.00	94.5%
Soils w/ EI < 8.0	87,128	4.35	Soybeans	28.40	0.00	0.30	0.00	98.9%	1.73	0.00	93.9%
Jefferson County											
Soils w/ EI >	255,304	20.33	Soybeans	57.32	0.00	0.59	0.00	99.0%	3.09	0.00	94.6%
Soils w/ EI < 8.0	82,130	4.88	Soybeans	24.78	0.00	0.26	0.00	99.0%	1.50	0.00	94.0%
Johnson County											
Soils w/ EI >	100,279	23.84	Soybeans	49.96	0.00	0.50	0.00	99.0%	2.58	0.00	94.8%
Soils w/ EI < 8.0	109,231	5.20	Soybeans	26.00	0.00	0.27	0.00	98.9%	1.59	0.00	93.9%
Leavenworth County											
Soils w/ EI >	141,996	27.83	Soybeans	53.46	0.00	0.65	0.00	98.8%	3.48	0.00	93.5%
Soils w/ EI < 8.0	89,058	4.32	Soybeans	26.34	0.00	0.28	0.00	98.9%	1.60	0.00	93.9%
Lyon County											
Soils w/ EI >	299,632	29.23	Soybeans	43.89	0.00	0.45	0.00	99.0%	2.44	0.00	94.4%
Soils w/ EI < 8.0	280,929	5.00	Soybeans	24.32	0.00	0.25	0.00	99.0%	1.47	0.00	93.9%
Miami County											
Soils w/ EI >	154,970	16.96	Soybeans	34.75	0.00	0.36	0.00	99.0%	2.09	0.00	94.0%
Soils w/ EI < 8.0	150,956	4.73	Soybeans	20.34	0.00	0.21	0.00	99.0%	1.25	0.00	93.9%
Marshall County											
Soils w/ EI >	272,246	25.01	Soybeans	62.89	0.00	0.64	0.00	99.0%	3.39	0.00	94.6%
Soils w/ EI < 8.0	296,414	4.47	Soybeans	23.30	0.00	0.24	0.00	99.0%	1.41	0.00	94.0%
Nemaha County											
Soils w/ EI >	373,281	23.28	Soybeans	67.72	0.00	0.69	0.00	99.0%	3.68	0.00	94.6%
Soils w/ EI < 8.0	120,091	3.99	Soybeans	28.49	0.00	0.30	0.00	98.9%	1.74	0.00	93.9%
Osage County											
Soils w/ EI >	234,946	25.33	Soybeans	48.33	0.00	0.49	0.00	99.0%	2.65	0.00	94.5%
Soils w/ EI < 8.0	219,974	4.73	Soybeans	22.47	0.00	0.24	0.00	98.9%	1.37	0.00	93.9%
Pottawatomie County											
Soils w/ EI >	389,449	29.79	Soybeans	78.09	0.00	0.79	0.00	99.0%	4.34	0.00	94.4%
Soils w/ EI < 8.0	202,777	4.90	Soybeans	26.83	0.00	0.28	0.00	99.0%	1.62	0.00	94.0%
Shawnee County											
Soils w/ EI >	179,672	24.75	Soybeans	47.87	0.00	0.48	0.00	99.0%	2.51	0.00	94.8%
Soils w/ EI < 8.0	99,790	4.80	Soybeans	25.00	0.00	0.26	0.00	98.9%	1.52	0.00	93.9%
Wabaunsee County											
Soils w/ EI >	493,913	36.08	Soybeans	59.79	0.00	0.60	0.00	99.0%	3.26	0.00	94.5%
Soils w/ EI < 8.0	132,773	4.91	Soybeans	23.78	0.00	0.25	0.00	99.0%	1.43	0.00	94.0%
Wyandotte County											
Soils w/ EI >	17,614	27.83	Soybeans	53.46	0.00	0.65	0.00	98.8%	3.48	0.00	93.5%
Soils w/ EI < 8.0	14,579	4.38	Soybeans	24.58	0.00	0.26	0.00	99.0%	1.49	0.00	93.9%

Table 2.9.1 Wind and Water Erosion Reduction, 24 Years, Tons per Acre Region 4

			Most Profitable Grain			Switchgrass			Black Locust		
Soil	**Acres**	**Erosion Index** (average)	**Crop**	**Water** (average)	**Wind** (average)	**Water** (average)	**Wind** (average)	**Total Reduction**	**Water** (average)	**Wind** (average)	**Total Reduction**
Allen County											
Soils w/ EI > 8.0	192,418	27.57	Soybeans	51.33	0.00	0.53	0.00	99.0%	0.37	0.00	99.3%
Soils w/ EI > 8.0	99,298	4.73	Soybeans	19.81	0.00	0.22	0.00	98.9%	0.15	0.00	99.3%
Anderson County											
Soils w/ EI > 8.0	146,073	29.01	Soybeans	57.11	0.00	0.58	0.00	99.0%	0.42	0.00	99.3%
Soils w/ EI > 8.0	216,852	5.50	Soybeans	21.99	0.00	0.24	0.00	98.9%	0.16	0.00	99.3%
Bourbon County											
Soils w/ EI > 8.0	221,741	24.65	Soybeans	43.37	0.00	0.46	0.00	98.9%	0.33	0.00	99.2%
Soils w/ EI > 8.0	124,258	4.73	Soybeans	19.81	0.00	0.22	0.00	98.9%	0.15	0.00	99.3%
Coffey County											
Soils w/ EI > 8.0	294,974	25.31	Soybeans	36.79	0.00	0.40	0.00	98.9%	0.29	0.00	99.2%
Soils w/ EI > 8.0	122,626	4.91	Soybeans	23.73	0.00	0.26	0.00	98.9%	0.17	0.00	99.3%
Cherokee County											
Soils w/ EI > 8.0	216,664	26.33	Soybeans	34.86	0.00	0.39	0.00	98.9%	0.33	0.00	99.1%
Soils w/ EI > 8.0	88,912	5.10	Soybeans	17.58	0.00	0.19	0.00	98.9%	0.12	0.00	99.3%
Crawford County											
Soils w/ EI > 8.0	183,667	27.10	Soybeans	43.61	0.00	0.46	0.00	98.9%	0.34	0.00	99.2%
Soils w/ EI > 8.0	118,084	4.39	Soybeans	19.50	0.00	0.21	0.00	98.9%	0.14	0.00	99.3%
Labette County											
Soils w/ EI > 8.0	297,431	25.97	Soybeans	39.40	0.00	0.42	0.00	98.9%	0.31	0.00	99.2%
Soils w/ EI > 8.0	94,031	32.91	Soybeans	18.36	0.00	0.20	0.00	98.9%	0.13	0.00	99.3%
Linn County											
Soils w/ EI > 8.0	317,433	315.64	Soybeans	45.95	0.00	0.47	0.00	99.0%	0.33	0.00	99.3%
Soils w/ EI > 8.0	66,432	37.04	Soybeans	21.07	0.00	0.23	0.00	98.9%	0.15	0.00	99.3%
Montgomery County											
Soils w/ EI > 8.0	318,589	36.87	Soybeans	48.96	0.00	0.51	0.00	99.0%	0.38	0.00	99.2%
Soils w/ EI > 8.0	109,949	5.16	Soybeans	20.71	0.00	0.22	0.00	98.9%	0.15	0.00	99.3%
Neosho County											
Soils w/ EI > 8.0	233,470	29.65	Soybeans	41.65	0.00	0.44	0.00	98.9%	0.32	0.00	99.2%
Soils w/ EI > 8.0	116,878	5.42	Soybeans	23.24	0.00	0.25	0.00	98.9%	0.17	0.00	99.3%
Wilson County											
Soils w/ EI > 8.0	300,681	32.78	Soybeans	49.17	0.00	0.51	0.00	99.0%	0.36	0.00	99.3%
Soils w/ EI > 8.0	98,261	4.88	Soybeans	20.50	0.00	0.22	0.00	98.9%	0.15	0.00	99.3%
Woodson County											
Soils w/ EI > 8.0	238,070	30.32	Soybeans	44.06	0.00	0.46	0.00	99.0%	0.33	0.00	99.2%
Soils w/ EI > 8.0	91,100	4.22	Soybeans	20.52	0.00	0.22	0.00	98.9%	0.15	0.00	99.3%

Table 2.9.1 Wind and Water Erosion Reduction, 24 Years, Tons per Acre — Region 5

			Most Profitable Grain			Switchgrass			Black Locust		
Soil	**Acres**	**Erosion Index** (average)	**Crop**	**Water** (average)	**Wind** (average)	**Water** (average)	**Wind** (average)	**Total Reduction**	**Water** (average)	**Wind** (average)	**Total Reduction**
Butler County											
Soils w/ EI > 8.0	610,141	36.29	Wheat	20.61	0.00	0.36	0.00	98.3%	0.28	0.00	98.6%
Soils w/ EI > 8.0	417,415	3.43	Wheat	15.05	0.00	0.21	0.00	98.6%	0.14	0.00	99.1%
Cowley County											
Soils w/ EI > 8.0	530,156	31.04	Wheat	24.55	0.00	0.35	0.00	98.6%	0.28	0.00	98.8%
Soils w/ EI > 8.0	228,196	3.18	Wheat	13.17	0.00	0.18	0.00	98.6%	0.12	0.00	99.1%
Chautauqua County											
Soils w/ EI > 8.0	372,506	36.90	Soybeans	25.69	0.00	0.31	0.00	98.8%	0.24	0.00	99.1%
Soils w/ EI > 8.0	71,323	4.40	Wheat	11.09	0.00	0.19	0.00	98.3%	0.12	0.00	98.9%
Elk County											
Soils w/ EI > 8.0	446,728	40.06	Soybeans	25.27	0.00	0.29	0.00	98.9%	0.23	0.00	99.1%
Soils w/ EI > 8.0	52,934	5.10	Wheat	12.20	0.00	0.19	0.00	98.4%	0.13	0.00	99.0%
Greenwood County											
Soils w/ EI > 8.0	326,827	33.91	Wheat	25.92	0.00	0.30	0.00	98.9%	0.24	0.00	99.1%
Soils w/ EI > 8.0	51,067	4.49	Wheat	10.99	0.00	0.21	0.00	98.1%	0.14	0.00	98.7%
Harvey County											
Soils w/ EI > 8.0	32,528	14.96	Wheat	26.74	0.00	0.36	0.00	98.7%	0.28	0.00	98.9%
Soils w/ EI > 8.0	285,234	2.87	Wheat	16.07	0.00	0.18	0.00	98.9%	0.12	0.00	99.3%
Sedgwick County											
Soils w/ EI > 8.0	6,522	24.41	Wheat	23.34	0.00	0.33	0.00	98.6%	0.26	0.00	98.9%
Soils w/ EI > 8.0	161,191	2.83	Soybeans	14.47	0.00	0.17	0.00	98.9%	0.12	0.00	99.2%
Sumner County											
Soils w/ EI > 8.0	19,213	42.00	Soybeans	32.87	0.00	0.28	0.00	99.2%	0.32	0.00	99.0%
Soils w/ EI > 8.0	725,851	3.13	Wheat	14.38	0.00	0.16	0.00	98.9%	0.11	0.00	99.2%

Table 2.9.1 Wind and Water Erosion Reduction, 24 Years, Tons per Acre Region 6

Soil	Acres	Erosion Index (average)	Most Profitable Grain Crop Crop	Water (average)	Wind (average)	Switchgrass Water (average)	Wind (average)	Total Reduction	Black Locust Water (average)	Wind (average)	Total Reduction
Barber County											
Soils w/ EI > 8.0	418,980	33.71	Wheat	26.85	0.00	0.27	0.00	99.0%	1.99	0.00	92.6%
Soils w/ EI < 8.0	478,843	2.24	Soybeans	13.10	0.00	0.11	0.00	99.1%	0.82	0.00	93.7%
Comanche County											
Soils w/ EI > 8.0	302,474	37.10	Soybeans	40.11	0.00	0.36	0.00	99.1%	2.59	0.00	93.5%
Soils w/ EI < 8.0	343,410	2.27	Soybeans	14.30	0.00	0.12	0.00	99.1%	0.88	0.00	93.9%
Edwards County											
Soils w/ EI > 8.0	52,100	27.20	Soybeans	39.17	0.00	0.33	0.00	99.2%	2.44	0.00	93.8%
Soils w/ EI < 8.0	363,504	2.42	Soybeans	11.51	0.00	0.11	0.00	99.1%	0.78	0.00	93.2%
Harper County											
Soils w/ EI > 8.0	60,334	24.61	Wheat	21.55	0.00	0.25	0.00	98.8%	1.80	0.00	91.6%
Soils w/ EI < 8.0	442,874	2.55	Soybeans	14.64	0.00	0.13	0.00	99.1%	0.94	0.00	93.5%
Kingman County											
Soils w/ EI > 8.0	72,347	18.60	Soybeans	22.68	0.00	0.27	0.00	98.8%	1.96	0.00	91.4%
Soils w/ EI < 8.0	477,677	2.51	Soybeans	15.33	0.00	0.13	0.00	99.1%	0.99	0.00	93.5%
Kiowa County											
Soils w/ EI > 8.0	177,773	34.79	Soybeans	40.27	0.00	0.36	0.00	99.1%	2.55	0.00	93.7%
Soils w/ EI < 8.0	334,485	2.34	Soybeans	12.76	0.00	0.11	0.00	99.1%	0.81	0.00	93.6%
Pawnee County											
Soils w/ EI > 8.0	55,163	21.17	Soybeans	33.73	0.00	0.28	0.00	99.2%	2.07	0.00	93.9%
Soils w/ EI < 8.0	415,973	2.29	Soybeans	11.84	0.00	0.12	0.00	99.0%	0.87	0.00	92.7%
Pratt County											
Soils w/ EI > 8.0	197,331	9.38	Soybeans	33.00	0.00	0.30	0.00	99.1%	2.19	0.00	93.4%
Soils w/ EI < 8.0	309,846	2.17	Soybeans	11.19	0.00	0.10	0.00	99.1%	0.75	0.00	93.3%
Reno County											
Soils w/ EI > 8.0	106,606	122.43	Soybeans	21.93	0.00	0.22	0.00	99.0%	1.61	0.00	92.7%
Soils w/ EI < 8.0	828,374	2.62	Soybeans	13.10	0.00	0.12	0.00	99.1%	0.86	0.00	93.5%
Stafford County											
Soils w/ EI > 8.0	48,310	9.33	Soybeans	29.87	0.00	0.27	0.00	99.1%	2.03	0.00	93.2%
Soils w/ EI < 8.0	499,790	2.78	Soybeans	13.03	0.00	0.12	0.00	99.1%	0.86	0.00	93.4%

3) Reduced Surface Water Runoff (flood protection)

The same attributes that make switchgrass and black locust attractive from an erosion reduction standpoint (continuous cover which shields the soil surface from the impact of rainfall and extensive root systems which hold topsoil in place), also help to significantly reduce surface runoff from rainfall, thereby helping to reduce the risk of flooding and allowing a greater portion of precipitation to percolate to groundwater. Table 2.9.2 below compares the ALMANAC calculated surface runoff (Q) for the 24-year average of all soils for switchgrass, black locust, and the four conventional grain crops, for each of the six climate regions. The estimated runoff for switchgrass in region 5 is unexplainably high and should be investigated further if extensive planting of switchgrass in that region were being considered. As with erosion, potential reduction for a specific project is site specific.

Table 2.9.2 ALMANAC Estimated Surface Runoff

	24 Year Cumulative Surface Runoff of Precipitation (inches)					
Climate Region	Switchgrass	Black locust	Wheat	Corn	Soybeans	Grain Sorghum
1	14.96	10.10	28.55	35.40	35.18	36.24
2	44.75	31.45	61.37	78.42	77.72	80.71
3	74.00	74.54	126.61	145.39	141.80	148.00
4	88.17	58.94	147.93	170.25	165.41	174.66
5	88.73	30.44	66.99	85.61	85.89	166.76
6	7.79	6.43	21.76	28.22	28.04	29.01

4) Reduced Nutrient Loss

The United States Environmental Protection Agency (USEPA) has identified the transport of nutrients (nitrogen and phosphorus) by erosion, runoff, and/or leaching as the major anthropogenic cause of eutrophication of our nation's streams, lakes, and reservoirs. Transport of nitrogen and phosphorus from non-point source pollution, primarily agricultural operations, was singled out as a significant contributor to the contamination of our water supply. Eutrophication is defined as an increase in the fertility status of a natural water system thereby causing an increase in algae growth. This increase in algal growth leads to a reduction in water transparency, a depletion of dissolved oxygen, and a general degradation of water quality.

Specific water quality problems associated with eutrophication include increased difficulty (and costs) associated with water safety (purification) from an increase in suspended sediments that contain nitrogen and phosphorus. In turn, increased sedimentation can contribute to decreased lake depth. Previous studies have shown that eutrophication due to nitrogen is overwhelmingly caused by sediment-bound nitrogen (versus soluble nitrogen). In addition, phosphorus leached to groundwater has been historically below the eutrophication threshold. This is primarily due to the high sorption capacity of soils for phosphorus; therefore, the primary concern of phosphorus-induced eutrophication is from its loss with sediment and runoff. Recent research by Sharpley and Halvorson (in press) indicates a significant reduction in particulate phosphorus (from erosion or sediment) on soils with native grasses versus those managed with conventional, reduced, and no-tillage scenarios. Because eutrophication is caused in large part from nitrogen and phosphorus due to erosion and runoff, the qualities possessed by switchgrass and black locust mentioned in the previous soil erosion and runoff sections, should also be beneficial to helping control nitrogen and phosphorus movement into the local watershed.

Percent reductions of various nutrient parameters due to switchgrass and black locust production versus the most profitable grain crop were determined for all soil types in each county in each of the 6 regions. The following nutrient loss and fate parameters were analyzed by the ALMANAC program:

- organic N loss with sediment (YON)
- P loss with sediment (YP)
- soluble P loss in runoff (YAP)
- NO_3 loss in surface runoff (YNO3)
- mineral N loss in subsurface flow (SSFN)
- mineral N loss in percolate (PKRN)

Similar to the erosion analysis, percent reductions in each of the parameters are partioned for soils with EI's greater than 8 and those less than 8. The percent reduction in each of these parameters was calculated in the same manner as water erosion.

For all counties within each of the 6 regions, and for each EI case considered, the percent reductions in YON and YP (organic N and P loss with sediment) due to switchgrass and black locust exceeded 96% versus the most profitable grain crop and generally had an average reduction of 99%. Both YON and YP are a function of the amount of rainfall induced erosion that occurs. Both bioenergy crops provide excellent cover over the soil surface keeping soil/sediment from being transported; therefore the probability that applied nitrogen and phosphorus will be transported with sediment is minimal.

Average percent reductions in YAP (soluble P loss in runoff) and YNO3 (NO_3 loss in surface runoff) were generally in the low 90 percent range for both bioenergy crops for all soil types considered. YAP and YNO3 are both functions of the amount of runoff that occurs. Since switchgrass and black locust provide excellent cover over the soil surface thereby holding topsoil in place, this allows for greater infiltration rates of water/rainfall hence, less runoff versus conventional commodity crops.

Average percent reductions in mineral N loss in subsurface flow (SSFN) were in the upper 80 to mid 90 percent for switchgrass, but in several cases ranged from the low 90 percent to an actual percent increase for black locust production. The amount of nitrogen leached to the subsurface and hence transported away from the soil structure by subsurface flow, is a function of the following four parameters: soil type, amount of moisture used by each crop for establishment and growth, amount of nitrogen applied, and amount of rainfall received.

Switchgrass requires significant amounts of moisture for plant establishment and growth; therefore, a majority or all of the available moisture from rainfall can be accounted for in this manner and there will be little or no water lost to subsurface flow. By contrast, black locust has a higher percentage of nitrogen leached to the subsurface primarily because it is a legume. Therefore, because less nitrogen is absorbed by the tree, a higher concentration of nitrogen is available to be leached to the subsurface. One limitation of the ALMANAC program is that it applies nitrogen based on optimizing crop growth needs and is unable to adjust the quantity of nitrogen applied based on the leaching characteristics of the soil. Therefore, in certain cases some of the nitrogen applied for crop growth was actually lost to subsurface flow and not employed for crop growth.

Percent reductions associated with mineral N loss with percolate (PKRN) were, in general, positive for switchgrass production with the exception of several soils in region 2. PKRN is also a function of the same four parameters that affect SSFN. A positive percent reduction in PKRN implies that the combination of amount of rainfall received, water absorption by each bioenergy crop for plant establishment and growth, and soil type is not conducive to percolation. In addition, the amount of N applied does not exceed what is required for optimal plant establishment and growth on that particular soil type. When a negative percent reduction occurs in PKRN the opposite has occurred in one or more of these areas. Again, the ALMANAC program is, at this time, unable to detect the percolation characteristics of the soil with respect to the amount of nitrogen applied.

However, black locust production showed a marked increase in mineral N loss with percolate with the exception of region 5. This is due to basically the same reason that there is an increase in SSFN for black locust. Whether the nitrogen is leached to the subsurface (SSFN) or is percolated out of the soil structure (PKRN) is highly dependent upon the soil type and the quantity of moisture received.

Overall, the effect of using switchgrass and black locust has a postive impact when considering the loss of nitrogen and phosphorus to sediment, subsurface flow, and percolation when compared to the four conventional commodity crops.

Table 2.9.3 Nutrient Movement, 24 Years, Pounds per Acre, Average of All Soils

Region 1

			Most Profitable Grain Crop							Switchgrass - Percent Reduction						Black Locust - Percent Reduction					
Soil	Acres	EI	Crop	YON (organic N loss w/ sediment)	YP (P loss w/ sedi-ment)	YAP (solu-ble P loss in runoff)	YNO3 (NO3 loss in surface runoff)	SSFN (mineral N loss in subsur-face flow)	PKRN (mineral N loss in perco-late)	YON	YP	YAP	YNO3	SSFN	PKRN	YON	YP	YAP	YNO3	SSFN	PKRN
Barton County																					
Soils w/ EI >	31443	21.3	Wheat	99.24	18.43	0.11	171.48	416.43	79.03	99%	99%	100%	97%	94%	89%	99%	100%	100%	97%	68%	-49%
Soils w/ EI <	459159	2.8	Wheat	28.43	5.11	0.16	118.34	341.74	4.49	99%	99%	98%	97%	94%	56%	100%	100%	99%	97%	75%	-894%
Ellis County																					
Soils w/ EI >	182582	49.7	Wheat	110.01	23.15	0.30	153.18	198.48	156.60	99%	99%	90%	94%	93%	92%	99%	100%	95%	95%	60%	-44%
Soils w/ EI <	436291	3.7	Wheat	33.15	5.79	0.16	78.97	346.60	6.14	99%	99%	97%	97%	95%	73%	100%	100%	100%	97%	75%	-384%
Ellsworth County																					
Soils w/ EI >	339885	22.1	Wheat	97.64	16.95	0.18	158.56	310.20	55.29	99%	99%	96%	97%	94%	87%	100%	100%	99%	97%	68%	-83%
Soils w/ EI <	226213	4.0	Wheat	26.60	4.64	0.00	78.57	364.09	5.35	99%	99%	na	97%	96%	78%	100%	100%	na	97%	78%	-93%
Jewell County																					
Soils w/ EI >	85649	55.2	Wheat	96.56	20.03	0.00	158.71	280.10	182.38	98%	99%	na	95%	93%	91%	99%	100%	na	95%	68%	-6%
Soils w/ EI <	524329	3.8	Wheat	34.75	6.44	0.18	87.83	272.82	4.60	99%	99%	95%	96%	95%	90%	100%	100%	98%	97%	75%	-174%
Lincoln County																					
Soils w/ EI >	183196	22.8	Wheat	121.82	23.10	0.29	206.87	250.11	77.36	99%	99%	86%	96%	93%	88%	99%	100%	93%	96%	58%	-103%
Soils w/ EI <	336626	3.8	Wheat	42.19	6.97	0.12	88.53	227.33	1.04	99%	99%	96%	96%	95%	85%	100%	100%	99%	97%	76%	-155%
Mitchell County																					
Soils w/ EI >	47284	26.0	Wheat	153.73	33.45	0.00	207.87	239.47	116.47	98%	99%	na	94%	93%	88%	99%	99%	na	94%	65%	-65%
Soils w/ EI <	501934	3.6	Wheat	48.22	8.56	0.17	102.79	229.21	1.98	99%	99%	93%	96%	95%	87%	100%	100%	98%	97%	74%	-187%
Osborne County																					
Soils w/ EI >	286402	56.2	Wheat	146.46	35.14	0.00	182.34	206.30	182.38	98%	99%	na	93%	92%	91%	99%	99%	na	93%	64%	-6%
Soils w/ EI <	503052	3.9	Wheat	36.71	6.86	0.25	83.20	294.90	6.55	99%	99%	95%	96%	95%	90%	100%	100%	98%	97%	73%	-166%
Phillips County																					
Soils w/ EI >	45251	47.9	Wheat	103.24	21.26	0.17	152.74	297.64	161.78	99%	99%	97%	96%	93%	93%	99%	100%	99%	96%	66%	-5%
Soils w/ EI <	518008	4.0	Wheat	33.34	5.91	0.17	76.14	324.20	4.50	99%	99%	97%	97%	95%	90%	100%	100%	100%	97%	77%	-137%
Rice County																					
Soils w/ EI >	110698	20.4	Wheat	107.12	19.83	0.19	180.79	336.88	56.27	99%	99%	97%	97%	94%	89%	100%	100%	99%	97%	69%	-56%
Soils w/ EI <	374364	2.6	Wheat	25.00	4.67	0.12	131.42	393.62	6.10	99%	100%	98%	98%	95%	53%	100%	100%	100%	98%	76%	-983%
Rush County																					
Soils w/ EI >	89153	22.7	Wheat	58.05	11.53	0.22	104.99	269.53	52.07	99%	99%	95%	95%	94%	90%	100%	100%	98%	96%	71%	-123%
Soils w/ EI <	308913	3.4	Wheat	28.57	5.24	0.13	83.78	324.57	6.47	99%	99%	98%	96%	95%	94%	100%	100%	99%	97%	77%	-95%
Rooks County																					
Soils w/ EI >	114923	54.3	Wheat	103.81	21.32	0.12	152.55	227.25	153.53	99%	99%	94%	95%	93%	93%	99%	100%	98%	95%	66%	-12%
Soils w/ EI <	468867	3.8	Wheat	32.37	5.66	0.18	70.77	308.52	5.68	99%	99%	97%	97%	94%	88%	100%	100%	100%	97%	74%	-101%
Russel County																					
Soils w/ EI >	165849	47.4	Wheat	100.41	19.75	0.00	190.98	278.63	175.46	98%	99%	na	95%	93%	90%	99%	100%	na	95%	65%	-20%
Soils w/ EI <	332119	4.1	Wheat	42.81	7.58	0.25	83.58	296.09	7.08	99%	99%	95%	96%	94%	88%	100%	100%	98%	97%	72%	-107%
Smith County																					
Soils w/ EI >	84978	52.8	Wheat	116.74	24.01	0.13	166.84	221.65	175.47	99%	99%	94%	95%	93%	93%	99%	100%	98%	95%	64%	-12%
Soils w/ EI <	518953	3.8	Wheat	37.34	6.96	0.22	74.64	285.73	5.68	99%	99%	95%	96%	95%	90%	100%	100%	98%	97%	74%	-166%

Table 2.9.3 Nutrient Movement, 24 Years, Pounds per Acre, Average of All Soils

Region 2

			Most Profitable Grain Crop							Switchgrass - Percent Reduction						Black Locust - Percent Reduction					
Soil	Acres	EI	Crop	YON (organic N loss w/ sediment)	YP (P loss w/ sediment)	YAP (soluble P loss in runoff)	YNO3 (NO3 loss in surface runoff)	SSFN (mineral N loss in subsurface flow)	PKRN (mineral N loss in percolate)	YON	YP	YAP	YNO3	SSFN	PKRN	YON	YP	YAP	YNO3	SSFN	PKRN
Cloud County																					
Soils w/ EI >	98,990	21.29	Wheat	347.31	55.96	1.11	160.93	260.84	63.94	99%	99%	91%	93%	93%	-39%	99%	99%	92%	92%	57%	-1059%
Soils w/ EI <	288,169	3.61	Wheat	38.54	6.41	0.19	105.19	323.84	11.97	98%	99%	92%	91%	95%	59%	99%	99%	94%	89%	76%	-414%
Chase County																					
Soils w/ EI >	540,044	34.70	Wheat	218.36	34.74	0.29	344.29	231.27	57.29	97%	98%	78%	93%	94%	89%	98%	99%	86%	93%	65%	-50%
Soils w/ EI <	142,295	4.12	Wheat	63.71	10.83	0.00	234.67	169.25	0.00	97%	98%	na	93%	95%	na	98%	99%	na	92%	76%	na
Clay County																					
Soils w/ EI >	90,921	23.94	Wheat	394.42	61.79	1.06	185.22	194.17	105.95	98%	99%	88%	92%	92%	-10%	99%	99%	91%	92%	50%	-724%
Soils w/ EI <	307,235	3.63	Wheat	51.79	8.43	0.21	126.72	330.85	20.67	98%	99%	93%	93%	95%	91%	99%	99%	94%	91%	76%	57%
Dickinson County																					
Soils w/ EI >	98,035	21.90	Soybeans	521.19	80.94	1.58	158.62	258.62	158.90	99%	99%	90%	93%	89%	75%	99%	100%	92%	93%	41%	-149%
Soils w/ EI <	422,046	3.44	Wheat	57.92	9.70	0.30	169.86	294.22	7.77	98%	99%	92%	92%	95%	73%	99%	99%	93%	92%	75%	-76%
Geary County																					
Soils w/ EI >	199,951	28.18	Wheat	238.14	36.75	0.51	219.67	271.19	80.85	98%	98%	90%	93%	92%	63%	99%	99%	93%	92%	63%	-216%
Soils w/ EI <	112,970	4.03	Wheat	59.79	10.00	0.19	161.21	325.63	13.96	98%	99%	93%	93%	95%	74%	99%	99%	94%	92%	76%	-65%
Marion County																					
Soils w/ EI >	293,715	30.73	Wheat	399.30	62.62	1.06	259.21	191.44	101.98	98%	99%	88%	93%	92%	-24%	99%	99%	91%	92%	49%	-820%
Soils w/ EI <	308,540	3.67	Wheat	57.95	10.03	0.06	195.60	172.88	0.00	97%	98%	93%	92%	95%	na	99%	99%	94%	91%	76%	na
McPherson County																					
Soils w/ EI >	214,828	17.87	Soybeans	175.91	28.31	0.67	166.60	271.47	58.56	98%	99%	92%	94%	93%	-47%	99%	99%	93%	93%	64%	-954%
Soils w/ EI <	367,318	2.84	Wheat	42.75	7.46	0.22	150.87	301.31	7.06	98%	99%	92%	91%	95%	82%	99%	99%	93%	91%	76%	-204%
Morris County																					
Soils w/ EI >	295,334	41.11	Wheat	381.70	60.59	0.72	298.75	173.91	77.02	97%	98%	83%	92%	93%	84%	98%	99%	88%	92%	55%	-107%
Soils w/ EI <	236,524	3.93	Wheat	59.73	10.03	0.08	189.09	229.89	0.00	97%	99%	93%	92%	95%	na	99%	99%	94%	91%	77%	na
Ottawa County																					
Soils w/ EI >	205,490	23.18	Soybeans	412.44	65.59	1.48	164.64	201.17	86.41	99%	99%	91%	93%	92%	-32%	99%	100%	92%	92%	48%	-1004%
Soils w/ EI <	303,598	59.68	Wheat	42.74	7.23	0.24	123.60	319.64	10.19	98%	99%	94%	92%	95%	90%	99%	99%	95%	90%	77%	5%
Riley County																					
Soils w/ EI >	227,890	30.14	Wheat	328.23	52.53	0.67	289.12	220.97	72.46	98%	98%	88%	93%	93%	86%	99%	99%	91%	93%	59%	-80%
Soils w/ EI <	201,854	4.14	Wheat	51.53	8.67	0.18	155.53	364.76	13.70	98%	99%	93%	94%	95%	89%	99%	99%	94%	92%	77%	-124%
Republic County																					
Soils w/ EI >	37,160	20.82	Soybeans	421.82	67.86	1.33	162.54	291.07	84.18	99%	99%	90%	93%	93%	91%	99%	99%	92%	92%	53%	-61%
Soils w/ EI <	404,360	3.75	Wheat	47.52	7.81	0.23	107.29	342.60	12.13	98%	99%	93%	92%	95%	54%	99%	99%	94%	90%	75%	-513%
Saline County																					
Soils w/ EI >	286,286	21.30	Soybeans	324.74	52.54	1.00	188.07	205.85	64.14	98%	99%	91%	93%	93%	-46%	99%	99%	92%	92%	57%	-977%
Soils w/ EI <	220,676	3.23	Wheat	42.80	7.34	0.14	147.58	260.04	0.59	98%	99%	93%	91%	95%	56%	99%	99%	94%	90%	76%	-187%
Washington County																					
Soils w/ EI >	217,255	23.38	Soybeans	420.80	65.85	1.06	261.64	233.70	116.94	98%	99%	87%	94%	92%	-12%	99%	99%	90%	93%	50%	-723%
Soils w/ EI <	335,512	4.62	Wheat	76.84	12.14	0.26	139.98	417.95	25.68	98%	99%	93%	94%	95%	60%	99%	99%	94%	92%	75%	-229%

Table 2.9.3 Nutrient Movement, 24 Years, Pounds per Acre, Average of All Soils

Region 3

			Most Profitable Grain Crop							Switchgrass - Percent Reduction						Black Locust - Percent Reduction					
Soil	Acres	EI	Crop	YON (organic N loss w/ sediment)	YP (P loss w/ sedi-ment)	YAP (solu-ble P loss in runoff)	YNO3 (NO3 loss in surface runoff)	SSFN (mineral N loss in subsur-face flow)	PKRN (mineral N loss in perco-late)	YON	YP	YAP	YNO3	SSFN	PKRN	YON	YP	YAP	YNO3	SSFN	PKRN
Atchison County																					
Soils w/ EI >	175,796	26.94	Soybeans	806.53	130.85	2.52	268.21	123.84	73.02	99%	99%	86%	92%	86%	66%	98%	98%	83%	90%	7%	-1773%
Soils w/ EI <	120,408	4.34	Soybeans	254.05	37.19	1.95	191.96	229.44	42.00	99%	100%	90%	93%	87%	27%	98%	98%	85%	90%	15%	-4669%
Brown County																					
Soils w/ EI >	317,805	19.66	Soybeans	823.60	125.60	2.70	215.94	127.73	139.18	99%	99%	85%	91%	84%	73%	98%	98%	83%	88%	-7%	-756%
Soils w/ EI <	482,947	3.87	Soybeans	351.01	50.42	2.06	213.35	155.96	13.52	99%	99%	89%	92%	86%	77%	98%	98%	83%	89%	8%	-856%
Douglas County																					
Soils w/ EI >	163,607	22.04	Soybeans	467.22	71.13	2.10	201.06	237.16	180.43	99%	99%	86%	91%	87%	74%	98%	98%	85%	89%	3%	-794%
Soils w/ EI <	89,836	5.22	Soybeans	294.45	43.12	1.99	200.85	218.04	36.95	99%	100%	90%	92%	88%	48%	98%	98%	84%	89%	14%	-5993%
Doniphan County																					
Soils w/ EI >	60,649	32.96	Soybeans	902.25	144.95	2.41	278.72	166.78	117.26	99%	99%	85%	92%	86%	61%	98%	98%	84%	90%	10%	-2775%
Soils w/ EI <	180,463	4.16	Soybeans	313.57	45.34	1.94	189.68	207.24	36.00	99%	100%	90%	93%	87%	27%	98%	98%	85%	89%	15%	-4669%
Franklin County																					
Soils w/ EI >	194,768	24.14	Soybeans	344.17	56.22	2.05	253.96	257.98	192.47	99%	99%	86%	91%	88%	83%	98%	98%	83%	89%	15%	-510%
Soils w/ EI <	196,566	5.48	Soybeans	231.20	34.76	2.71	283.75	145.01	12.05	99%	99%	87%	91%	88%	81%	97%	97%	79%	87%	18%	-1494%
Jackson County																					
Soils w/ EI >	353,775	21.12	Soybeans	870.39	133.10	2.84	220.69	129.66	158.63	99%	99%	84%	90%	84%	35%	98%	98%	83%	88%	-28%	-1217%
Soils w/ EI <	87,128	4.35	Soybeans	323.00	46.90	2.16	219.03	151.60	16.36	99%	99%	89%	92%	86%	65%	98%	98%	82%	88%	0%	-1314%
Jefferson County																					
Soils w/ EI >	255,304	20.33	Soybeans	663.24	101.37	2.47	205.88	169.67	155.57	99%	100%	85%	91%	86%	72%	98%	98%	84%	89%	-3%	-847%
Soils w/ EI <	82,130	4.88	Soybeans	281.77	41.13	1.97	204.51	273.69	37.49	99%	100%	90%	93%	87%	30%	98%	98%	85%	90%	16%	-8462%
Johnson County																					
Soils w/ EI > 8.0	100,279	23.84	Soybeans	753.30	112.37	3.03	262.59	135.45	208.73	99%	99%	83%	91%	86%	74%	98%	98%	83%	89%	-13%	-640%
Soils w/ EI < 8.0	109,231	5.20	Soybeans	301.98	44.04	2.03	193.15	146.91	19.96	99%	100%	89%	91%	87%	38%	98%	98%	82%	88%	6%	-19170%
Leavenworth County																					
Soils w/ EI >	141,996	27.83	Soybeans	677.19	107.21	2.28	248.62	158.80	126.35	99%	99%	86%	92%	86%	66%	98%	98%	85%	90%	6%	-1743%
Soils w/ EI <	89,058	4.32	Soybeans	297.59	43.10	1.89	177.76	190.61	31.88	99%	100%	90%	92%	87%	16%	98%	98%	85%	89%	9%	-7405%
Lyon County																					
Soils w/ EI >	299,632	29.23	Soybeans	657.04	99.17	2.94	296.77	163.82	133.50	99%	99%	82%	90%	86%	-	97%	97%	80%	87%	-15%	-152030%
Soils w/ EI <	280,929	5.00	Soybeans	351.54	51.16	2.61	260.65	110.86	6.89	99%	99%	87%	91%	88%	81%	97%	97%	79%	87%	8%	-1494%
Miami County																					
Soils w/ EI >	154,970	16.96	Soybeans	416.13	64.40	2.92	271.78	125.40	103.21	99%	99%	85%	91%	89%	70%	97%	97%	80%	87%	1%	-941%
Soils w/ EI <	150,956	4.73	Soybeans	249.65	37.40	2.24	220.30	145.66	16.07	99%	99%	88%	90%	87%	81%	98%	98%	80%	87%	9%	-1494%
Marshall County																					
Soils w/ EI >	272,246	25.01	Soybeans	829.92	127.34	2.89	259.73	125.25	125.35	99%	99%	83%	90%	83%	19%	98%	98%	81%	87%	-28%	-1555%
Soils w/ EI <	296,414	4.47	Soybeans	271.18	39.45	1.95	201.43	253.14	16.64	99%	100%	90%	93%	88%	15%	98%	98%	84%	89%	9%	-10841%

Table 2.9.3 Nutrient Movement, 24 Years, Pounds per Acre, Average of All Soils **Region 3 (continued)**

			Most Profitable Grain Crop							Switchgrass - Percent Reduction						Black Locust - Percent Reduction					
Soil	Acres	EI	Crop	YON (organic N loss w/ sediment)	YP (P loss w/ sedi-ment)	YAP (solu-ble P loss in runoff)	YNO3 (NO3 loss in surface runoff)	SSFN (mineral N loss in subsur-face flow)	PKRN (mineral N loss in perco-late)	YON	YP	YAP	YNO3	SSFN	PKRN	YON	YP	YAP	YNO3	SSFN	PKRN
Nemaha County																					
Soils w/ EI >	373,281	23.28	Soybeans	903.31	138.17	2.84	224.31	124.54	157.96	99%	99%	84%	90%	84%	27%	98%	98%	82%	88%	-30%	-1363%
Soils w/ EI <	120,091	3.99	Soybeans	318.22	45.91	1.88	193.29	154.96	18.85	99%	100%	90%	92%	86%	45%	98%	98%	84%	89%	-4%	-2460%
Osage County																					
Soils w/ EI >	234,946	25.33	Soybeans	677.93	102.47	2.98	261.26	140.89	152.13	99%	99%	83%	90%	86%	-	98%	98%	81%	87%	-25%	-139458%
Soils w/ EI <	219,974	4.73	Soybeans	296.83	43.60	2.49	256.77	130.16	8.03	99%	99%	87%	91%	88%	81%	97%	97%	80%	87%	10%	-1494%
Pottawatomie County																					
Soils w/ EI >	389,449	29.79	Soybeans	1,202.42	181.88	3.11	282.79	109.41	111.20	99%	99%	82%	90%	84%	-60%	98%	98%	79%	86%	-31%	-24164%
Soils w/ EI <	202,777	4.90	Soybeans	307.89	44.77	1.71	166.49	268.17	39.20	100%	100%	90%	93%	87%	51%	99%	99%	87%	90%	13%	-4965%
Shawnee County																					
Soils w/ EI >	179,672	24.75	Soybeans	749.20	112.57	2.93	251.27	159.04	142.79	99%	99%	84%	91%	85%	-	98%	98%	82%	88%	-7%	-166277%
Soils w/ EI <	99,790	4.80	Soybeans	302.50	43.96	2.10	210.74	198.66	29.56	99%	100%	90%	93%	87%	39%	98%	98%	84%	89%	11%	-6119%
Wabaunsee County																					
Soils w/ EI >	493,913	36.08	Soybeans	1,060.31	156.60	3.18	291.12	118.67	132.62	99%	99%	81%	90%	85%	-	97%	97%	78%	86%	-35%	-187567%
Soils w/ EI <	132,773	4.91	Soybeans	301.77	43.93	2.08	206.59	211.14	25.64	99%	100%	89%	92%	88%	32%	98%	98%	83%	89%	12%	-7908%
Wyandotte County																					
Soils w/ EI >	17,614	27.83	Soybeans	677.19	107.21	2.28	248.62	158.80	126.35	99%	99%	86%	92%	86%	66%	98%	98%	85%	90%	6%	-1743%
Soils w/ EI <	14,579	4.38	Soybeans	282.20	40.81	1.80	173.35	227.88	35.36	99%	100%	91%	93%	88%	28%	98%	98%	86%	90%	13%	-7752%

Table 2.9.3 Nutrient Movement, 24 Years, Pounds per Acre, Average of All Soils

Region 4

			Most Profitable Grain Crop							Switchgrass - Percent Reduction						Black Locust - Percent Reduction					
Soil	Acres	EI	Crop	YON (organic N loss w/ sediment)	YP (P loss w/ sedi-ment)	YAP (solu-ble P loss in runoff)	YNO3 (NO3 loss in surface runoff)	SSFN (mineral N loss in subsur-face flow)	PKRN (mineral N loss in perco-late)	YON	YP	YAP	YNO3	SSFN	PKRN	YON	YP	YAP	YNO3	SSFN	PKRN
Allen County																					
Soils w/ EI >	192,418	27.57	Soybeans	756.77	118.22	4.62	484.66	276.83	233.07	99%	99%	87%	94%	87%	87%	100%	100%	94%	94%	28%	-89%
Soils w/ EI >	99,298	4.73	Soybeans	260.60	40.00	4.09	374.99	225.46	47.18	99%	99%	92%	95%	87%	86%	100%	100%	96%	95%	49%	-328%
Anderson County																					
Soils w/ EI >	146,073	29.01	Soybeans	714.53	113.72	4.31	429.29	298.29	255.44	99%	99%	88%	94%	88%	89%	100%	100%	95%	95%	32%	-288%
Soils w/ EI >	216,852	5.50	Soybeans	279.31	43.44	4.30	411.06	230.66	34.00	99%	99%	92%	95%	87%	89%	100%	100%	96%	95%	52%	-466%
Bourbon County																					
Soils w/ EI >	221,741	24.65	Soybeans	466.78	75.13	4.05	421.12	297.96	274.94	99%	99%	89%	94%	88%	89%	100%	100%	95%	95%	34%	-107%
Soils w/ EI >	124,258	4.73	Soybeans	260.60	40.00	4.09	374.99	225.46	47.18	99%	99%	92%	95%	87%	86%	100%	100%	96%	95%	49%	-328%
Coffey County																					
Soils w/ EI >	294,974	25.31	Soybeans	443.15	71.71	4.40	495.86	300.58	128.77	99%	99%	88%	94%	88%	89%	100%	100%	94%	94%	41%	-363%
Soils w/ EI >	122,626	4.91	Soybeans	294.17	45.66	3.99	361.76	231.63	47.18	99%	99%	93%	95%	88%	86%	100%	100%	96%	96%	50%	-328%
Cherokee County																					
Soils w/ EI >	216,664	26.33	Soybeans	287.35	50.73	3.26	495.04	476.53	227.69	99%	99%	90%	94%	87%	90%	99%	100%	96%	95%	45%	-33%
Soils w/ EI >	88,912	5.10	Soybeans	200.29	32.57	4.54	452.02	196.96	74.57	99%	99%	91%	94%	87%	90%	100%	100%	96%	95%	50%	-790%
Crawford County																					
Soils w/ EI >	183,667	27.10	Soybeans	459.38	74.73	4.02	427.63	329.66	263.40	99%	99%	89%	94%	87%	90%	100%	100%	95%	94%	35%	-188%
Soils w/ EI >	118,084	4.39	Soybeans	226.47	35.83	4.22	408.21	222.66	48.13	99%	99%	92%	95%	86%	63%	100%	100%	96%	95%	45%	-450%
Labette County																					
Soils w/ EI >	297,431	25.97	Soybeans	343.91	57.81	3.95	426.63	340.56	274.60	99%	99%	90%	94%	88%	91%	100%	100%	96%	95%	41%	-80%
Soils w/ EI >	94,031	32.91	Soybeans	237.01	37.45	4.58	439.03	173.38	59.68	99%	99%	91%	95%	87%	88%	100%	100%	96%	95%	48%	-486%
Linn County																					
Soils w/ EI >	317,433	315.64	Soybeans	621.55	98.12	4.51	438.45	264.62	211.22	99%	99%	89%	94%	88%	89%	100%	100%	95%	95%	37%	-251%
Soils w/ EI >	66,432	37.04	Soybeans	207.91	33.37	3.66	330.56	252.43	59.47	99%	100%	93%	95%	87%	90%	100%	100%	97%	96%	54%	-400%
Montgomery County																					
Soils w/ EI >	318,589	36.87	Soybeans	571.55	93.83	4.38	450.31	347.65	275.46	99%	99%	88%	94%	87%	89%	100%	100%	95%	94%	35%	-26%
Soils w/ EI >	109,949	5.16	Soybeans	259.59	39.94	3.89	342.52	221.27	55.04	99%	99%	92%	94%	86%	86%	100%	100%	96%	95%	48%	-328%
Neosho County																					
Soils w/ EI >	233,470	29.65	Soybeans	440.44	72.33	4.13	442.22	335.61	272.12	99%	99%	89%	94%	88%	90%	100%	100%	95%	95%	39%	-58%
Soils w/ EI >	116,878	5.42	Soybeans	275.29	42.73	4.16	385.08	229.04	58.11	99%	99%	92%	95%	86%	88%	100%	100%	96%	95%	49%	-279%
Wilson County																					
Soils w/ EI >	300,681	32.78	Soybeans	626.31	100.66	4.43	446.92	321.16	259.80	99%	99%	87%	94%	87%	89%	100%	100%	94%	94%	33%	-66%
Soils w/ EI >	98,261	4.88	Soybeans	255.78	39.11	3.85	344.81	215.20	62.32	99%	99%	92%	95%	86%	83%	100%	100%	96%	95%	41%	-341%
Woodson County																					
Soils w/ EI >	238,070	30.32	Soybeans	536.30	86.52	4.45	451.57	311.64	227.57	99%	99%	87%	93%	87%	89%	100%	100%	94%	94%	38%	-189%
Soils w/ EI >	91,100	4.22	Soybeans	235.57	36.78	3.90	358.99	237.88	47.97	99%	100%	93%	95%	87%	90%	100%	100%	97%	96%	51%	-318%

Table 2.9.3 Nutrient Movement, 24 Years, Pounds per Acre, Average of All Soils

Region 5

			Most Profitable Grain Crop							**Switchgrass - Percent Reduction**						**Black Locust - Percent Reduction**					
Soil	**Acres**	**EI**	**Crop**	**YON** (organic N loss w/ sediment)	**YP** (P loss w/ sedi-ment)	**YAP** (solu-ble P loss in runoff)	**YNO3** (NO3 loss in surface runoff)	**SSFN** (mineral N loss in subsur-face flow)	**PKRN** (mineral N loss in perco-late)	**YON**	**YP**	**YAP**	**YNO3**	**SSFN**	**PKRN**	**YON**	**YP**	**YAP**	**YNO3**	**SSFN**	**PKRN**
Butler County																					
Soils w/ EI >	610,141	36.29	Wheat	403.54	65.62	0.51	500.31	206.63	82.60	97%	98%	73%	92%	94%	92%	99%	99%	94%	95%	56%	-54%
Soils w/ EI >	417,415	3.43	Wheat	132.73	22.38	0.65	255.63	202.18	10.21	97%	98%	89%	91%	94%	100%	100%	100%	99%	97%	67%	77%
Cowley County																					
Soils w/ EI >	530,156	31.04	Wheat	332.35	54.62	0.64	393.62	345.73	96.93	97%	98%	86%	91%	93%	95%	99%	100%	98%	96%	62%	32%
Soils w/ EI >	228,196	3.18	Wheat	104.83	18.14	0.91	243.40	348.52	54.92	98%	99%	90%	92%	94%	100%	100%	100%	99%	97%	67%	68%
Chautauqua County																					
Soils w/ EI >	372,506	36.90	Soybeans	328.73	55.84	1.59	299.89	274.74	134.34	98%	99%	87%	89%	92%	96%	100%	100%	97%	96%	54%	-4%
Soils w/ EI >	71,323	4.40	Wheat	92.90	16.06	0.89	221.90	348.81	11.01	97%	98%	88%	91%	95%	100%	100%	100%	99%	97%	69%	61%
Elk County																					
Soils w/ EI >	446,728	40.06	Soybeans	345.90	58.14	1.97	336.85	252.44	149.90	98%	99%	87%	89%	92%	97%	100%	100%	97%	95%	51%	28%
Soils w/ EI >	52,934	5.10	Wheat	83.09	15.03	0.59	232.16	280.75	11.92	97%	98%	88%	91%	95%	100%	100%	100%	99%	97%	71%	71%
Greenwood County																					
Soils w/ EI >	326,827	33.91	Wheat	340.62	57.80	1.86	351.74	281.00	134.07	98%	99%	87%	89%	92%	97%	99%	100%	97%	95%	52%	40%
Soils w/ EI >	51,067	4.49	Wheat	97.98	17.46	0.46	284.55	272.60	9.86	97%	98%	88%	91%	95%	100%	100%	100%	99%	97%	71%	65%
Harvey County																					
Soils w/ EI >	32,528	14.96	Wheat	158.99	30.18	0.72	190.04	327.59	95.77	98%	99%	92%	91%	93%	99%	100%	100%	99%	97%	70%	80%
Soils w/ EI >	285,234	2.87	Wheat	136.96	22.66	1.38	227.19	267.33	57.58	98%	99%	90%	91%	93%	100%	100%	100%	99%	97%	64%	60%
Sedgwick County																					
Soils w/ EI >	6,522	24.41	Wheat	140.58	27.69	0.58	237.04	266.81	76.61	98%	99%	92%	91%	93%	99%	100%	100%	99%	96%	72%	80%
Soils w/ EI >	161,191	2.83	Soybeans	117.17	19.73	1.21	237.08	368.11	69.72	98%	99%	91%	92%	93%	100%	100%	100%	99%	97%	66%	68%
Sumner County																					
Soils w/ EI >	19,213	42.00	Soybeans	40.13	9.96	0.95	67.62	824.22	187.33	99%	100%	93%	91%	90%	99%	100%	100%	100%	100%	91%	82%
Soils w/ EI >	725,851	3.13	Wheat	102.24	17.69	1.04	266.89	371.01	66.12	98%	99%	91%	92%	94%	99%	100%	100%	99%	97%	68%	67%

Table 2.9.3 Nutrient Movement, 24 Years, Pounds per Acre, Average of All Soils

Region 6

			Most Profitable Grain Crop							**Switchgrass - Percent Reduction**						**Black Locust - Percent Reduction**					
Soil	**Acres**	**EI**	**Crop**	YON (organic N loss w/ sediment)	YP (P loss w/ sedi-ment)	YAP (solu-ble P loss in runoff)	YNO3 (NO3 loss in surface runoff)	SSFN (mineral N loss in subsur-face flow)	PKRN (mineral N loss in perco-late)	YON	YP	YAP	YNO3	SSFN	PKRN	YON	YP	YAP	YNO3	SSFN	PKRN
Barber County																					
Soils w/ EI >	418,980	33.71	Wheat	55.23	11.39	0.61	139.02	313.13	13.16	100%	100%	99%	98%	94%	94%	98%	98%	98%	98%	62%	-1316%
Soils w/ EI <	478,843	2.24	Soybeans	49.73	8.09	1.01	122.49	430.75	13.13	100%	100%	98%	98%	92%	96%	99%	99%	95%	98%	56%	-4437%
Comanche County																					
Soils w/ EI >	302,474	37.10	Soybeans	231.32	41.29	1.14	165.05	302.19	50.79	100%	100%	95%	97%	93%	94%	99%	99%	95%	98%	42%	-1060%
Soils w/ EI <	343,410	2.27	Soybeans	47.18	7.71	0.96	116.93	350.86	12.27	100%	100%	98%	98%	92%	93%	99%	99%	95%	98%	54%	-4032%
Edwards County																					
Soils w/ EI >	52,100	27.20	Soybeans	162.18	30.21	1.25	135.07	322.88	52.09	100%	100%	95%	97%	92%	96%	99%	99%	94%	97%	44%	-144%
Soils w/ EI <	363,504	2.42	Soybeans	43.68	7.16	0.93	133.05	383.34	12.07	100%	100%	98%	98%	92%	96%	98%	98%	95%	98%	53%	-4458%
Harper County																					
Soils w/ EI >	60,334	24.61	Wheat	55.39	11.84	0.55	174.22	314.07	13.76	99%	100%	99%	98%	94%	93%	97%	98%	98%	98%	63%	-1690%
Soils w/ EI <	442,874	2.55	Soybeans	54.10	8.84	0.94	133.79	376.16	12.32	100%	100%	98%	98%	92%	98%	98%	98%	95%	98%	54%	-3825%
Kingman County																					
Soils w/ EI >	72,347	18.60	Soybeans	59.86	13.01	0.51	192.42	299.34	13.56	99%	100%	99%	98%	94%	92%	97%	97%	98%	98%	63%	-1943%
Soils w/ EI <	477,677	2.51	Soybeans	67.11	10.82	1.07	149.87	359.28	13.37	100%	100%	97%	98%	92%	95%	98%	98%	93%	97%	55%	-5638%
Kiowa County																					
Soils w/ EI >	177,773	34.79	Soybeans	234.00	41.85	1.22	168.75	295.53	48.26	100%	100%	94%	97%	93%	94%	98%	98%	93%	97%	41%	-1039%
Soils w/ EI <	334,485	2.34	Soybeans	47.17	7.69	0.95	123.84	371.66	13.77	100%	100%	98%	98%	92%	94%	98%	99%	96%	98%	52%	-2103%
Pawnee County																					
Soils w/ EI >	55,163	21.17	Soybeans	251.44	41.01	1.33	168.62	382.76	36.87	100%	100%	95%	97%	92%	95%	99%	99%	92%	97%	51%	-210%
Soils w/ EI <	415,973	2.29	Soybeans	45.10	7.42	0.77	127.24	339.03	4.14	100%	100%	98%	98%	92%	96%	97%	98%	95%	97%	54%	-5785%
Pratt County																					
Soils w/ EI >	197,331	9.38	Soybeans	55.93	10.73	0.76	86.63	426.34	17.34	100%	100%	99%	99%	93%	97%	100%	100%	99%	99%	63%	-1934%
Soils w/ EI <	309,846	2.17	Soybeans	49.52	8.10	0.98	149.25	480.86	23.37	100%	100%	98%	98%	91%	96%	98%	98%	96%	98%	57%	-4386%
Reno County																					
Soils w/ EI >	106,606	122.43	Soybeans	74.59	13.43	0.74	152.59	329.43	13.54	99%	100%	98%	97%	93%	99%	97%	97%	96%	97%	61%	-1776%
Soils w/ EI <	828,374	2.62	Soybeans	47.79	7.92	0.89	124.63	394.72	15.36	100%	100%	99%	98%	92%	94%	98%	99%	96%	98%	54%	-2436%
Stafford County																					
Soils w/ EI > 8.0	48,310	9.33	Soybeans	58.85	11.03	0.78	86.78	478.94	24.91	100%	100%	99%	99%	92%	99%	100%	100%	99%	99%	65%	-2216%
Soils w/ EI < 8.0	499,790	2.78	Soybeans	53.25	8.89	1.11	164.20	417.98	11.52	100%	100%	98%	98%	92%	93%	98%	98%	94%	97%	54%	-4948%

5) Reduced Carbon Emissions and Carbon Sequestering

Substituting biomass fuels for conventional fuels in power generation can reduce net emissions of carbon dioxide, a principal greenhouse gas. By capturing and storing solar energy greater than the fossil fuel inputs required to produce, deliver, and process them, biomass fuels recycle atmospheric carbon; thus reducing the need for fossil fuel, the combustion of which increases net atmospheric carbon.

Table 2.9.4 Switchgrass Embodied Energy and Energy Profit Ratio (edge of field) **Region 1**

Land Area			**Embodied Energy (Ave)**						**Energy Profit Ratio**		
Soil	**Area (acres)**		Equip-ment (MMBtu/ ton)	Fuel (MMBtu/ton)	Ferti-lizer (MMBtu/ton)	Chem-icals & Materials (MMBtu / ton)	Labor (MMBtu/ton)	Total (MMBtu/ton)	**Max**	**Min**	**Ave**
Barton County	490,602	CRP Average	0.0625	0.4992	0.7788	0.0024	0.0006	1.3435	30.57	0.82	12.74
		All Other Average	0.0493	0.3875	0.8061	0.0023	0.0005	1.2457	31.06	0.88	14.13
Ellis County	618,873	CRP Average	0.0714	0.5704	0.8411	0.0025	0.0007	1.4860	27.60	0.74	11.37
		All Other Average	0.0492	0.3876	0.8016	0.0023	0.0005	1.2413	31.34	0.88	14.13
Ellsworth County	566,098	CRP Average	0.0582	0.4634	0.7797	0.0024	0.0006	1.3043	29.36	0.89	13.01
		All Other Average	0.0485	0.3821	0.7409	0.0023	0.0005	1.1743	33.96	0.91	15.10
Jewell County	609,978	CRP Average	0.0701	0.5608	0.8237	0.0025	0.0007	1.4578	29.22	0.74	11.84
		All Other Average	0.0496	0.3899	0.7975	0.0023	0.0005	1.2398	31.97	0.90	14.15
Lincoln County	519,823	CRP Average	0.0650	0.5211	0.7301	0.0025	0.0006	1.3193	29.03	0.88	12.60
		All Other Average	0.0482	0.3792	0.7610	0.0023	0.0005	1.1912	33.03	0.91	14.68
Mitchell County	549,218	CRP Average	0.0713	0.5727	0.7672	0.0025	0.0007	1.4144	29.64	0.75	12.13
		All Other Average	0.0491	0.3866	0.7767	0.0023	0.0005	1.2151	31.72	0.90	14.40
Osborne County	789,455	CRP Average	0.0794	0.6381	0.8169	0.0026	0.0008	1.5376	27.96	0.61	11.21
		All Other Average	0.0500	0.3934	0.7940	0.0023	0.0005	1.2402	31.45	0.89	14.13
Phillips County	563,259	CRP Average	0.0706	0.5644	0.8463	0.0025	0.0007	1.4845	28.64	0.72	11.65
		All Other Average	0.0488	0.3840	0.8154	0.0023	0.0005	1.2511	30.79	0.91	13.89
Rice County	485,061	CRP Average	0.0587	0.4675	0.7872	0.0024	0.0006	1.3164	29.41	0.88	12.93
		All Other Average	0.0494	0.3877	0.8204	0.0023	0.0005	1.2602	30.59	0.88	13.92
Rush County	398,065	CRP Average	0.0636	0.5056	0.8299	0.0024	0.0006	1.4021	29.59	0.84	12.16
		All Other Average	0.0491	0.3870	0.7967	0.0023	0.0005	1.2356	31.02	0.89	14.24
Rooks County	583,789	CRP Average	0.0698	0.5582	0.8345	0.0025	0.0007	1.4656	28.76	0.73	11.70
		All Other Average	0.0490	0.3858	0.7974	0.0023	0.0005	1.2351	31.55	0.90	14.21
Russel County	497,967	CRP Average	0.0695	0.5583	0.7613	0.0025	0.0007	1.3923	28.99	0.78	12.27
		All Other Average	0.0494	0.3890	0.7920	0.0023	0.0005	1.2332	31.57	0.89	14.21
Smith County	603,931	CRP Average	0.0727	0.5830	0.8307	0.0025	0.0007	1.4896	28.84	0.71	11.54
		All Other Average	0.0498	0.3920	0.8061	0.0023	0.0005	1.2508	31.01	0.90	13.92
Region 1 Total	7,276,121										
		CRP Regional Average	**0.0679**	**0.5433**	**0.8021**	**0.0025**	**0.0007**	**1.4164**	**29.05**	**0.78**	**12.09**
		All Other Regional Average	**0.0492**	**0.3871**	**0.7927**	**0.0023**	**0.0005**	**1.2318**	**31.62**	**0.90**	**14.24**

Notes: Averages not area weighted.

Table 2.9.4 Switchgrass Embodied Energy and Energy Profit Ratio (edge of field) **Region 2**

Land Area			Embodied Energy (Ave)						Energy Profit Ratio		
Soil	Area (acres)		Equip-ment (MMBtu/ ton)	Fuel (MMBtu/ton)	Ferti-lizer (MMBtu/ton)	Chem-icals & Materials (MMBtu / ton)	Labor (MMBtu/ton)	Total (MMBtu/ton)	Max	Min	Ave
Cloud County	387,159	CRP Average	0.0423	0.3307	0.8308	0.0023	0.0004	1.2065	26.15	1.96	13.38
		All Other Average	0.0331	0.2545	0.8568	0.0022	0.0003	1.1470	26.62	3.55	14.28
Chase County	682,339	CRP Average	0.0426	0.3324	0.8150	0.0023	0.0004	1.1927	26.63	2.34	13.66
		All Other Average	0.0316	0.2438	0.7953	0.0022	0.0003	1.0732	31.69	3.53	15.89
Clay County	398,157	CRP Average	0.0477	0.3753	0.7809	0.0023	0.0004	1.2068	27.03	1.40	13.39
		All Other Average	0.0330	0.2537	0.8357	0.0022	0.0003	1.1249	26.76	3.60	14.67
Dickinson County	520,082	CRP Average	0.0528	0.4172	0.7889	0.0024	0.0005	1.2618	27.25	1.21	12.93
		All Other Average	0.0330	0.2536	0.8451	0.0022	0.0003	1.1342	26.67	3.50	14.46
Geary County	312,921	CRP Average	0.0437	0.3418	0.8150	0.0023	0.0004	1.2033	27.77	2.28	13.63
		All Other Average	0.0329	0.2535	0.8398	0.0022	0.0003	1.1288	27.92	3.49	14.74
Marion County	602,255	CRP Average	0.0489	0.3845	0.7766	0.0023	0.0005	1.2128	27.64	1.35	13.39
		All Other Average	0.0326	0.2510	0.8067	0.0022	0.0003	1.0928	29.37	3.44	15.36
McPherson County	582,146	CRP Average	0.0406	0.3163	0.8371	0.0023	0.0004	1.1967	26.82	1.94	13.48
		All Other Average	0.0330	0.2540	0.8562	0.0022	0.0003	1.1458	26.78	3.50	14.33
Morris County	531,858	CRP Average	0.0478	0.3751	0.7790	0.0023	0.0004	1.2047	27.39	1.56	13.47
		All Other Average	0.0314	0.2420	0.8183	0.0022	0.0003	1.0943	29.40	3.58	15.39
Ottawa County	509,087	CRP Average	0.0449	0.3521	0.8100	0.0023	0.0004	1.2096	27.22	1.50	13.38
		All Other Average	0.0332	0.2551	0.8527	0.0022	0.0003	1.1435	26.76	3.53	14.36
Riley County	429,743	CRP Average	0.0440	0.3440	0.8010	0.0023	0.0004	1.1917	27.25	1.94	13.72
		All Other Average	0.0321	0.2476	0.8158	0.0022	0.0003	1.0979	30.70	3.58	15.91
Republic County	441,520	CRP Average	0.0443	0.3473	0.8290	0.0023	0.0004	1.2232	25.73	1.90	13.21
		All Other Average	0.0331	0.2541	0.8530	0.0022	0.0003	1.1427	26.75	3.55	14.35
Saline County	506,962	CRP Average	0.0435	0.3401	0.8140	0.0023	0.0004	1.2003	27.00	1.61	13.43
		All Other Average	0.0329	0.2533	0.8403	0.0022	0.0003	1.1291	27.46	3.53	14.58
Washington County	552,767	CRP Average	0.0477	0.3761	0.7625	0.0023	0.0005	1.1891	27.68	1.46	13.79
		All Other Average	0.0327	0.2521	0.8053	0.0022	0.0003	1.0926	29.77	3.58	15.91
Region 2 Total	6,456,996										
		CRP Regional Average	**0.04545**	**0.35637**	**0.80307**	**0.002314**	**0.00043**	**1.20763**	**27.04**	**1.73**	**13.45**
		All Other Regional Average	**0.03267**	**0.25141**	**0.83237**	**0.002221**	**0.0003**	**1.11898**	**28.20**	**3.53**	**14.94**

Notes: Averages not area weighted.

Table 2.9.4 Switchgrass Embodied Energy and Energy Profit Ratio (edge of field) **Region 3**

Land Area			**Embodied Energy (Ave)**						**Energy Profit Ratio**		
Soil	**Area (acres)**		Equip-ment (MMBtu/ ton)	Fuel (MMBtu/ton)	Ferti-lizer (MMBtu/ton)	Chem-icals & Materials (MMBtu / ton)	Labor (MMBtu/ton)	Total (MMBtu/ton)	**Max**	**Min**	**Ave**
Atchison County	296,204	CRP Average	0.0371	0.2886	0.8501	0.0023	0.0003	1.1783	29.06	1.50	13.75
		All Other Average	0.0283	0.2181	0.7838	0.0022	0.0003	1.0326	33.77	2.83	16.85
Brown County	800,752	CRP Average	0.0505	0.3997	0.7850	0.0024	0.0005	1.2380	30.60	0.82	13.19
		All Other Average	0.0285	0.2196	0.7706	0.0022	0.0003	1.0211	33.09	2.91	16.75
Douglas County	253,444	CRP Average	0.0439	0.3445	0.8214	0.0023	0.0004	1.2126	29.21	1.32	13.41
		All Other Average	0.0277	0.2131	0.8048	0.0022	0.0003	1.0481	32.27	2.85	16.39
Doniphan County	241,112	CRP Average	0.0402	0.3156	0.7980	0.0023	0.0004	1.1565	28.94	1.71	14.21
		All Other Average	0.0288	0.2215	0.8001	0.0022	0.0003	1.0529	33.38	2.74	16.48
Franklin County	391,334	CRP Average	0.0461	0.3610	0.8698	0.0023	0.0004	1.2797	28.07	0.88	12.54
		All Other Average	0.0277	0.2130	0.8376	0.0022	0.0003	1.0808	29.09	2.73	15.27
Jackson County	440,903	CRP Average	0.0425	0.3335	0.7960	0.0023	0.0004	1.1747	29.96	1.29	13.83
		All Other Average	0.0279	0.2144	0.7467	0.0022	0.0003	0.9914	36.17	3.00	17.75
Jefferson County	337,434	CRP Average	0.0402	0.3151	0.7953	0.0023	0.0004	1.1533	29.88	1.80	14.24
		All Other Average	0.0287	0.2207	0.8034	0.0022	0.0003	1.0553	33.01	3.04	16.57
Johnson County	209,510	CRP Average	0.0447	0.3508	0.7902	0.0023	0.0004	1.1884	29.69	1.27	13.63
		All Other Average	0.0272	0.2092	0.7954	0.0022	0.0003	1.0342	32.36	2.90	16.54
Leavenworth County	231,054	CRP Average	0.0383	0.2994	0.8179	0.0023	0.0004	1.1582	29.15	1.81	14.12
		All Other Average	0.0286	0.2200	0.8022	0.0022	0.0003	1.0533	32.86	2.69	16.31
Lyon County	580,562	CRP Average	0.0441	0.3452	0.8136	0.0023	0.0004	1.2056	28.98	1.17	13.26
		All Other Average	0.0274	0.2109	0.8158	0.0022	0.0003	1.0565	29.14	2.92	15.59
Miami County	305,926	CRP Average	0.0361	0.2787	0.8609	0.0022	0.0003	1.1782	28.95	1.45	13.61
		All Other Average	0.0275	0.2112	0.8408	0.0022	0.0003	1.0819	29.64	2.76	15.34
Marshall County	568,660	CRP Average	0.0424	0.3315	0.7882	0.0023	0.0004	1.1647	29.96	1.63	14.00
		All Other Average	0.0289	0.2221	0.7846	0.0022	0.0003	1.0381	34.11	2.91	16.75
Nemaha County	493,372	CRP Average	0.0421	0.3293	0.7905	0.0023	0.0004	1.1645	30.09	1.25	13.98
		All Other Average	0.0274	0.2108	0.7265	0.0022	0.0003	0.9671	37.09	2.79	18.21
Osage County	454,920	CRP Average	0.0430	0.3357	0.8141	0.0023	0.0004	1.1955	29.49	1.06	13.35
		All Other Average	0.0270	0.2082	0.7911	0.0022	0.0002	1.0289	33.37	2.97	16.84
Pottawatomie County	592,226	CRP Average	0.0407	0.3183	0.7936	0.0023	0.0004	1.1553	29.38	1.76	14.04
		All Other Average	0.0289	0.2224	0.8026	0.0022	0.0003	1.0563	32.08	2.77	16.16
Shawnee County	279,462	CRP Average	0.0421	0.3306	0.7814	0.0023	0.0004	1.1568	29.61	1.64	14.06
		All Other Average	0.0286	0.2197	0.7902	0.0022	0.0003	1.0409	32.37	2.83	16.40
Wabaunsee County	626,686	CRP Average	0.0428	0.3352	0.7764	0.0023	0.0004	1.1572	29.70	1.31	13.85
		All Other Average	0.0282	0.2170	0.8252	0.0022	0.0003	1.0728	29.52	2.81	15.46
Wyandotte County	32,194	CRP Average	0.0383	0.2994	0.8179	0.0023	0.0004	1.1582	29.15	1.81	14.12
		All Other Average	0.0288	0.2215	0.8070	0.0022	0.0003	1.0598	34.10	2.47	16.54
Region 3 Total	7,135,756										
		CRP Regional Average	**0.0419**	**0.3285**	**0.8089**	**0.0023**	**0.0004**	**1.1820**	**29.44**	**1.41**	**13.73**
		All Other Regional Average	**0.0281**	**0.2163**	**0.7960**	**0.0022**	**0.0003**	**1.0429**	**32.63**	**2.83**	**16.46**

Notes: Averages not area weighted.

Table 2.9.4 Switchgrass Embodied Energy and Energy Profit Ratio (edge of field) **Region 4**

Land Area			**Embodied Energy (Ave)**						**Energy Profit Ratio**		
Soil	**Area (acres)**		Equip-ment (MMBtu/ ton)	Fuel (MMBtu/ton)	Ferti-lizer (MMBtu/ton)	Chem-icals & Materials (MMBtu / ton)	Labor (MMBtu/ton)	Total (MMBtu/ton)	**Max**	**Min**	**Ave**
Allen County	291,717	CRP Average	0.0378	0.2953	0.8341	0.0023	0.0004	1.1698	24.41	2.69	13.75
		All Other Average	0.0224	0.1721	0.8527	0.0022	0.0002	1.0496	25.97	5.25	15.56
Anderson County	362,926	CRP Average	0.0326	0.2520	0.8614	0.0022	0.0003	1.1486	24.45	3.21	14.01
		All Other Average	0.0217	0.1664	0.8617	0.0021	0.0002	1.0522	25.62	5.23	15.49
Bourbon County	345,999	CRP Average	0.0361	0.2815	0.8564	0.0022	0.0003	1.1767	23.20	2.87	13.62
		All Other Average	0.0224	0.1721	0.8527	0.0022	0.0002	1.0496	25.97	5.25	15.56
Coffey County	417,600	CRP Average	0.0336	0.2611	0.8650	0.0022	0.0003	1.1622	24.50	3.50	13.92
		All Other Average	0.0217	0.1663	0.8547	0.0021	0.0002	1.0450	25.45	5.66	15.59
Cherokee County	305,576	CRP Average	0.0348	0.2716	0.9145	0.0022	0.0003	1.2234	21.49	3.79	13.14
		All Other Average	0.0233	0.1791	0.8880	0.0022	0.0002	1.0929	25.16	5.53	15.04
Crawford County	301,752	CRP Average	0.0368	0.2869	0.8652	0.0023	0.0003	1.1915	23.52	2.60	13.46
		All Other Average	0.0237	0.1818	0.8625	0.0022	0.0002	1.0703	25.26	5.27	15.22
Labette County	391,461	CRP Average	0.0346	0.2698	0.8837	0.0022	0.0003	1.1907	22.67	3.29	13.49
		All Other Average	0.0239	0.1832	0.8573	0.0022	0.0002	1.0667	26.65	5.23	15.41
Linn County	289,834	CRP Average	0.0326	0.2520	0.8678	0.0022	0.0003	1.1549	24.16	3.17	13.92
		All Other Average	0.0225	0.1727	0.8793	0.0022	0.0002	1.0768	25.47	4.85	15.17
Montgomery County	428,538	CRP Average	0.0364	0.2826	0.8692	0.0022	0.0003	1.1908	23.51	2.32	13.41
		All Other Average	0.0230	0.1762	0.8533	0.0022	0.0002	1.0549	26.46	4.69	15.52
Neosho County	350,348	CRP Average	0.0353	0.2734	0.8660	0.0022	0.0003	1.1773	23.78	2.47	13.60
		All Other Average	0.0231	0.1775	0.8603	0.0022	0.0002	1.0634	26.34	4.95	15.37
Wilson County	398,942	CRP Average	0.0377	0.2944	0.8586	0.0023	0.0004	1.1934	23.80	2.63	13.46
		All Other Average	0.0239	0.1836	0.8279	0.0022	0.0002	1.0378	26.67	4.41	15.69
Woodson County	329,169	CRP Average	0.0366	0.2852	0.8576	0.0023	0.0003	1.1821	23.86	2.91	13.63
		All Other Average	0.0224	0.1714	0.8628	0.0021	0.0002	1.0589	25.50	5.50	15.42
Region 4 Total	4,213,861										
		CRP Regional Average	**0.0354**	**0.2755**	**0.8666**	**0.0022**	**0.0003**	**1.1801**	**23.61**	**2.96**	**13.62**
		All Other Regional Average	**0.0228**	**0.1752**	**0.8594**	**0.0022**	**0.0002**	**1.0598**	**25.88**	**5.15**	**15.42**

Notes: Averages not area weighted.

Table 2.9.4 Switchgrass Embodied Energy and Energy Profit Ratio (edge of field) **Region 5**

Land Area			**Embodied Energy (Ave)**						**Energy Profit Ratio**		
Soil	**Area (acres)**		Equip-ment (MMBtu/ ton)	Fuel (MMBtu/ton)	Ferti-lizer (MMBtu/ton)	Chem-icals & Materials (MMBtu / ton)	Labor (MMBtu/ton)	Total (MMBtu/ton)	**Max**	**Min**	**Ave**
Butler County	1,027,556	CRP Average	0.0383	0.2984	0.7585	0.0023	0.0004	1.0979	24.40	6.43	14.85
		All Other Average	0.0277	0.2125	0.7907	0.0022	0.0003	1.0334	27.94	8.31	16.26
Cowley County	758,352	CRP Average	0.0375	0.2915	0.8295	0.0023	0.0003	1.1611	22.31	6.28	13.93
		All Other Average	0.0279	0.2142	0.8211	0.0022	0.0003	1.0656	25.79	8.04	15.67
Chautauqua County	443,829	CRP Average	0.0400	0.3115	0.8265	0.0023	0.0004	1.1807	22.31	5.16	13.66
		All Other Average	0.0277	0.2127	0.8086	0.0022	0.0003	1.0514	24.86	8.30	15.75
Elk County	499,661	CRP Average	0.0407	0.3167	0.8118	0.0023	0.0004	1.1718	22.57	5.02	13.77
		All Other Average	0.0269	0.2067	0.8215	0.0022	0.0002	1.0576	25.91	8.28	15.84
Greenwood County	377,894	CRP Average	0.0397	0.3089	0.8320	0.0023	0.0004	1.1832	22.16	5.22	13.63
		All Other Average	0.0268	0.2062	0.7899	0.0022	0.0002	1.0254	28.72	8.32	16.56
Harvey County	317,762	CRP Average	0.0324	0.2493	0.8760	0.0022	0.0003	1.1602	21.94	7.11	13.92
		All Other Average	0.0288	0.2208	0.8340	0.0022	0.0003	1.0860	24.87	7.92	15.25
Sedgwick County	167,712	CRP Average	0.0312	0.2401	0.8927	0.0022	0.0003	1.1665	21.48	7.20	13.89
		All Other Average	0.0282	0.2168	0.8456	0.0022	0.0003	1.0932	24.24	7.91	15.13
Sumner County	745,064	CRP Average	0.0304	0.2335	0.9835	0.0022	0.0003	1.2499	19.05	6.73	12.86
		All Other Average	0.0283	0.2170	0.8488	0.0022	0.0003	1.0966	24.55	7.93	15.16
Region 5 Total	4,337,831										
		CRP Regional Average	**0.03628**	**0.28125**	**0.85131**	**0.00225**	**0.00034**	**1.17142**	**22.03**	**6.14**	**13.82**
		All Other Regional Average	**0.02778**	**0.21337**	**0.82004**	**0.00219**	**0.00026**	**1.06364**	**25.86**	**8.13**	**15.70**

Notes: Averages not area weighted.

Table 2.9.4 Switchgrass Embodied Energy and Energy Profit Ratio (edge of field) **Region 6**

Land Area			**Embodied Energy (Ave)**						**Energy Profit Ratio**		
Soil	**Area (acres)**		Equip-ment (MMBtu/ ton)	Fuel (MMBtu/ton)	Ferti-lizer (MMBtu/ton)	Chem-icals & Materials (MMBtu/ton)	Labor (MMBtu/ton)	Total (MMBtu/ton)	**Max**	**Min**	**Ave**
Barber County	897,822	CRP Average	0.0316	0.2427	0.9335	0.0022	0.0003	1.2103	22.50	6.27	13.40
		All Other Average	0.0293	0.2248	0.8858	0.0022	0.0003	1.1423	22.26	7.16	14.31
Comanche	645,885	CRP Average	0.0371	0.2883	0.8875	0.0023	0.0003	1.2155	22.42	5.40	13.29
		All Other Average	0.0292	0.2240	0.8700	0.0022	0.0003	1.1255	22.58	7.13	14.52
Edwards County	415,605	CRP Average	0.0410	0.3215	0.9295	0.0023	0.0004	1.2946	21.34	4.76	12.54
		All Other Average	0.0301	0.2313	0.8792	0.0022	0.0003	1.1431	22.37	6.91	14.27
Harper County	503,207	CRP Average	0.0315	0.2417	0.9447	0.0022	0.0003	1.2204	21.66	6.17	13.28
		All Other Average	0.0300	0.2310	0.8708	0.0022	0.0003	1.1344	22.73	6.87	14.45
Kingman County	550,024	CRP Average	0.0300	0.2300	0.9510	0.0022	0.0003	1.2135	21.79	6.44	13.43
		All Other Average	0.0303	0.2332	0.8761	0.0022	0.0003	1.1421	22.51	6.81	14.29
Kiowa County	512,259	CRP Average	0.0405	0.3172	0.8889	0.0023	0.0004	1.2493	22.25	4.85	12.94
		All Other Average	0.0298	0.2289	0.8616	0.0022	0.0003	1.1228	22.95	7.09	14.59
Pawnee County	471,135	CRP Average	0.0386	0.2999	0.8996	0.0023	0.0004	1.2406	20.80	4.54	12.88
		All Other Average	0.0299	0.2294	0.8592	0.0022	0.0003	1.1209	22.92	6.97	14.56
Pratt County	507,177	CRP Average	0.0310	0.2378	0.9521	0.0022	0.0003	1.2234	21.98	6.08	13.23
		All Other Average	0.0303	0.2330	0.8966	0.0022	0.0003	1.1624	22.10	7.01	14.02
Reno County	934,980	CRP Average	0.0314	0.2415	0.9215	0.0022	0.0003	1.1969	22.28	6.01	13.59
		All Other Average	0.0298	0.2285	0.8787	0.0022	0.0003	1.1394	22.62	7.02	14.38
Stafford County	548,100	CRP Average	0.0310	0.2376	0.9406	0.0022	0.0003	1.2117	22.60	5.96	13.46
		All Other Average	0.0304	0.2336	0.9068	0.0022	0.0003	1.1733	21.87	6.81	13.85
Region 6 Total	5,986,194										
		CRP Regional Average	**0.0344**	**0.2658**	**0.9249**	**0.0022**	**0.0003**	**1.2276**	**21.96**	**5.65**	**13.20**
		All Other Regional Average	**0.0299**	**0.2298**	**0.8785**	**0.0022**	**0.0003**	**1.1406**	**22.49**	**6.98**	**14.32**

Notes: Averages not area weighted.

Table 2.9.5 Black Locust Embodied Energy and Energy Profit Ratio (edge of field) **Region 1**

Land Area			**Embodied Energy (Ave)**						**Energy Profit Ratio**		
Soil	**Area (acres)**		Equip-ment (MMBtu/ ton)	Fuel (MMBtu/ton)	Ferti-lizer (MMBtu/ton)	Chem-icals & Materials (MMBtu / ton)	Labor (MMBtu/ton)	Total (MMBtu/ton)	**Max**	**Min**	**Ave**
Barton County	490,602	CRP Average	0.0876	0.5146	0.0000	0.0040	0.0003	0.6065	37.18	19.46	30.46
		All Other Average	0.0813	0.4777	0.0000	0.0037	0.0003	0.5631	39.82	21.36	32.71
Ellis County	618,873	CRP Average	0.0969	0.5690	0.0000	0.0045	0.0003	0.6706	35.12	17.77	28.61
		All Other Average	0.0814	0.4779	0.0000	0.0037	0.0003	0.5633	39.87	21.32	32.72
Ellsworth County	566,098	CRP Average	0.0851	0.4999	0.0000	0.0039	0.0003	0.5892	38.41	20.20	31.47
		All Other Average	0.0804	0.4719	0.0000	0.0037	0.0003	0.5563	40.30	21.66	33.08
Jewell County	609,978	CRP Average	0.1016	0.5969	0.0000	0.0047	0.0004	0.7036	33.57	16.69	27.27
		All Other Average	0.0804	0.4719	0.0000	0.0037	0.0003	0.5563	40.35	21.63	33.10
Lincoln County	519,823	CRP Average	0.0859	0.5044	0.0000	0.0040	0.0003	0.5946	38.12	19.85	31.18
		All Other Average	0.0798	0.4685	0.0000	0.0037	0.0003	0.5523	40.63	21.84	33.35
Mitchell County	549,218	CRP Average	0.1007	0.5916	0.0000	0.0046	0.0004	0.6973	34.25	16.89	27.76
		All Other Average	0.0800	0.4698	0.0000	0.0037	0.0003	0.5538	40.52	21.75	33.25
Osborne County	789,455	CRP Average	0.1122	0.6588	0.0000	0.0052	0.0004	0.7765	31.16	14.76	25.12
		All Other Average	0.0809	0.4749	0.0000	0.0037	0.0003	0.5598	40.11	21.47	32.91
Phillips County	563,259	CRP Average	0.1001	0.5877	0.0000	0.0046	0.0004	0.6928	33.99	16.96	27.64
		All Other Average	0.0802	0.4711	0.0000	0.0037	0.0003	0.5553	40.34	21.72	33.13
Rice County	485,061	CRP Average	0.0846	0.4968	0.0000	0.0039	0.0003	0.5855	38.51	20.41	31.59
		All Other Average	0.0815	0.4789	0.0000	0.0038	0.0003	0.5645	39.66	21.31	32.60
Rush County	398,065	CRP Average	0.0937	0.5501	0.0000	0.0043	0.0003	0.6484	36.46	18.53	29.69
		All Other Average	0.0815	0.4786	0.0000	0.0038	0.0003	0.5641	39.82	21.30	32.68
Rooks County	583,789	CRP Average	0.0975	0.5725	0.0000	0.0045	0.0003	0.6749	34.85	17.59	28.37
		All Other Average	0.0808	0.4747	0.0000	0.0037	0.0003	0.5595	40.13	21.49	32.94
Russel County	497,967	CRP Average	0.0986	0.5790	0.0000	0.0045	0.0003	0.6824	34.40	17.21	27.97
		All Other Average	0.0806	0.4735	0.0000	0.0037	0.0003	0.5582	40.22	21.55	33.01
Smith County	603,931	CRP Average	0.1001	0.5877	0.0000	0.0046	0.0004	0.6928	33.99	16.96	27.64
		All Other Average	0.0805	0.4729	0.0000	0.0037	0.0003	0.5574	40.26	21.58	33.04
Region 1 Total	**7,276,121**										
		CRP Regional Average	**0.0957**	**0.5622**	**0.0000**	**0.0044**	**0.0003**	**0.6627**	**35.39**	**17.94**	**28.83**
		All Other Regional Average	**0.0807**	**0.4740**	**0.0000**	**0.0037**	**0.0003**	**0.5588**	**40.16**	**21.54**	**32.96**

Notes: Averages not area weighted.

Table 2.9.5 Black Locust Embodied Energy and Energy Profit Ratio (edge of field) Region 2

Land Area			Embodied Energy (Ave)						Energy Profit Ratio		
Soil	Area (acres)		Equip-ment (MMBtu/ ton)	Fuel (MMBtu/ton)	Ferti-lizer (MMBtu/ton)	Chem-icals & Materials (MMBtu / ton)	Labor (MMBtu/ton)	Total (MMBtu/ton)	Max	Min	Ave
Cloud County	387,159	CRP Average	0.0693	0.4067	0.0000	0.0032	0.0002	0.4794	46.35	23.76	38.50
		All Other Average	0.0655	0.3846	0.0000	0.0030	0.0002	0.4534	48.51	25.28	40.45
Chase County	682,339	CRP Average	0.0708	0.4156	0.0000	0.0033	0.0002	0.4899	45.63	22.86	37.75
		All Other Average	0.0658	0.3866	0.0000	0.0030	0.0002	0.4556	48.28	25.13	40.24
Clay County	398,157	CRP Average	0.0704	0.4136	0.0000	0.0032	0.0002	0.4875	45.79	23.19	37.97
		All Other Average	0.0658	0.3863	0.0000	0.0030	0.0002	0.4554	48.29	25.26	40.30
Dickinson County	520,082	CRP Average	0.0874	0.5130	0.0233	0.0040	0.0003	0.6280	40.22	19.92	33.26
		All Other Average	0.0657	0.3860	0.0000	0.0030	0.0002	0.4550	48.32	25.15	40.26
Geary County	312,921	CRP Average	0.0825	0.4843	0.0204	0.0038	0.0003	0.5912	42.62	21.27	35.28
		All Other Average	0.0662	0.3885	0.0000	0.0030	0.0002	0.4580	47.99	25.05	40.03
Marion County	602,255	CRP Average	0.0729	0.4283	0.0000	0.0034	0.0003	0.5048	44.39	22.06	36.69
		All Other Average	0.0660	0.3874	0.0000	0.0030	0.0002	0.4566	48.29	25.07	40.22
McPherson County	582,146	CRP Average	0.0684	0.4019	0.0000	0.0032	0.0002	0.4738	46.90	24.02	38.95
		All Other Average	0.0659	0.3868	0.0000	0.0030	0.0002	0.4560	48.31	25.07	40.21
Morris County	531,858	CRP Average	0.0721	0.4237	0.0000	0.0033	0.0003	0.4995	44.81	22.29	37.03
		All Other Average	0.0646	0.3794	0.0000	0.0030	0.0002	0.4472	49.03	25.74	40.90
Ottawa County	509,087	CRP Average	0.0698	0.4099	0.0000	0.0032	0.0002	0.4832	46.25	23.50	38.35
		All Other Average	0.0660	0.3875	0.0000	0.0030	0.0002	0.4567	48.23	25.09	40.20
Riley County	429,743	CRP Average	0.0706	0.4148	0.0000	0.0033	0.0002	0.4889	45.55	23.01	37.73
		All Other Average	0.0654	0.3843	0.0000	0.0030	0.0002	0.4529	48.49	25.45	40.47
Republic County	441,520	CRP Average	0.0709	0.4164	0.0000	0.0033	0.0002	0.4908	45.27	23.20	37.62
		All Other Average	0.0653	0.3833	0.0000	0.0030	0.0002	0.4518	48.67	25.41	40.58
Saline County	506,962	CRP Average	0.0693	0.4068	0.0000	0.0032	0.0002	0.4795	46.42	23.70	38.52
		All Other Average	0.0656	0.3852	0.0000	0.0030	0.0002	0.4540	48.40	25.16	40.34
Washington County	552,767	CRP Average	0.0710	0.4172	0.0000	0.0033	0.0002	0.4918	45.40	23.02	37.63
		All Other Average	0.0659	0.3868	0.0000	0.0030	0.0002	0.4559	48.26	25.25	40.25
Region 2 Total	**6,456,996**										
		CRP Regional Average	**0.07273**	**0.4271**	**0.00336**	**0.003348**	**0.00026**	**0.50679**	**45.05**	**22.75**	**37.33**
		All Other Regional Average	**0.06565**	**0.38559**	**0**	**0.003023**	**0.00023**	**0.4545**	**48.39**	**25.24**	**40.34**

Notes: Averages not area weighted.

Table 2.9.5 Black Locust Embodied Energy and Energy Profit Ratio (edge of field) Region 3

Land Area			Embodied Energy (Ave)						Energy Profit Ratio		
Soil	Area (acres)		Equip-ment (MMBtu/ ton)	Fuel (MMBtu/ton)	Ferti-lizer (MMBtu/ton)	Chem-icals & Materials (MMBtu / ton)	Labor (MMBtu/ton)	Total (MMBtu/ton)	Max	Min	Ave
Atchison County	296,204	CRP Average	0.0635	0.3732	0.0000	0.0029	0.0002	0.4399	53.26	23.07	42.61
		All Other Average	0.0627	0.3685	0.0000	0.0029	0.0002	0.4344	53.96	23.60	43.19
Brown County	800,752	CRP Average	0.0626	0.3678	0.0000	0.0029	0.0002	0.4336	53.99	23.29	43.15
		All Other Average	0.0631	0.3703	0.0000	0.0029	0.0002	0.4366	53.64	23.58	42.98
Douglas County	253,444	CRP Average	0.0692	0.4064	0.0000	0.0032	0.0002	0.4790	49.20	21.41	39.42
		All Other Average	0.0626	0.3674	0.0005	0.0029	0.0002	0.4335	53.99	23.60	43.23
Doniphan County	241,112	CRP Average	0.0651	0.3825	0.0001	0.0030	0.0002	0.4509	51.84	22.75	41.57
		All Other Average	0.0632	0.3711	0.0000	0.0029	0.0002	0.4374	53.64	23.51	42.94
Franklin County	391,334	CRP Average	0.0728	0.4274	0.0000	0.0034	0.0003	0.5038	46.92	20.19	37.55
		All Other Average	0.0641	0.3762	0.0011	0.0029	0.0002	0.4445	52.44	23.16	42.08
Jackson County	440,903	CRP Average	0.0661	0.3884	0.0000	0.0030	0.0002	0.4579	51.09	22.32	40.96
		All Other Average	0.0618	0.3631	0.0000	0.0028	0.0002	0.4280	54.64	23.79	43.71
Jefferson County	337,434	CRP Average	0.0650	0.3816	0.0001	0.0030	0.0002	0.4499	51.99	22.81	41.70
		All Other Average	0.0633	0.3718	0.0000	0.0029	0.0002	0.4383	53.40	23.38	42.77
Johnson County	209,510	CRP Average	0.0672	0.3948	0.0001	0.0031	0.0002	0.4654	50.06	22.03	40.21
		All Other Average	0.0619	0.3638	0.0005	0.0029	0.0002	0.4292	54.51	23.77	43.61
Leavenworth County	231,054	CRP Average	0.0646	0.3796	0.0000	0.0030	0.0002	0.4475	52.23	22.87	41.88
		All Other Average	0.0622	0.3653	0.0000	0.0029	0.0002	0.4305	54.40	23.76	43.53
Lyon County	580,562	CRP Average	0.0698	0.4099	0.0000	0.0032	0.0002	0.4832	48.62	21.16	38.97
		All Other Average	0.0634	0.3725	0.0005	0.0029	0.0002	0.4397	53.13	23.33	42.60
Miami County	305,926	CRP Average	0.0660	0.3875	0.0000	0.0030	0.0002	0.4568	51.04	22.20	40.90
		All Other Average	0.0633	0.3715	0.0013	0.0029	0.0002	0.4391	53.26	23.30	42.65
Marshall County	568,660	CRP Average	0.0656	0.3854	0.0001	0.0030	0.0002	0.4544	51.74	22.48	41.40
		All Other Average	0.0634	0.3723	0.0000	0.0029	0.0002	0.4388	53.33	23.12	42.64
Nemaha County	493,372	CRP Average	0.0657	0.3856	0.0001	0.0030	0.0002	0.4546	51.42	22.46	41.22
		All Other Average	0.0609	0.3576	0.0000	0.0028	0.0002	0.4215	55.48	24.18	44.36
Osage County	454,920	CRP Average	0.0676	0.3971	0.0000	0.0031	0.0002	0.4681	49.82	21.73	39.95
		All Other Average	0.0630	0.3698	0.0006	0.0029	0.0002	0.4366	53.53	23.47	42.89
Pottawatomie County	592,226	CRP Average	0.0668	0.3926	0.0001	0.0031	0.0002	0.4628	50.66	22.08	40.59
		All Other Average	0.0629	0.3696	0.0000	0.0029	0.0002	0.4357	53.80	23.44	43.05
Shawnee County	279,462	CRP Average	0.0667	0.3917	0.0000	0.0031	0.0002	0.4617	50.60	22.19	40.59
		All Other Average	0.0628	0.3688	0.0000	0.0029	0.0002	0.4347	53.85	23.51	43.10
Wabaunsee County	626,686	CRP Average	0.0682	0.4006	0.0000	0.0031	0.0002	0.4722	49.58	21.58	39.72
		All Other Average	0.0629	0.3694	0.0004	0.0029	0.0002	0.4358	53.66	23.46	42.98
Wyandotte County	32,194	CRP Average	0.0646	0.3796	0.0000	0.0030	0.0002	0.4475	52.23	22.87	41.88
		All Other Average	0.0627	0.3680	0.0000	0.0029	0.0002	0.4338	54.07	23.67	43.27
Region 3 Total	**7,135,756**										
		CRP Regional Average	**0.0665**	**0.3907**	**0.0000**	**0.0031**	**0.0002**	**0.4605**	**50.91**	**22.19**	**40.79**
		All Other Regional Average	**0.0628**	**0.3687**	**0.0003**	**0.0029**	**0.0002**	**0.4349**	**53.82**	**23.53**	**43.09**

Notes: Averages not area weighted.

Table 2.9.5 Black Locust Embodied Energy and Energy Profit Ratio (edge of field) Region 4

Land Area			Embodied Energy (Ave)						Energy Profit Ratio		
Soil	Area (acres)		Equip-ment (MMBtu/ ton)	Fuel (MMBtu/ton)	Ferti-lizer (MMBtu/ton)	Chem-icals & Materials (MMBtu / ton)	Labor (MMBtu/ton)	Total (MMBtu/ton)	Max	Min	Ave
Allen County	291,717	CRP Average	0.0527	0.3093	0.0005	0.0024	0.0002	0.3651	59.81	31.15	50.59
		All Other Average	0.0459	0.2695	0.0000	0.0021	0.0002	0.3178	68.43	35.34	57.57
Anderson County	362,926	CRP Average	0.0503	0.2951	0.0004	0.0023	0.0002	0.3482	62.38	32.60	52.75
		All Other Average	0.0448	0.2633	0.0000	0.0021	0.0002	0.3104	70.00	36.22	58.84
Bourbon County	345,999	CRP Average	0.0525	0.3083	0.0005	0.0024	0.0002	0.3639	60.20	31.42	50.91
		All Other Average	0.0459	0.2695	0.0000	0.0021	0.0002	0.3178	68.43	35.34	57.57
Coffey County	417,600	CRP Average	0.0521	0.3059	0.0000	0.0024	0.0002	0.3606	60.67	31.69	51.32
		All Other Average	0.0452	0.2653	0.0007	0.0021	0.0002	0.3134	69.46	35.73	58.34
Cherokee County	305,576	CRP Average	0.0535	0.3142	0.0004	0.0025	0.0002	0.3707	59.21	30.84	50.04
		All Other Average	0.0455	0.2673	0.0000	0.0021	0.0002	0.3150	69.02	35.71	58.05
Crawford County	301,752	CRP Average	0.0530	0.3114	0.0002	0.0024	0.0002	0.3672	59.58	31.17	50.44
		All Other Average	0.0454	0.2666	0.0000	0.0021	0.0002	0.3143	69.16	35.77	58.15
Labette County	391,461	CRP Average	0.0523	0.3070	0.0004	0.0024	0.0002	0.3623	60.46	31.64	51.15
		All Other Average	0.0458	0.2687	0.0000	0.0021	0.0002	0.3167	68.77	35.44	57.80
Linn County	289,834	CRP Average	0.0501	0.2941	0.0007	0.0023	0.0002	0.3473	62.68	32.65	52.97
		All Other Average	0.0446	0.2621	0.0000	0.0021	0.0002	0.3089	70.43	36.34	59.16
Montgomery County	428,538	CRP Average	0.0522	0.3069	0.0002	0.0024	0.0002	0.3619	60.06	31.55	50.87
		All Other Average	0.0462	0.2714	0.0000	0.0021	0.0002	0.3200	67.99	35.03	57.19
Neosho County	350,348	CRP Average	0.0520	0.3056	0.0002	0.0024	0.0002	0.3604	60.35	31.68	51.11
		All Other Average	0.0460	0.2704	0.0000	0.0021	0.0002	0.3187	68.20	35.22	57.38
Wilson County	398,942	CRP Average	0.0522	0.3068	0.0000	0.0024	0.0002	0.3617	60.40	31.65	51.09
		All Other Average	0.0460	0.2699	0.0000	0.0021	0.0002	0.3182	68.36	35.30	57.49
Woodson County	329,169	CRP Average	0.0520	0.3054	0.0002	0.0024	0.0002	0.3602	60.57	31.64	51.21
		All Other Average	0.0452	0.2654	0.0000	0.0021	0.0002	0.3129	69.56	35.92	58.48
Region 4 Total	**4,213,861**										
		CRP Regional Average	**0.0521**	**0.3058**	**0.0003**	**0.0024**	**0.0002**	**0.3608**	**60.53**	**31.64**	**51.20**
		All Other Regional Average	**0.0455**	**0.2675**	**0.0001**	**0.0021**	**0.0002**	**0.3153**	**68.98**	**35.61**	**58.00**

Notes: Averages not area weighted.

Table 2.9.5 Black Locust Embodied Energy and Energy Profit Ratio (edge of field) Region 5

Land Area			Embodied Energy (Ave)						Energy Profit Ratio		
Soil	Area (acres)		Equip-ment (MMBtu/ ton)	Fuel (MMBtu/ton)	Ferti-lizer (MMBtu/ton)	Chem-icals & Materials (MMBtu / ton)	Labor (MMBtu/ton)	Total (MMBtu/ton)	Max	Min	Ave
Butler County	1,027,556	CRP Average	0.0662	0.3890	0.0000	0.0031	0.0002	0.4586	49.21	23.79	40.47
		All Other Average	0.0609	0.3575	0.0000	0.0028	0.0002	0.4213	52.69	26.65	43.70
Cowley County	758,352	CRP Average	0.0843	0.4948	0.0295	0.0039	0.0003	0.6127	43.07	20.41	35.32
		All Other Average	0.0614	0.3604	0.0000	0.0028	0.0002	0.4249	52.18	26.36	43.28
Chautauqua County	443,829	CRP Average	0.0660	0.3876	0.0000	0.0030	0.0002	0.4569	49.24	24.03	40.57
		All Other Average	0.0614	0.3608	0.0000	0.0028	0.0002	0.4253	52.13	26.25	43.20
Elk County	499,661	CRP Average	0.0669	0.3929	0.0000	0.0031	0.0002	0.4631	48.71	23.57	40.06
		All Other Average	0.0602	0.3533	0.0000	0.0028	0.0002	0.4164	53.22	26.93	44.13
Greenwood County	377,894	CRP Average	0.0671	0.3940	0.0000	0.0031	0.0002	0.4644	48.56	23.47	39.94
		All Other Average	0.0613	0.3600	0.0000	0.0028	0.0002	0.4244	52.31	26.44	43.35
Harvey County	317,762	CRP Average	0.0885	0.5200	0.0410	0.0041	0.0003	0.6539	43.95	21.48	36.26
		All Other Average	0.0652	0.3829	0.0065	0.0030	0.0002	0.4579	50.81	25.45	42.06
Sedgwick County	167,712	CRP Average	0.0892	0.5241	0.0410	0.0041	0.0003	0.6587	43.49	20.98	35.81
		All Other Average	0.0640	0.3761	0.0042	0.0029	0.0002	0.4476	51.01	25.70	42.28
Sumner County	745,064	CRP Average	0.1533	0.9001	0.1473	0.0070	0.0005	1.2083	20.67	8.34	16.58
		All Other Average	0.0616	0.3618	0.0000	0.0028	0.0002	0.4265	51.98	26.24	43.12
Region 5 Total	**4,337,831**										
		CRP Regional Average	**0.0852**	**0.5003**	**0.0323**	**0.0039**	**0.0003**	**0.6221**	**43.36**	**20.76**	**35.63**
		All Other Regional Average	**0.0620**	**0.3641**	**0.0013**	**0.0029**	**0.0002**	**0.4305**	**52.04**	**26.25**	**43.14**

Notes: Averages not area weighted.

Table 2.9.5 Black Locust Embodied Energy and Energy Profit Ratio (edge of field) **Region 6**

Land Area			**Embodied Energy (Ave)**						**Energy Profit Ratio**		
Soil	**Area (acres)**		Equip-ment (MMBtu/ ton)	Fuel (MMBtu/ton)	Ferti-lizer (MMBtu/ton)	Chem-icals & Materials (MMBtu / ton)	Labor (MMBtu/ton)	Total (MMBtu/ton)	**Max**	**Min**	**Ave**
Barber County	897,822	CRP Average	0.0730	0.4290	0.0000	0.0034	0.0003	0.5057	44.28	20.95	36.55
		All Other Average	0.0756	0.4437	0.0052	0.0035	0.0003	0.5282	43.21	20.48	35.65
Comanche	645,885	CRP Average	0.0747	0.4385	0.0000	0.0034	0.0003	0.5169	43.51	20.85	35.99
		All Other Average	0.0746	0.4382	0.0050	0.0034	0.0003	0.5214	43.78	20.69	36.11
Edwards County	415,605	CRP Average	0.0792	0.4649	0.0000	0.0036	0.0003	0.5479	41.13	19.34	33.94
		All Other Average	0.0728	0.4275	0.0000	0.0034	0.0003	0.5039	44.39	21.03	36.61
Harper County	503,207	CRP Average	0.0740	0.4349	0.0000	0.0034	0.0003	0.5126	43.66	20.69	36.08
		All Other Average	0.0730	0.4287	0.0000	0.0034	0.0003	0.5053	44.17	20.99	36.48
Kingman County	550,024	CRP Average	0.0762	0.4474	0.0000	0.0035	0.0003	0.5273	42.41	20.03	35.05
		All Other Average	0.0732	0.4298	0.0000	0.0034	0.0003	0.5066	44.05	20.94	36.38
Kiowa County	512,259	CRP Average	0.0778	0.4572	0.0000	0.0036	0.0003	0.5389	41.86	19.76	34.58
		All Other Average	0.0731	0.4291	0.0000	0.0034	0.0003	0.5058	44.21	21.06	36.50
Pawnee County	471,135	CRP Average	0.0778	0.4568	0.0000	0.0036	0.0003	0.5384	41.41	19.59	34.22
		All Other Average	0.0729	0.4282	0.0000	0.0034	0.0003	0.5047	44.36	21.00	36.57
Pratt County	507,177	CRP Average	0.0717	0.4208	0.0000	0.0033	0.0003	0.4960	44.99	21.46	37.18
		All Other Average	0.0747	0.4389	0.0000	0.0034	0.0003	0.5174	43.20	20.51	35.66
Reno County	934,980	CRP Average	0.0734	0.4313	0.0000	0.0034	0.0003	0.5084	43.82	20.84	36.23
		All Other Average	0.0731	0.4291	0.0000	0.0034	0.0003	0.5058	44.26	20.96	36.50
Stafford County	548,100	CRP Average	0.0725	0.4260	0.0000	0.0033	0.0003	0.5021	44.43	21.17	36.73
		All Other Average	0.0746	0.4381	0.0000	0.0034	0.0003	0.5163	43.28	20.53	35.72
Region 6 Total	**5,986,194**										
		CRP Regional Average	**0.0750**	**0.4407**	**0.0000**	**0.0035**	**0.0003**	**0.5194**	**43.15**	**20.47**	**35.65**
		All Other Regional Average	**0.0737**	**0.4331**	**0.0010**	**0.0034**	**0.0003**	**0.5115**	**43.89**	**20.82**	**36.22**

Notes: Averages not area weighted.

The energy profit ratios and fossil carbon content shown in tables 2.9.4 and 2.9.5 above are useful, but do not reflect the actual impact of using biomass fuels. Fuel acquisition criteria could give preference to sites with greater energy profit ratios. Transportation and fuel processing are important and must be considered for all fuels. The atmospheric carbon impacts of two specific biomass power generation projects are evaluated in Section 5.

In addition to cycling atmospheric carbon, biomass fuels sequester carbon in their root systems which, as part of a perennials plant, are more extensive than roots of annual grain crops. The value of root carbon sequestering would of course be lost if the plantation were taken out of production.

2.10 Identifying Most Promising Regions and Plant Sites

A major task of this project is to identify the most promising regions, based on low biomass cost and concentration of adequate volumes at low costs, for biomass fueled electric power generation. In Section 2.8 the cost and potential volume of biomass production for both switchgrass and black locust in competition with conventional grain producing land and on land potentially eligible for CRP was assessed. Figures 2.11.1 (switchgrass) and 2.11.3 (black locust) identify the parcels of land with the lowest average biomass cost per million Btus at the field edge, in cost increments,with potential production adequate to meet the 5% co-firing scenario for the CRP land access scenario. Figures 2.11.2 (switchgrass) and 2.11.4 (black locust) provide similar information for land access in competition with grain. The regions with significant concentrations of land parcels with costs below $1.50/MBtu obviously represent the lowest cost regions and therefore the best opportunity, subject to the impact of transportation cost and proximity to suitable plant sites.

Co-Firing at Existing Coal Fired Generating Plants

Cofiring offers the lowest cost strategy for biomass fueled electric power generation. The potential for co-firing biomass with an existing coal plant is directly influenced by the cost of fuel transportation from the areas of lowest cost biomass production to coal plants suitable for co-firing. Table 5.2 lists the location of pulverized coal and cyclone boiler fueled coal plants owned by KEURP member utilities. Among these generating plants, Jeffrey, LaCygne, and Riverton are all located within the areas of concentration of low cost biomass energy (on CRP land). The Riverton plant lies in the far southeast corner of the state. Lacking data from Missouri and Oklahoma, analysis of Riverton would rely on only one about one fourth of the land nearest the plant, and it was therefore not evaluated. Jeffrey and LaCygne with pulverized and cyclonic coal boilers were selected for further evaluation.

Biomass Fueled Gas Turbines

The technology for biomass gasification is well developed and evaluation of a “green field” gas turbine project was considered. However, future gas turbine installations that are currently part of KEURP member’s long range plans are all peaking units. The substantial cost of biomass gasification equipment requires a high annual plant factor for acceptable amortization, a condition that would not be met by a seasonal peaking plant. Therefore two coal plant co-firing projects, (one with a pulverized coal boiler, the other cyclonic), were investigated as described above and in Section 5.

2.11 Transportation to the Plant Gate

Transportation from field edge to plant gate represents a significant cost and source of added embodied energy. The larger the plant and the more diffuse the resource, the greater the impact on cost and embodied energy of transportation. Developing a strategy to minimize the duration of outdoor storage permitting biological degradation, and minimizing both the number of times the material must be handled and the number of miles it must be transported are important if transportation costs are to be minimized.

Detailed route optimization was beyond the scope of this study. Travel distance was calculated by using the GIS database to determine the distance from the centroid of each SSURGO land parcel to the plant gate and the shortest X and Y vectors that matched the distance. This assumes the road grid is complete and rectangular with no short-cuts (diagonals) and no need to drive a route that is not headed directly to the plant (no missing roads or bridges in the grid). A review of the extensive network of county and township roads in the areas being investigated indicated these are reasonable assumptions for this level of analysis.

The plant gate cost per ton was estimated for each parcel within 50 miles of the Jeffrey and LaCygne plants using the following formula:

Plant Gate Cost ($/dry ton) = Edge of Field Cost + Load/unload Cost + (cost per ton mile x distance)

Where:

- the Edge of Field Cost for each land parcel is as calculated by BEPCEE for the soil series within the Region
- the load/unload cost per ton is fixed at $4.00/dry ton,
- the cost per ton mile is fixed at $0.10 per dry ton mile, including delivery and return to the same path,
- the distance is the sum of the minimum X and Y vectors of the line from the plant gate to the land parcel centroid.

The production cost data sets for CRP land and conventional crop land were converted to Plant Gate Cost within the 50 mile radii, and the lowest cost parcels were garnered until the required production volume was acquired, constrained by limits of no more than 50% of the land area of any soil series and no more than 10% of the total potentially eligible land area within any county.

Table 2.11.1 Jeffrey Switchgrass Source and Cost for 2% and 5% Co-firing (CRP Land)
58,730 tons required for 2% cofire, 146,788 for 5% cofire (as determined by BIOPOWER)

County	Soil Series	Acres (total in Co.)	Yield (average dry tons/acre)	Harvested Production (dry tons, 50% of land)	Biomass Cost (edge of field $/d.t.)	Average Transport Cost ($/d.t.)	Plant Gate Cost ($/d.t.)	Ton Miles
2% Co-fire								
Shawnee	Dwight	2,138	5.09	5,4441	$21.05	$6.75	$27.79	149,397
Pottawatomie	Pawnee	8,920	5.57	24,855	$23.36	$4.68	$28.03	168,168
Wabaunsee	Florence	29	4.27	62	$22.49	$5.62	$28.11	1,001
Jackson	Pawnee	3,689	5.57	10,279	$23.36	$4.84	$28.19	86,019
Jackson	Burchard	15	5.60	41	$23.54	$4.77	$28.31	314
Wabaunsee	Pawnee	327	5.57	911	$23.36	$5.09	$28.45	9,930
Shawnee	Pawnee	359	5.57	1,001	$23.36	$5.10	$28.46	11,034
Wabaunsee	Pawnee	12,170	5.57	16,141	$23.36	$5.60	$28.96	258,049
Total/Average Ton				**58,730**	**$23.14**	**$5.16**	**$28.31**	**683,912**
Average per MMBtu					**$1.46**	**$0.33**	**$1.79**	**0.74**
5% Co-fire (add to above)								
Wabaunsee	Pawnee	12,170	5.57	17,770	$23.36	$5.60	$28.96	284,092
Pottawatomie	Martin	1,138	6.29	3,579	$24.14	$4.98	$29.12	35,044
Shawnee	Dwight	150	5.09	4,254	$21.05	$8.11	$29.15	174,629
Pottawatomie	Pawnee	1,256	5.57	62,455	$23.36	$5.98	$29.33	1,233,670
Total/Average Ton				**146,788**	**$23.22**	**$5.64**	**$28.87**	**2,558,095**
Average per MMBtu					**$1.47**	**$0.36**	**$1.82**	**1.10**

Table 2.11.2 Jeffrey Switchgrass Source and Cost for 2% and 5% Co-firing (vs. Grain)

52,028 tons required for 2% cofire, 130,070 for 5% cofire (as determined by BIOPOWER)

County	Soil Series	Acres	Yield (average dry tons/acre)	Harvested Production (dry tons, 50% of land)	Biomass Cost (edge of field $/d.t.)	Average Transport Cost ($/d.t.)	Plant Gate Cost ($/d.t.)	Ton Miles
2% Co-fire								
Riley	Sarpy	45	4.12	93	$37.21	$6.75	$43.96	2,493
Riley	Mayberry	47	5.13	121	$37.79	$6.48	$44.27	2,899
Riley	Sarpy	918	4.12	1,892	$37.21	$7.89	$45.10	71,327
Riley	Sutphen	1893	4.67	4,422	$38.43	$6.90	$45.33	124,450
Clay	Sarpy	159	4.12	327	$37.21	$9.24	$46.45	16,605
Riley	Mayberry	1996	5.13	5,117	$37.79	$8.76	$46.55	235,985
Riley	Irwin	939	5.31	2,493	$39.98	$6.76	$46.75	66,778
Geary	Sarpy	384	4.12	791	$37.21	$9.67	$46.88	43,502
Riley	Dwight	23	4.55	52	$40.45	$6.52	$46.97	1,271
Riley	Pawnee	43	4.97	107	$40.49	$6.50	$47.00	2,594
Geary	Sarpy	190	4.12	392	$37.21	$9.82	$47.03	22,117
Riley	Mayberry	94	5.13	241	#37.79	$9.40	$47.19	12,622
Riley	Florence	688	4.06	1,395	$40.69	$7.29	$47.98	44,459
Riley	Irwin	34,735	5.31	41,286	$39.98	$8.45	$48.44	1,178,398
Total/Average Ton				**52,028**	**$39.51**	**$8.27**	**$47.78**	**2,429,498**
Average per MMBtu					**$2.49**	**$0.52**	**$3.02**	**2.61**
5% Co-fire (add to above)								
Riley	Irwin	34,735	5.31	50,974	$39.98	$7.29	$47.98	2,200,654
Wabaunsee	Mayberry	2,173	45.13	5,572	$37.79	$10.81	$48.60	367,857
Riley	Dwight	19,634	4.55	31,511	$40.45	$8.16	$48.61	1,270,689
Total/Average Ton				**130,070**	**$48.22**	**$8.41**	**$48.22**	**6,268,699**
Average per MMBtu					**$2.51**	**$0.53**	**$3.04**	**2.70**

Table 2.11.3 Jeffrey Black Locust Source and Cost for 2% and 5% Co-firing (CRP Land)

55,631 tons required for 2% cofire, 139,078 for 5% cofire (as determined by BIOPOWER)

County	Soil Series	Acres	Yield (average dry tons/acre)	Harvested Production (dry tons, 50% of land)	Biomass Cost (edge of field $/d.t.)	Average Transport Cost ($/d.t.)	Plant Gate Cost ($/d.t.)	Ton Miles
2% Co-fire								
Shawnee	Dwight	4,347	2.89	6,290	$41.86	$7.59	$49.45	225,580
Lyon	Lula	24	3.02	36	$40.17	$9.71	$49.88	2,083
Osage	Lula	12,876	3.02	19,416	$40.17	$10.09	$50.26	1,182,005
Clay	Holder	495	2.86	709	$42.26	$9.34	$51.60	36,715
Geary	Holder	2,042	2.86	2,924	$42.26	$9.48	$51.74	155,225
Osage	Dwight	1,781	2.89	2,576	$41.86	$9.92	$51.78	152,650
Riley	Smolan	4,059	2.95	5,981	$47.44	$8.62	$56.06	267,988
Pottawatomie	Burchard	38	3.08	59	$50.55	$6.23	$56.79	1,321
Pottawatomie	Clime	33,090	2.77	17,639	$52.34	$4.60	$56.95	106,715
Total/Average Ton				**55,631**	**$45.23**	**$7.86**	**$53.08**	**2,130,284**
Average per MMBtu					**$2.68**	**$0.47**	**$3.15**	**2.27**
5% Co-fire (add to above)								
Pottawatomie	Clime	33,090	2.77	45,856	$52.34	$4.60	$56.95	170,714
Wabaunsee	Elmont	1,138	3.11	1,772	$51.48	$5.52	$57.00	26,911
Marshall	Smolan	1,018	2.95	1,503	$47.44	$9.66	$57.10	82,526
Nemaha	Burchard	15,346	3.08	23,666	$50.55	$6.55	$57.11	604,283
Jackson	Burchard	13,107	3.08	20,213	$50.55	$6.65	$57.20	535,986

Morris	Burchard	69	3.08	106	$50.55	$6.68	$57.23	2,840
Wabaunsee	Florence	138	2.37	164	$51.04	$6.20	$57.24	3,611
Jackson	Clime	1,941	2.77	2,689	$52.34	$4.94	$57.28	25,296
Pottawatamie	Steinauer	68	3.17	107	$50.72	$6.56	$57.28	2,751
Nemaha	Steinauer	175	3.17	278	$50.72	$6.61	$57.34	7,265
Wabaunsee	Clime	1,000	2.77	1,385	$52.34	$5.06	$57.40	14,615
Pottawatamie	Martin	914	3.10	550	$52.68	$4.73	$57.40	4,003
Jackson	Martin	2,632	3.10	2,796	$52.68	$4.74	$57.42	20,731
Total/Average Ton				**139,078**	**$48.87**	**$6.62**	**$55.49**	**3,631,816**
Average per MMBtu					**$2.90**	**$0.39**	**$3.29**	**1.55**

Table 2.11.4 Jeffrey Black Locust Source and Cost for 2% and 5% Co-firing (vs. Grain)

55,631 tons required for 2% cofire, 139,078 for 5% cofire (as determined by BIOPOWER)

County	Soil Series	Acres	Yield (average dry tons/acre)	Harvested Production (dry tons, 50% of land)	Biomass Cost (edge of field $/d.t.)	Average Transport Cost ($/d.t.)	Plant Gate Cost ($/d.t.)	Ton Miles
2% Co-fire								
Jackson	Sogn	487	2.76	672	$44.34	$7.17	$51.52	21,316
Wabaunsee	Sogn	55	2.76	76	$44.34	$7.41	$51.76	2,603
Shawnee	Sogn	20,581	2.76	28,432	$44.34	$7.74	$52.08	1,063,369
Jefferson	Sogn	7,315	2.76	10,105	$44.34	$7.99	$52.33	402,931
Osage	Sogn	1,763	2.76	2,435	$44.34	$9.13	$53.48	125,054
Douglas	Sogn	7,551	2.76	10,431	$44.34	$10.03	$54.38	629,327
Riley	Sarpy	41	2.44	51	$53.12	$6.64	$59.77	1,341
Riley	Sarpy	922	2.44	1,127	$53.12	$7.77	$60.89	42,457
Riley	Mayberry	47	2.86	67	$55.62	$6.40	$62.03	1,618
Geary	Sarpy	33	2.44	40	$53.12	$8.95	$62.07	2,001
Riley	Dwight	3,289	2.74	2,193	$55.09	$7.04	$62.13	66,578
Total/Average Ton				**55,631**	**$44.97**	**$8.24**	**$53.15**	**2,358,594**
Average per MMBtu					**$2.67**	**$0.49**	**$3.15**	**2.51**
5% Co-fire (add to above)								
Riley	Dwight	3,289	2.74	2,314	$55.09	$7.04	$62.13	70,245
Clay	Sarpy	159	2.44	194	$53.12	$9.08	$62.20	9,852
Riley	Sutphen	149	2.71	201	$56.01	$6.44	$62.45	4,903
Geary	Sarpy	542	2.44	662	$53.12	$9.58	$62.70	36,932
Riley	Sutpehn	1,744	2.71	2,362	$56.01	$6.85	$62.85	67,217
Riley	Kipson	895	2.56	1,147	$54.10	$9.09	$63.19	58,377
Coffey	Kipson	8,302	2.56	10,637	$54.10	$9.36	$63.46	570,228
Riley	Dwight	22,896	2.74	31,376	$55.09	$8.52	$63.62	1,419,538
Dickinson	Kipson	4	2.56	5	$54.10	$9.76	$63.86	287
Riley	Mayberry	2,090	2.86	2,992	$55.62	$8.64	$64.26	138,790
Washington	Kipson	5,782	2.56	7,408	$54.10	$10.34	$64.44	469,841
Morris	Dwight	2,230	2.74	3,056	$55.09	$9.48	$64.57	167,460
Riley	Wymore	464	2.72	631	$57.75	$7.03	$64.79	19,130
Morris	Kipson	1,845	2.56	2,364	$54.10	$10.73	$64.83	159,143
Washington	Kipson	336	2.56	431	$54.10	$11.01	$65.10	30,171
Riley	Dwight	574	2.74	787	$55.09	$10.05	$65.14	47,597
Morris	Kipson	1,303	2.56	1,670	$54.10	$11.05	$65.15	117,793
Morris	Dwight	5,255	2.74	7,201	$55.09	$10.54	$65.63	471,186
Riley	Wymore	50,503	2.72	8,011	$57.75	$8.40	$66.15	352,366
Total/Average Ton				**139,078**	**$51.06**	**$8.72**	**$59.78**	**6,569,551**
Average per MMBtu					**$3.03**	**$0.52**	**$3.54**	**2.80**

Table 2.11.5 LaCygne Switchgrass Source and Cost for 2% and 5% Co-firing (CRP Land)
52,028 tons required for 2% cofire, 130,070 for 5% cofire (as determined by BIOPOWER)

County	Soil Series	Acres	Yield (average dry tons/acre)	Harvested Production (dry tons, 50% of land)	Biomass Cost (edge of field $/d.t.)	Average Transport Cost ($/d.t.)	Plant Gate Cost ($/d.t.)	Ton Miles
2% Co-firing								
Linn	Summit	28,656	8.43	52,028	$19.75	$6.25	$26.00	1,173,725
Total/Average Ton				**52,028**	**$19.75**	**$6.25**	**$26.00**	**1,173,725**
Average per MMBtu					**$1.25**	**$0.39**	**$1.64**	**1.42**
5% Co-firing (add to above)								
Linn	Summit	28,656	8.43	68,759	$19.75	$6.25	$26.00	1,551,159
Bourbon	Summit	1,495	8.43	6,300	$19.75	$7.42	$27.16	215,326
Anderson	Summit	12,550	8.43	2,983	$19.75	$7.78	$27.53	112,722
Total/Average Ton				**130,070**	**$19.75**	**$6.35**	**$26.09**	**3,052,932**
Average per MMBtu					**$1.25**	**$0.40**	**$1.65**	**1.48**

Table 2.11.6 LaCygne Switchgrass Source and Cost for 2% and 5% Co-firing (vs. Grain)
52,028 tons required for 2% cofire, 130,070 for 5% cofire (as determined by BIOPOWER)

County	Soil Series	Acres	Yield (average dry tons/acre)	Harvested Production (dry tons, 50% of land)	Biomass Cost (edge of field $/d.t.)	Average Transport Cost ($/d.t.)	Plant Gate Cost ($/d.t.)	Ton Miles
2% Co-firing								
Linn	Dennis	17,858	8.17	52,028	$32.68	$5.83	$38.50	949,774
Total/Average Ton				**52,028**	**$32.68**	**$5.83**	**$38.50**	**949,774**
Average per MMBtu					**$2.06**	**$0.37**	**$2.43**	**1.15**
5% Co-firing (add to above)								
Linn	Dennis	17,858	8.17	20,915	$32.68	$5.83	$38.50	381,802
Linn	Hepler	244	6.47	790	$33.11	$5.60	$38.71	12,623
Bourbon	Tamaha	2,201	7.00	7,705	$30.99	$7.83	$38.82	295,115
Linn	Kenoma	42,529	7.55	48,632	$32.94	$6.39	$39.33	1,161,499
Total/Average Ton				**130,070**	**$32.68**	**$6.15**	**$38.83**	**2,800,813**
Average per MMBtu					**$2.06**	**$0.39**	**$2.45**	**1.35**

Table 2.11.7 LaCygne Black Locust Source and Cost for 2% and 5% Co-firing (CRP Land)

48,966 tons required for 2% cofire, 122,415 for 5% cofire (as determined by BIOPOWER)

County	Soil Series	Acres	Yield (average dry tons/acre)	Harvested Production (dry tons, 50% of land)	Biomass Cost (edge of field $/d.t.)	Average Transport Cost ($/d.t.)	Plant Gate Cost ($/d.t.)	Ton Miles
2% Co-firing								
Linn	Summit	28,656	4.13	48,966	$36.65	$6.26	$42.91	1,104,648
Total/Average Ton				48,966	$36.65	$6.26	$42.91	1,104,648
Average per MMBtu					$2.17	$0.37	$2.54	1.34
5% Co-firing (add to above)								
Linn	Summit	28,656	4.13	10,201	$36.65	$6.26	$42.91	230,134
Linn	Parsons	15,360	4.25	32,637	$37.60	$5.77	$43.37	577,495
Bourbon	Summit	1,495	4.13	3,086	$36.65	$7.42	$44.07	105,477
Bourbon	Tamaha	2,201	4.08	4,492	$36.81	$7.83	$44.64	172,045
Linn	Lebo	2,2392	3.97	4,754	$39.22	$5.80	$45.03	85,778
Anderson	Summit	19,950	4.13	18,287	$36.65	$8.39	$45.04	801,964
Total/Average Ton				**122,415**	**$37.01**	**$6.51**	**$43.53**	**3,077,542**
Average per MMBtu					**$2.19**	**$0.39**	**$2.58**	**1.49**

Table 2.11.8 LaCygne Black Locust Source and Cost for 2% and 5% Co-firing (vs. Grain)

48,966 tons required for 2% cofire, 122,415 for 5% cofire (as determined by BIOPOWER)

County	Soil Series	Acres	Yield (average dry tons/acre)	Harvested Production (dry tons, 50% of land)	Biomass Cost (edge of field $/d.t.)	Average Transport Cost ($/d.t.)	Plant Gate Cost ($/d.t.)	Ton Miles
2% Co-firing								
Linn	Collinsville	687	2.80	950	$34.93	$8.15	$43.08	39,403
Anderson	Collinsville	2,778	2.80	3,889	$34.93	$8.73	$43.66	183,907
Allen	Collinsville	2,516	2.80	3,522	$34.93	$9.63	$44.56	198,367
Neosho	Shidler	165	2.82	234	$40.54	$10.98	$51.52	16,295
Allen	Shidler	25	2.82	36	$40.54	$10.98	$51.52	2,482
Anderson	Talihina	2,814	3.53	4,973	$45.31	$7.86	$53.17	191,863
Bourbon	Tamaha	2,201	4.08	4,492	$46.72	$7.83	$54.55	172,045
Allen	Talihina	1,216	3.53	2,150	$45.31	$10.26	$55.57	134,523
Bourbon	Bolivar	81	3.67	149	$49.89	$6.76	$56.66	4,111
Bourbon	Bolivar	536	3.67	983	$49.89	$9.12	$59.01	50,347
Linn	Dennis	14,213	4.17	27,590	$55.30	$5.93	$61.23	531,712
Total/Average Ton				**48,966**	**$49.37**	**$7.11**	**$56.49**	**1,525,055**
Average per MMBtu					**$2.93**	**$0.42**	**$3.35**	**1.85**
5% Co-firing (add to above)								
Linn	Dennis	14,213	4.17	2,044	$55.30	$5.93	$61.23	39,396
Linn	Woodson	7,302	3.94	14,403	$56.23	$5.30	$61.53	187,510
Linn	Clareson	6,142	3.75	11,525	$56.32	$5.52	$61.84	174,821
Linn	Kenoma	3,108	3.88	6,035	$57.52	$4.47	$61.99	28,083
Linn	Bates	200	3.80	380	$57.70	$4.32	$62.02	1,217
Bourbon	Dennis	3,337	4.17	6,958	$55.30	$6.89	$62.19	201,176
Anderson	Dennis	176	4.17	367	$55.30	$6.95	$62.25	10,833
Linn	Dennis	1,113	4.17	2,320	$55.30	$7.79	$63.09	87,908
Linn	Clareson	14,175	3.75	26,600	$56.32	$7.04	$63.37	809,801
Linn	Woodson	12,041	3.94	2,819	$56.23	$7.39	$63.62	95,547
Total/Average Ton				**122,415**	**$53.50**	**$6.58**	**$60.08**	**3,161,346**
Average per MMBtu					**$3.17**	**$0.39**	**$3.56**	**1.53**

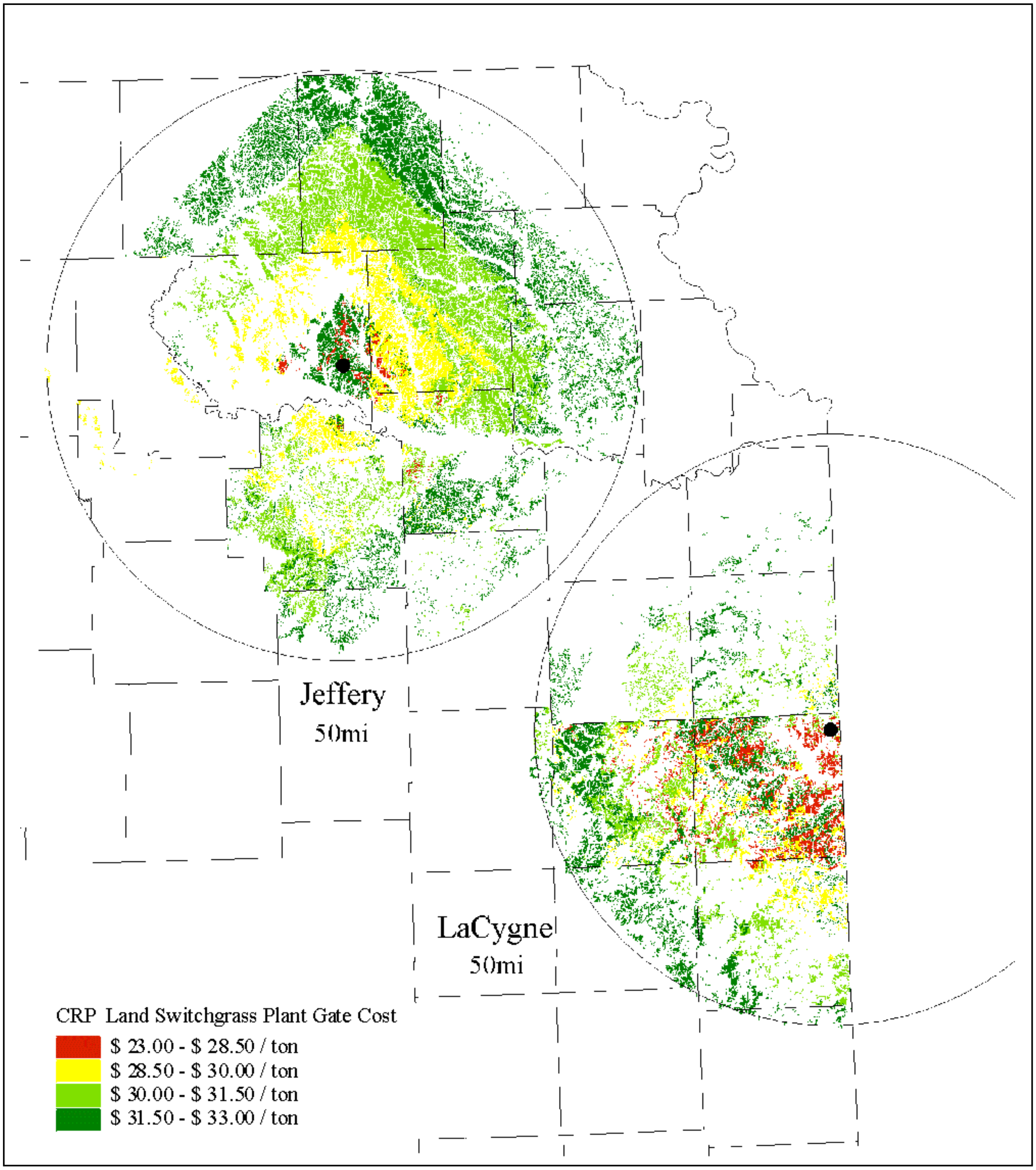

Figure 2.11.1 Map of Lowest Cost Switchgrass on CRP Land for Jeffrey and LaCygne

The fuel acquisition circles shown centered on Jeffery and LaCygne have radii of 50 miles. Switchgrass under the CRP scenario had the lowest plant gate cost at both plants. Yield and edge of field cost were important factors, but transportation distance was also important as suggested by the concentric diamonds around Jeffery. The diamonds result from the rectilinear road pattern. Note that the Jeffery is in climate region 3. The fuel circle includes parts of region 2 and while LaCygne is in region 4, essentially half of its fuel circle is in region 3. If data on Missouri were available, the reduced haul distance would slightly reduce the plant gate cost of biomass at LaCygne.

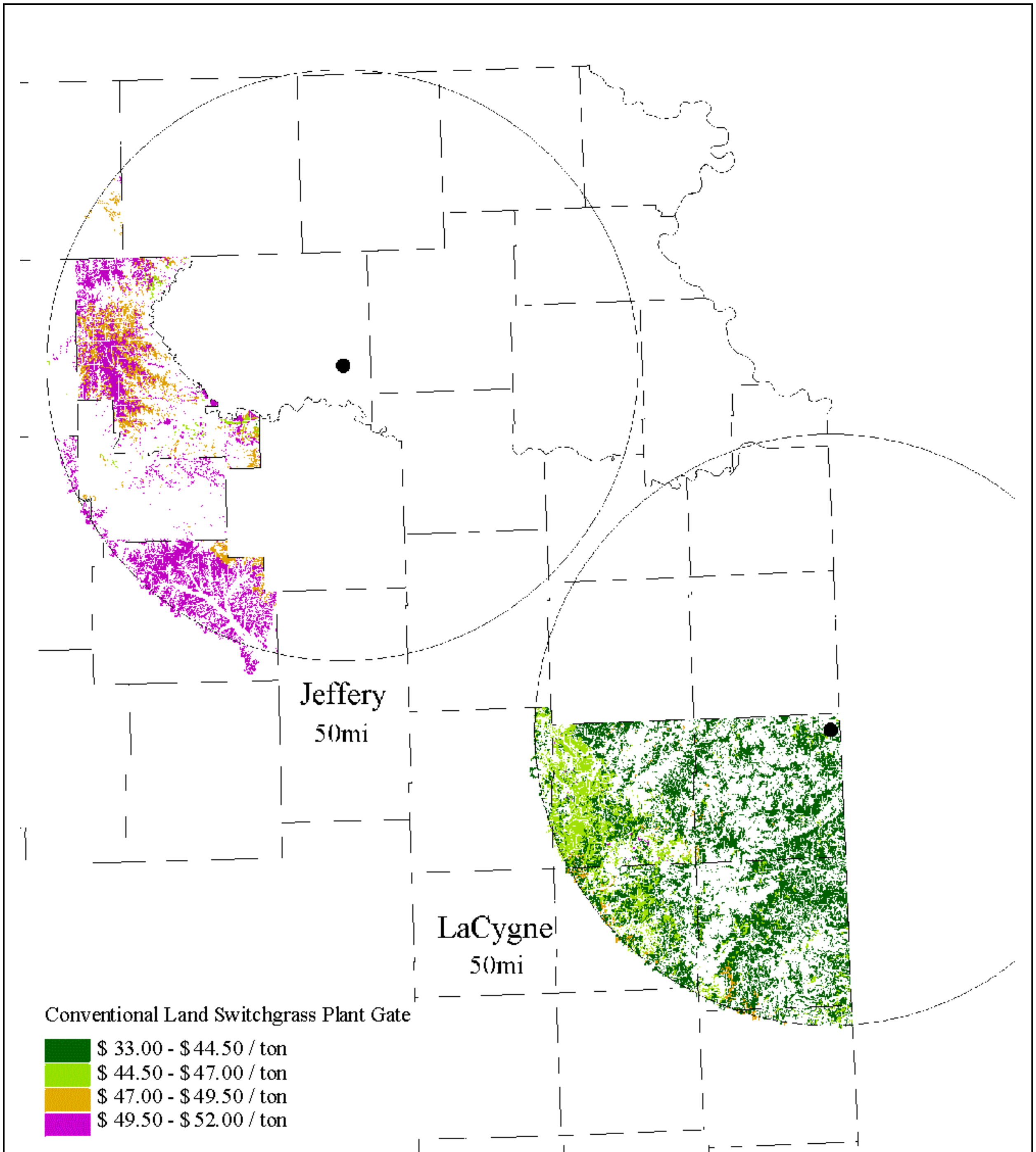

Figure 2.11.2 Map of Lowest Cost Switchgrass vs. Grain for Jeffrey and LaCygne
When competing with grain crops, switchgrass from region 3 delivered to the Jeffery plant gate can compete with switchgrass from region 2, where the competitive price of switchgrass is lower because grain yields are lower. Similarly, switchgrass competing with grain from region 3 delivered to the LaCygne plant gate, can not compete with switchgrass from region 4, where switchgrass yields are higher.

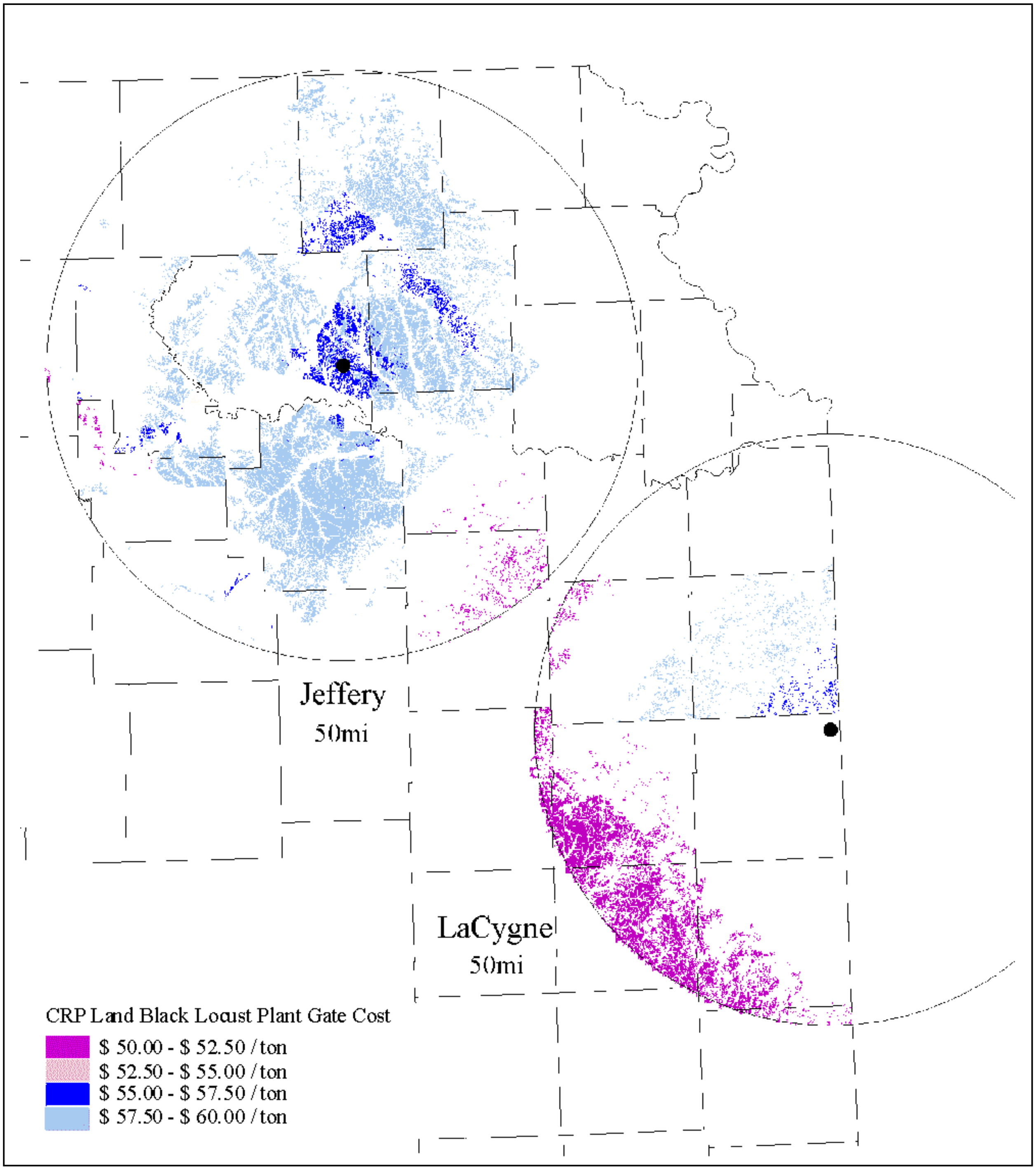

Figure 2.11.3 Map of Lowest Cost Black Locust on CRP Land for Jeffery and LaCygne
Black locust is substantially more expensive than switchgrass. Soils were a major factor in yield which more than offset transportation distance, resulting in the lower cost supply being located at toward the outer edge of the fuel supply circle for both Jeffery and LaCygne.

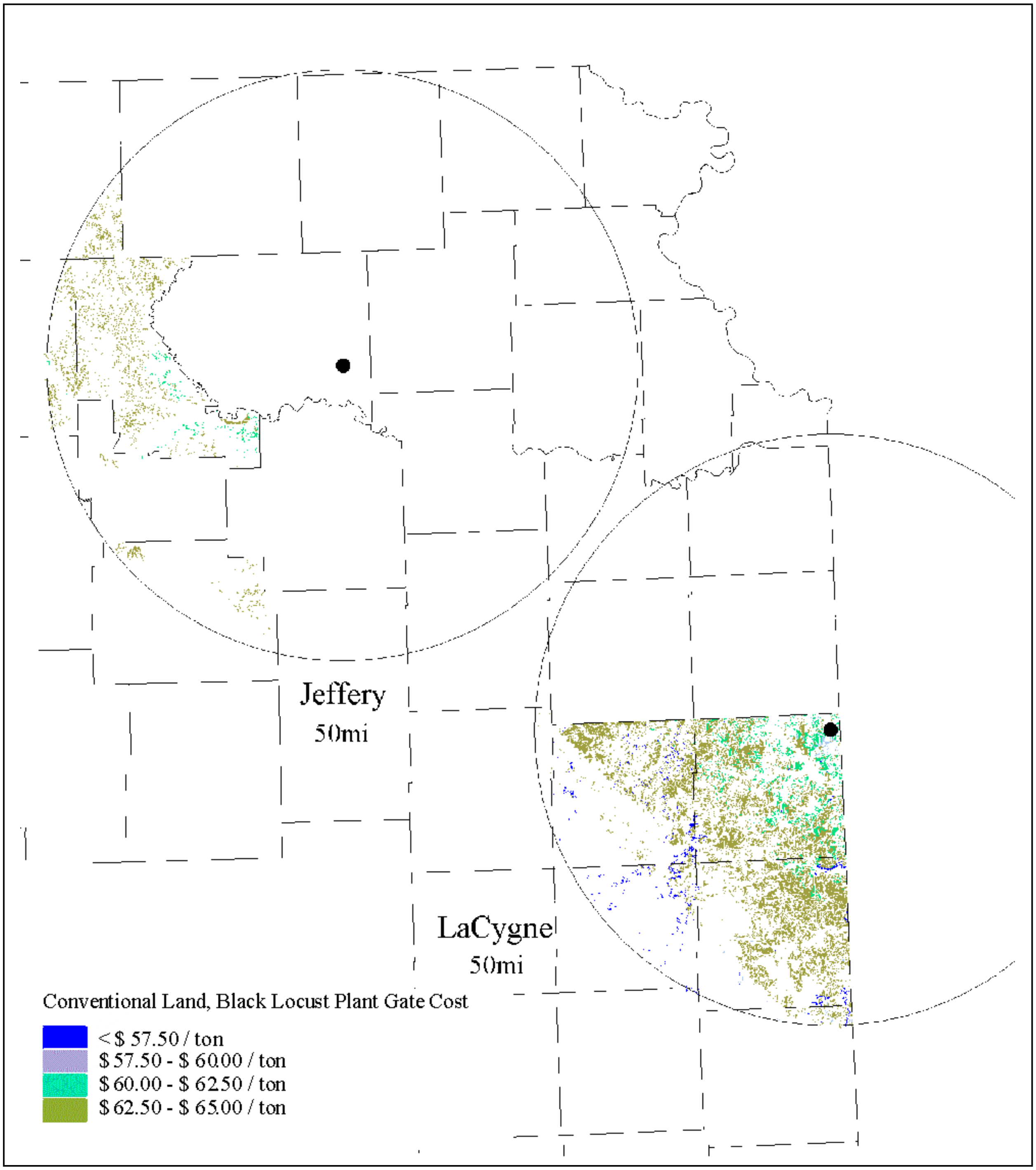

Figure 2.11.4 Map of Lowest Cost Black Locust on vs. Grain for Jeffrey and LaCygne
As with switchgrass, black locust at the plant gate competing with grain costs less in regions 2 and 4 than region 3.

3.0 WASTE ENERGY RESOURCES

3.1 Municipal Solid Waste (MSW)

Production of energy from municipal solid waste (MSW) supplies, which grew rapidly during the 1980s as a result of public policy at the Federal, State, and local levels that promoted the construction of waste-to-energy (WTE) facilities, has been curtailed during the 1990s. Current environmental policies encourage source reduction, reuse, and recycling and require costly pollution control at WTE facilities. Federal tax policy no longer favors investments in capital-intensive projects and limits municipal bond issues by States to finance the construction of facilities that are privately owned. The WTE industry is also feeling the competitive pressures of deregulation. Electricity prices are dropping and waste streams are going to the cheapest disposal option, which in many cases is out-of-state landfilling.

The MSW industry is also experiencing the effects of judicially driven deregulation decisions that have created uncertainty about the control of waste streams and protection of capital investments in WTE facilities. Two decisions by the U.S. Supreme Court (Fort Gratiot Landfill v. Michigan Department of Natural Resources and C&A Carbone, Inc. v. Town of Clarkstown, New York) have outlawed waste management practices in many municipalities throughout the country; however, recent decisions by lower courts interpreting the Supreme Court guidance have provided legally acceptable paths for municipalities to follow in developing waste management systems.

The use of landfills as a waste disposal option is likely to increase in the near term; however, it is unlikely that many landfills will begin converting waste to energy because of unfavorable economics, particularly with electricity prices declining.

3.2 Landfill Gas

Growth of the Landfill Gas Industry

This section discusses the development of the landfill gas industry and assesses its prospects for expansion. It describes the regulations that affect the landfill gas industry; provides information on U.S. Environmental Protection Agency (EPA) efforts to encourage the conversion of landfill gas (LFG) emissions into energy, the economic viability of LFG conversion into energy, and the impact of new environmental regulations.

One of the driving forces associated with the use of LFG as an alternative energy source is that methane and non-methane organic compounds emitted to the atmosphere through the decomposition of wastes in landfills contribute to global warming and to the creation of smog. In 1994, the USEPA established new Clean Air Act (CAA) guidelines as an addendum to Subtitle D of the Resource Conservation and Recovery Act (RCRA) for new and existing landfills to control methane and non-methane organic compounds emitted from landfills. Landfills that emit LFG in excess of 50 megagrams (50 metric tons) per year or those landfills that are designed to hold at least 2.5 million metric tons of waste are required to install a LFG collection system and have the option to either flare the gas or use it as an alternative energy source. Use of LFG as an alternative energy source does result in a smaller contribution to global warming because CO_2

emitted to the atmosphere through its combustion has less heat-trapping ability than does methane (~22 to 1).

However, it is possible that the impact of the RCRA/CAA regulations may have an adverse impact on LFG-to-energy projects because condensate generated by the conversion of methane into energy is designated as a hazardous waste and has an average cost of disposal approximately 80 percent lower than when the gas is flared. Therefore, while the introduction of these regulations may actually help reduce emissions, they may potentially discourage implementation of LFG-to-energy projects in favor of flaring.

The USEPA has established the Landfill Methane Outreach Program (LMOP) to help landfill owners/operators, cities, states, and other governmental agencies identify potential landfills for alternative energy production and determine the feasibility of producing fuel and/or electricity from LFG. As part of this program, a set of minimum criteria for evaluating the economic viability associated with implementing landfill gas-to-energy projects based on the experiences of previous projects located throughout the United States has been established, as listed:

- at least 1 million tons of waste in-place,
- a methane generation rate of at least 1 million cubic feet per day,
- still receiving wastes or closed for no more than 3 years.

It should be noted here that these criteria do not take into account any source reduction, reuse, and/or recycling programs that would have a direct effect on the amount of organic matter diverted from the landfill. Because the production of landfill methane is highly dependent upon organic materials such as paper and food and yard wastes, the amount of landfill gas could substantially decrease due to these reduction, reuse, and recycling programs.

Production of Landfill Gas in Kansas

Currently, no data exists concerning the production of LFG for energy purposes in Kansas nor do any LFG facilities exist within the state. A previous study by Nelson estimated the amount of methane (landfill-derived gas, tons per year) that could be produced in each county in 1990. This data was determined using an USEPA method for deriving methane production based on estimating the total quantity of waste in-place (tons) in 1990. The total amount of waste in-place was estimated from per capita waste generation, county population data, county rainfall data, and a national estimate of the amount of waste that is landfilled. Table 3.2.1 presents the estimated annual production of methane based on 1990 data and the potential total capacity and energy production (MW and kilowatt-hours) achievable using these amounts.

Table 3.2.1 Landfill Gas Production Potential in Kansas

County	MCF	kW-h	MW	County	MCF	kW-h	MW	County	MCF	kW-h	MW
Allen	12,682	1,039,940	0.12	Greenwood	6,914	566,921	0.06	Pawnee	4,985	408,773	0.05
Anderson	6,906	566,299	0.06	Hamilton	1,558	127,735	0.01	Phillips	4,498	368,815	0.04
Atchison	14,723	1,207,316	0.14	Harper	6,230	510,858	0.06	Pottawatomie	12,730	1,043,826	0.12
Barber	5,405	443,229	0.05	Harvey	25,152	2,062,495	0.24	Pratt	8,556	701,604	0.08
Barton	25,831	2,118,179	0.24	Haskell	2,436	199,753	0.02	Rawlins	2,450	200,896	0.02
Bourbon	12,784	1,048,316	0.12	Hodgeman	1,425	116,848	0.01	Reno	52,840	4,332,849	0.49
Brown	9,496	778,684	0.09	Jackson	9,528	781,287	0.09	Republic	5,890	482,991	0.06
Butler	38,821	3,183,306	0.36	Jefferson	12,927	1,060,054	0.12	Rice	9,320	764,205	0.09
Chase	2,601	213,260	0.02	Jewell	3,976	326,020	0.04	Riley	52,332	4,291,225	0.49
Chautauqua	3,940	323,102	0.04	**Johnson**	**332,098**	**27,232,055**	**3.11**	Rooks	4,265	349,742	0.04
Cherokee	18,084	1,482,856	0.17	Kearny	2,380	195,167	0.02	Rush	2,688	220,443	0.03
Cheyenne	2,264	185,659	0.02	Kingman	7,268	595,965	0.07	Russell	7,050	578,060	0.07
Clark	1,642	134,629	0.02	Kiowa	2,461	201,775	0.02	Saline	40,503	3,321,258	0.38
Clay	7,753	635,745	0.07	Labette	20,783	1,704,196	0.19	Scott	3,568	292,549	0.03
Cloud	9,772	801,293	0.09	Lane	1,558	127,768	0.01	Sedgwick	380,400	31,192,814	3.56
Coffey	7,504	615,316	0.07	Leavenworth	48,909	4,010,566	0.46	Seward	11,423	936,717	0.11
Comanche	2,051	168,191	0.02	Lincoln	3,159	259,046	0.03	Shawnee	243,375	19,956,715	2.28
Cowley	30,333	2,487,339	0.28	Linn	6,721	551,095	0.06	Sheridan	2,131	174,714	0.02
Crawford	30,712	2,518,406	0.29	Logan	2,102	172,388	0.02	Sherman	4,629	379,544	0.04
Decatur	2,781	228,060	0.03	Lyon	29,027	2,380,175	0.27	Smith	3,539	290,161	0.03
Dickinson	16,270	1,334,108	0.15	McPherson	22,281	1,827,032	0.21	Stafford	3,538	290,095	0.03
Doniphan	7,378	605,008	0.07	Marion	10,799	885,500	0.10	Stanton	1,505	123,384	0.01
Douglas	59,058	4,842,739	0.55	Marshall	10,269	842,074	0.10	Stevens	3,041	249,355	0.03
Edwards	2,569	210,630	0.02	Meade	2,909	238,521	0.03	Sumner	20,687	1,696,352	0.19
Elk	3,017	247,411	0.03	Miami	18,415	1,510,059	0.17	Thomas	5,382	441,319	0.05
Ellis	16,931	1,388,368	0.16	Mitchell	6,361	521,604	0.06	Trego	2,584	211,896	0.02
Ellsworth	5,277	432,753	0.05	Montgomery	34,012	2,788,946	0.32	Wabaunsee	5,527	453,178	0.05
Finney	17,840	1,462,891	0.17	Morris	5,222	428,203	0.05	Wallace	1,255	102,950	0.01
Ford	16,176	1,326,396	0.15	Morton	2,207	180,991	0.02	Washington	6,489	532,094	0.06
Franklin	18,115	1,485,459	0.17	Nemaha	9,005	738,408	0.08	Wichita	1,854	152,058	0.02
Geary	24,767	2,030,927	0.23	Neosho	15,321	1,256,362	0.14	Wilson	9,482	777,533	0.09
Gove	2,257	185,063	0.02	Ness	2,805	230,029	0.03	Woodson	3,605	295,609	0.03
Graham	2,469	202,479	0.02	Norton	4,080	334,530	0.04	Wyandotte	251,012	20,583,000	2.35
Grant	4,348	356,512	0.04	Osage	12,782	1,048,121	0.12	**KANSAS**	**2,312,585**	**189,631,956**	**21.65**
Gray	3,332	273,214	0.03	Osborne	4,547	372,873	0.04				
Greeley	1,141	93,552	0.01	Ottawa	4,795	393,175	0.04				

Using the criteria listed above, only the landfill in Johnson County has the potential to be economically feasible for generating energy from landfill gas. Sedgwick County meets the required methane generation rate, but wastes in Sedgwick County are divided between two separate landfills (one now closed) and the actual amount of waste contained in the closed landfill is not known, and the newer landfill does not have 1 million tons of waste in-place at this time. More importantly, the City of Wichita, which has contributed and continues to contribute a majority of the wastes to the landfills, has begun an aggressive paper and organic waste recycling and reuse (compost) campaign. Therefore, it is highly unlikely that given these circumstances landfill gas produced from the newer landfill would be economically feasible.

While the landfill located in Johnson County does meet all three criteria listed above, it too is currently subject to source reduction, reuse, and recycling programs within the county that could have a direct impact on the amount of methane produced. The extent of these programs on the waste stream (actual percentage of wastes reduced, reused, or recycled), and subsequently on the production of methane produced by the landfill, is yet to be determined. In order to fully ascertain the effect of these source reduction, reuse, and recycling programs on landfill gas production, a measurement of the amount of methane produced (cubic feet per day) as well as the composition throughout the course of at least one year (to determine the seasonal impact on production) would be required. Therefore, the economic feasibility associated with producing methane for the generation of electricity cannot be evaluated at this time.

3.3 Waste/Scrap Tires

The EPA claims that approximately 250 million car, truck and off-road tires are disposed of annually, with the majority currently being landfilled or stockpiled. This equates to nearly one tire for every person in the United States. According to excise tax records, the State of Kansas disposed of over 2.63 million tires in 1997.

Discarded tires pose serious environmental and health risks as fire hazards, which are extremely difficult to extinguish, and because their shape allows them to hold water, they provide an ideal breeding ground for mosquitoes.

Within the last 10 to 15 years, waste/scrap tires have been used as an alternative energy sources for the pulp and paper industry, cement kilns, and in utility boilers for electricity production. The EPA estimates that 11 percent of all waste/scrap tires are now being used for energy purposes. In general, tires are substituted for coal in utility boilers, typically less than 15%. Tires offer a fuel that has a higher heating value than coal (~15,000 Btu per pound versus 12,000 Btu per pound for most coals) and in most cases, burns cleaner than coal due to its low sulfur and nitrogen content. Waste/scrap tires have the greater combustion and economic efficiency when fired in cyclone or stoker burners.

Several utilities throughout the United States have co-fired waste/scrap tires in conjunction with coal, as listed below:

- Wisconsin Power & Light
- Illinois Power Company
- Northern States Power
- Manitowoc Public Utilities
- Ohio Edison
- Big Stone (South Dakota)
- Connecticut Power & Light

Wisconsin Power & Light and Illinois Power co-fire with 10% and 2% waste/scrap tires respectively while Ohio Edison used whole tires in its facility and Connecticut Power & Light was fueled entirely with waste/scrap tires.

In most instances where waste/scrap tires have been used as an alternative energy source for electricity production, the state has provided some financial incentive in helping to implement their use. Wisconsin Power & Light used grants from the Wisconsin Department of Natural Resources to purchase tire-derived fuel (TDF) handling equipment and conduct emissions testing during the start-up phase. In addition, Northern States Power and Manitowoc Public Utilities have received similar funding. Wisconsin implemented a program in 1995 that would pay a utility $40 per ton of scrap tires processed and used in their boilers. This roughly equates to a subsidy of $1.33/MBtu delivered.

Illinois Power Company used $457,000 in state grant funding to purchase fuel-handling equipment. They estimate that they will save $670,000 annually by combusting nearly 7.5 million tires in their two cyclone burners. Illinois' Used Tire Recovery Fund estimated that with the economic incentives it provides, by the end of 1995, it would have enough TDF-burning capacity on-line to combust the state's 12 million scrap tires generated annually.

The Kansas City metropolitan area generates enough waste/scrap tires which could potentially be used in the cyclone boilers at LaCygne to generate between 1.75 and 2 MW of electricity. However, a fair percentage of these waste/scrap tires are currently being sold for use in Illinois. In addition, no state grant programs exist such as those in Wisconsin or Illinois to make it economically attractive for a utility to consider investing in a TDF operation. For these reasons, it is highly unlikely that TDF will be used as an alternative energy source in Kansas.

3.4 Agricultural Residues

Crop residues from wheat, corn, and other agricultural production in Kansas, albeit diffuse, are a potential source of boiler fuel, estimated to be 3.5 to 5.5 million removable tons annually.[65]

Agricultural Crop Residues

The state of Kansas has significant bioenergy potential in the crop residues, especially corn and wheat, that remain after harvest. However, the amount of crop residue that can actually be removed from the field without affecting soil erosion and soil tilth is in most cases considerably less than the quantity of residue available immediately after harvest. The amount of residue that can be removed from a field without exceeding both the tolerable limit for soil loss and/or contributing to a sustained reduction in soil tilth is a function of crop type and yield, amount of tolerable soil loss, physical characteristics of the soil, cultural practices, and local climate conditions.

Soil tilth data were obtained for selected locations in Kansas from the Natural Resource Conservation Service (NRCS) in Lincoln, Nebraska. These values reflect the amount of agricultural crop residue that must be returned to the field on an annual basis in order to maintain soil tilth. Within the state of Kansas, soil tilth values for corn range from 3,841 pounds per acre in the northwest portion of the state to 4,444 pounds per acre in the southeast.

[65] 3.5 million ton/year value from NREL, ***Resource Assessment of Waste Feedstocks for Energy Use in the Western Regional Biomass Energy Area***, 1991; 5.5 million ton/year value from Kansas State University, Biomass Resource Assessment for the State of Kansas, 1992.

Each of the nine agricultural statistic districts (ASD) was assigned a soil tilth value based on the NRCS soil tilth data. These values were assigned to all counties within the individual ASD. The quantity of residue present at harvest based on county-level dryland and irrigated yields obtained from Kansas Agricultural Statistics, Topeka was compared to the assigned soil tilth value to determine the excess residue, if any, that would be available. In this manner, this soil tilth data can be used as an elimination procedure. It is important to note that this value does not account for residue that must be left on the field to prevent rainfall and/or wind erosion. No excess residue was present for both dryland and irrigated wheat and only minimal amounts (<< 1 ton) for dryland corn. However, in a majority of counties, excess residue from irrigated corn was available considering soil tilth alone.

An analysis of corn and wheat residue availability subject to erosion constraints only was performed on each soil type not classified as highly erodable in 92 of the 105 counties in Kansas (Nelson and Schrock, 1992). The soil types contained in the remaining 13 counties have been classified by the National Resources Conservation Service (NRCS) as highly erodable and removal of crop residue from these lands would only serve to worsen the erosion situation; therefore, these counties were not considered in the study. Residue removal was based on using the Revised Universal Soil Loss Equation (RUSLE) and the Wind Erosion Equation (WEQ) to estimate the amount of crop residue that must remain on the field such that soil loss would be no greater than the tolerable value as set by the NRCS.

Because the soil tilth analysis found that only irrigated corn residue should be considered, data from the erosion analysis focused only on irrigated corn residue. The amount of excess corn residue that could potentially be removed from irrigated land in each county on a per acre basis was estimated as the difference between the amount of residue available at the time of harvest and the greater value of the amount of residue required to control rainfall or wind erosion, divided by the amount of acres of irrigated corn within that county.

The range of values across the state from irrigated corn ranged from 3,841 to 3,383 pounds per acre. Therefore, in some counties it appears that residue from the harvest of irrigated corn may be available for alternative energy purposes.

Agricultural Crop Residues - Economic Considerations

Because the possibility exists that irrigated corn residue could be removed for energy purposes, an analysis of the costs associated with harvesting (swathing), baling and transporting irrigated corn residue to the field edge was performed. Cost data was obtained from custom rates (Kansas Custom Rates, 1996) typically used for agricultural crop residue harvest operations and is presented in terms of dollars per ton.

Corn Stover Cost Categories	
swathing	\$5.88 / ton
baling	\$15.00 / ton
hauling to field edge	\$3.00 / ton

miscellaneous (pickup trucks, fuel tanks, etc.)	10% of swathing and baling
Total "edge-of-field" Cost	$25.97 / ton

These values are for a custom operator, without any additional price mark-up. The energy content of corn stover is approximately 13 MBtu per ton. Therefore, $25.97 per ton translates into $1.99 per million Btu ($25.97/13 MBtu) at the field edge.

Agricultural Crop Residues - Transportation

Transportation costs associated with agricultural crop residues were determined from the same program (ORNLTRAN.xls) used for herbaceous energy crop transport. The following assumptions were made concerning corn stover transport: bale weight is equal to 2,000 pounds, moisture content is 15%, and a truck capacity of 40 bales. Using these inputs, the cost per dry ton and the cost per MBtu associated with transporting 40 bales of corn stover to the power plant for seven different one-way trips was analyzed. The cost per ton ranged from $1.55 – 3.34 and the cost per Mbtu ranged from $1.97 – 2.11, suggesting that transportation cost alone would make crop residue expensive fuel.

3.5 Animal Wastes

Kansas consistently ranks as one of the top three states in total cattle production and slaughter and in the top ten in swine production. Several state and regional studies (KSU and NEOS) have shown that the production of manure is significant from beef and dairy cattle, and swine in the state of Kansas. A majority of the manure generated in the state is attributable to beef cattle located on dirt feedlots, followed by swine and dairy cattle. However, there are several problems associated with the use of manures for large-scale energy production. First, collection of manures from beef cattle on dirt feedlots has been deemed infeasible for use in anaerobic technologies. Second, the generation of manures tends to be diffuse throughout Kansas, which implies increased collection and distribution costs. In addition, the technology required to convert the animal manures into a viable energy source is complex and has not been adequately demonstrated for large-scale electricity generation. For these reasons, the use of animal manures was eliminated as a potential biomass energy source for utility scale electricity production.

3.6 Wood Wastes

Wood wastes from logging and milling in the State are estimated to be 130,000 tons annually, but the resource is considered diffuse.[66] Kansas annually generates 390,000 dry tons of combustible municipal solid waste (after 50% recycling is considered).[67] This resource is highly location specific and its use is significantly affected by tipping fees that would otherwise be paid to dispose of the waste.

Kansas cities and towns generate significant quantities of wood wastes in the form of tree trimmings, branches and bark associated with scheduled tree trimming maintenance operations. Additionally, secondary wood processing operations such as finished cabinet makers generate

[66]Kansas State University, Biomass Resource Assessment for the State of Kansas, 1992.
[67]Union of Concerned Scientists, *Powering the Midwest,* 1993.

chips and sawdust through their manufacture of finished wood products. Most of the wastes that result from tree trimming operations in cities and towns are processed into mulch and sold commercially. Wood wastes from tree trimming operations in most Kansas cities and towns amounts to less than 1,000 dry tons per year and due to the location of generation is considered diffuse. Use of this resource for electricity generation purposes has been shown to be infeasible due to a small economy-of-scale and cost of transportation to the end-use.

A majority of the wood wastes such as those mentioned above are generated in the eastern 1/3 of the state. Walawender and Geyer (1997) conducted a survey of primary wood processing operations (sawmills) and secondary manufacturers in northeastern Kansas and found that about 17,200 tons of wood waste is generated per year with the majority from secondary manufacturers. Wood waste generation from primary and secondary wood processors is generally diffuse and quantities at any one location are small (<5,000 tons per year). In addition, a majority of the businesses surveyed either sold their wastes for animal bedding purposes or mulch, or burned them outdoors.

4.0 BIOMASS CONVERSION TECHNOLOGIES

4.1 Introduction

The primary technologies for the conversion of biomass to electricity production are direct combustion, gasification, and pyrolysis. Previous work has been conducted by several organizations to characterize these biomass conversion technologies. The Electric Power Research Institute, the Gas Research Institute, the National Renewable Energy Laboratory, Battelle Columbus, private industry and others have contributed to the base of knowledge. Previous characterizations of conversion systems, where appropriate, were used in this assessment to the extent possible to determine equipment costs, efficiencies, and operating characteristics for biomass conversion systems.

4.2 Direct Combustion

4.2.1 Overview of Combustion Systems

Direct combustion involves the oxidation of coal or biomass with air, giving off hot flue gases that are used to produce steam. Steam is used to produce electricity in a Rankine cycle. Older direct combustion systems were based on pile burner technology using stationary grates. The majority of utility power boilers now in service are fired by pulverized coal, cyclone, or stoker-grate systems. Increasingly, new steam-cycle power plants are using fluidized bed and improved pulverized systems.

Pulverized Coal and Cyclone Combustion Systems

First employed in the 1920s, pulverized coal is the dominant combustion system in US electric generating facilities, with over 80% of all coal-fired power plants using this technology. Pulverized coal systems are also the predominant generation technology used in Kansas, as all but one of the coal-fired facilities operated by KEURP members use this technology. In pulverized coal facilities, coal is processed to particle sizes as fine as talcum powder (~0.003 inch) via multi-stage crushing and milling, and the fineness of the pulverized coal particles and the turbulence provided by combustion air provides sufficient residence time for the coal particles to be efficiently combusted. The pulverized coal powder can be injected into furnaces via several firing methods, including the following:

- tangential (firing through the four corners of the furnace),
- single or front wall (firing through the front wall of the furnace),
- opposed (firing through the front and rear wall of the furnace), and
- turbo (firing in a downward direction).

Coal that has been crushed (which requires less equipment and horsepower to prepare than full pulverizing) and which has slightly larger dimensions (1/4 inch or less) can be used in a cyclone furnace. Fuel particles of this size are too large to burn completely in suspension and would pass through a pulverized coal boiler without burning all of the carbon. In a cyclone boiler, crushed coal particles are thrown against the inside surface of the furnace by high velocity circulating combustion air and are trapped in a high temperature molten slag layer where they burn to completion. Cyclone furnaces can handle a range of coals and have successfully co-fired several solid waste fuels. Only three coal-fired power plants in Kansas use a cyclone furnace/boiler system, and only one is owned and operated by a KEURP-member (KCP&L's La Cygne Unit 1).

Grate Combustion Systems

In stoker (or traveling) grate systems fuel is fed on to a revolving chain of grate bars.[68] Sized fuel is metered to a series of distribution devices that spread it uniformly over the stoker grate surface. As the grate moves across the furnace, the fuel is combusted. Finer particles of fuel are burned in suspension with the assistance of overfire air turbulence systems. Coarser, heavier fuel particles are spread evenly on the grate forming a thin, fast-burning fuel bed, with combustion air introduced from below the grate. Non-combustibles (residual matter, slag, and ash) are conveyed on the grate to the far end of the furnace and discharged into an ash hopper. Modern stoker grate boilers can be designed to handle various fuels and have exhibited few slagging problems with low- to medium-ash fuels. However, there are no stoker-grate combustion systems operating in Kansas.

Fluidized Bed Combustion Systems

Combustion systems using fluidized beds are a relatively new approach to combusting coal and other fuels for steam-cycle power generation. Fluidized bed combustion systems use a heated bed of circulating solids (sand or limestone) within a rising column of air to burn many types and classes of fuels.[69] The thermal "fly wheel effect" of the bed material in fluidized bed systems allows the system to handle varying feedstocks with different compositions and moisture contents yet maintain high combustion efficiency. If the fuel to be combusted contains sulfur, fluidized bed boilers use limestone instead of sand to reduce SO_2 emissions. Fluidized bed systems also limit the formation of NO_x emissions due to uniform, low combustion temperatures (1,500 to 1,600 ^oF). There are no fluidized bed combustion systems operating in Kansas.

4.2.2 Direct Combustion of Biomass

There are more than 500 dedicated wood-fired plants in the US, typically in the 10 to 25 MW capacity range. Only a third of these plants offer electricity for sale. The majority of the plants are owned and operated by paper and wood products companies. The availability of suitable feedstocks within 50 to 75 miles of the plants is the predominant size constraint. At present, nearly all wood-fired plants use steam turbines. Because of their relatively small capacities and the heat value and moisture characteristics of wood and waste materials, overall conversion efficiencies in dedicated wood-fired facilities have been limited to 20-25%. Such plants have an associated capital cost of $1300-2000/KW. This compares to conversion efficiencies of about 35% for a modern coal plant, with capital costs in the $1200-1800/KW range.

Table 4.1 lists the major biomass-fired generating facilities operated by US electric utilities. Fewer than 20 wood-fired facilities are owned and operated by investor- or publicly-owned utilities. Investor- and publicly-owned utilities have also been involved in only a handful of dedicated facilities using MSW, waste tires and other waste feedstocks. A growing number of

[68] Stoker grate-type boilers may use different fuel delivery and positioning approaches, including travelling and vibrating grates.

[69] Fluidized bed boilers may be either "circulating" or "bubbling." The distinguishing feature is the velocity of air through the boiler unit. Circulating systems, which have a higher combustion air velocity, have better combustion efficiencies and are better at desulfurization than bubbling systems.

utilities are conducting tests or full-scale operations using wood and waste materials to co-fire with coal in existing power plants.

Cofiring of wood, wood waste, MSW, and other biomass and waste feedstocks in retrofitted coal-fired power plants generally have higher efficiencies, lower capital requirements, and lower electricity costs than combusting the same fuels in dedicated biomass and waste fuel power plants.[70] The local availability and cost of biomass and waste resources is a principal factor in determining the feasibility of co-firing at a specific site. Optimal sites for co-firing are those areas where there is enough available biomass or waste fuel to easily support the level of co-firing and where the cost of the resource is less than that of coal.

In general, biofuels have higher volatility, lower sulfur and ash content (ash content from MSW combustion is higher), and a lower heating value (tire-derived fuels heating value is higher) relative to coal. Although low in total ash, herbaceous crops, agricultural residues, and some trees can have a relatively high alkaline metal content (20-35% of resulting ash), and are also rich in chlorine and silica. These materials cause rapid fouling of heat transfer surfaces and furnace slagging. Therefore, many agricultural fuels have been found unsuitable for co-firing in existing power boilers.

Coal fired units augmented to co-fire biomass almost always require a biomass fuel handling system. There must be adequate space for delivery, unloading, and storage.[71] Scales are required to weigh fuel trucks before and after fuel deliveries. Hydraulic truck tippers may be required unless self-unloading trucks are used. Processing equipment such as hoggers, hammermills, and screens may be required to properly size the biomass material. All fuel handling equipment must be connected by conveyor systems. If wood waste is used, magnetic separators may be required to remove nails and other metals.

A delivered price for biomass and waste fuels at half the coal price may be required to offset the costs of capital equipment, added personnel, and technical risks of conversion; however benefits associated with biomass and waste fuel co-firing (e.g. emission reductions, solid waste disposal, fuel diversity, and local economic benefits) may support a higher price for such fuels.[72]

From an operational standpoint, fluidized bed boilers are probably best suited for combusting high moisture/low Btu fuels such as biomass and waste fuels, either in co-fire (with coal) or dedicated operation. Fluidized beds can fire somewhat higher percentages of alkali fuels due to the potential for intimate mixing of inhibitors with the burning fuel. Additives have been used in fluidized bed designs in attempts to reduce slagging from low- to medium-alkali fuels, but so far no systematic study of the potential for specific additives to reduce slagging from high-alkali biomass fuels has been undertaken.[73] Conversely, fluidized bed power plants do not represent a

[70] Co-firng is a fuel substitution option for existing capacity, not a capacity expansion option.
[71] Fuel storage area requirements for wood are approximately 1 acre per MW.
[72] A drawback to the use of biomass in a co-firing application is the potential for reduced marketability of fly ash due to the commingling of biomass and coal ash. At present, ASTM standards for concrete admixtures precludes the use of non-coal ash.
[73] Alkali Deposits Found in Biomass Boilers: The Behavior of Inorganic Material in Biomass Fired Power Boilers - Field and Laboratory Experiences, National Renewable Energy Laboratory, et al, NREL/TP-433-8142, Volume II, February 1996.

good opportunity for biomass and waste co-firing due the limited number of plants currently in operation in the US. No fluidized bed combustion systems exist in Kansas.

Next in terms of suitability for co-firing biomass and waste fuels are boilers integrated with cyclone furnaces, which require minimal modifications for feeding and mixing alternate fuels with coal. EPRI studies indicate that one of the lowest cost opportunities for co-firing biomass and waste fuels are cyclone systems.[74] Because the particle size of the boiler fuel is relatively large (~1/4 inch) in cyclone-type systems, biomass and waste fuels are more easily co-fired than in pulverized coal systems. Modifications to conveyor and fuel crushing subsystems in cyclone units will still be required to handle and process biomass and waste materials. Like fluidized bed systems, cyclone systems do not represent a significant opportunity for biomass and waste fuel co-firing in Kansas due to the limited number of plants in operation. Of all the coal-fired power plants operating in Kansas, only one cyclone-fired furnace/boiler is operated by KEURP members.

The stoker-grate-type boiler is also readily adaptable for co-firing solid, low ash biomass fuels. When co-firing biomass in a grate-type boiler, modifications may be needed to some subsystems such as the fuel spreader and the fuel grate to maintain efficient operation. However, no coal-fired stoker-grate systems operate in Kansas.

The requirements for retrofitting pulverized coal (PC) boilers to accommodate biomass and waste fuels in a co-fire application are substantially higher than with fluidized bed, cyclone, and stoker-grate systems. First, conventional coal pulverizer systems can only process a small percentage of biomass and waste material conveyed with coal (2% to 5% by heat input). Biomass and waste fuel pre-processed to a nominal size less than 2 inches is introduced with coal into the coal pulverizer system, where the coal and wood are simultaneously reduced to particles of 1/16 inches or less for injection into the boiler. Cofiring wood at higher levels than 2% to 5% in pulverized coal boilers can entail not only higher costs for biomass fuel preparation, but also potentially the added cost of a separate feed system to deliver biomass and waste fuels to the boiler.[75] EPRI and DOE estimate the capital requirements associated with biomass handling and processing equipment at $50/kW for pulverized coal systems using co-firing than 2 to 5% biomass, and $180-200/kW for pulverized coal systems co-firing more than 2 to 5% biomass.[76] Although co-firing biomass and waste fuels in pulverized coal boilers is more problematic than other boiler types, it is the primary scenario for biomass and waste fuel co-firing in Kansas as nearly all coal-fired power plants in the state are pulverized coal designs.

Wood and Wood Waste

Wood and wood waste may be used as the primary fuel for utility boilers. Chipped wood, wood shavings, sawdust, and shredded bark are materials that have been used as boiler fuels. The availability of local wood and wood waste supplies has historically limited dedicated facilities using wood to 10 to 25 MW of capacity. The strategy of using plantations to produce densely

[74] Moore, Taylor, Harvesting the Benefits of Biomass, EPRI Journal, May/June 1996, page 21.
[75] To co-fire biomass and waste fuels in a pulverized coal boiler, adjustments to fuel injection ports and combustion air systems may be needed. In systems that separately process and feed biomass, the pulverized biomass is typically introduced into the boiler through the lower injection ports to increase residence time and ensure complete burnout.
[76] Renewable Energy Technology Characterizations, EPRI and US DOE, TR-109496, December 1997, page 2-2.

spaced, fast growing trees (which can be chipped or used whole) may support dedicated facilities with larger generation capacities, thus reducing cost of electricity produced from wood.

Fast growing trees grown in a managed plantation uptake CO_2 from the atmosphere and use it, along with sunlight, moisture, and soil nutrients, to produce cellulose, which in turn can be combusted. This "closed loop" approach to electrical generation, where carbon is emitted during combustion but resequestered during tree growth, has obvious greenhouse-gas benefits. Burning wood also has other environmental benefits. Wood contains only one-fourth the nitrogen of coal, and conventional wood-fired power plants emit about 45% less NO_x than coal fired units. Wood also has a low sulfur content (less than five times less than that of coal) and the ash content of wood is one tenth to one twentieth that of coal. Particulate emissions from the combustion of wood are also low compared to coal.

EPRI has estimated the cost of preparation equipment for making wood chips for a 25 MW stoker grate or fluidized bed facility to be about $230/kW.[77] In an effort to eliminate the cost associated with chipping harvested trees, biomass power facilities have been proposed that would combust whole trees harvested from tree plantations. Called Whole Tree Energy™ facilities, 100 MW plants have been proposed within a 50 to 100 mile radius of 80,000 acres of tree plantations.[78] A 100 MW plant would use about 650,000 tons (about 10,000 acres of plantation) of trees per year based on a 65% plant capacity factor.

Whole tree burning emphasizes the use of hardwood tree species that are not desirable to the pulp and paper industry. Mature trees would be harvested and trucked to the plant for storage and drying in a domed enclosure. Moisture content would be reduced from 50% to 25% during storage (approximately 30 days) through use of waste heat recovered from the boiler flue gas. Before insertion into the boiler pit, trees would be cut to a length of approximately 30 feet, and then burned in a three-stage combustion process. First the whole tree sections volatilize and become char, which burns on the grate in a pile. The volatiles are released in the upper pile. These volatiles are combusted above the tree pile with the mixing of overfire air. Third, char falls through the openings in the grate and burns below the pile using underfire air. The relatively low moisture content of the wood and the high combustion temperatures would allow complete combustion with relatively low excess air.

The advantage of a whole tree approach is the minimized fuel preparation and handling in the field and at the plant, the ability to use waste heat for fuel drying, reduced particulate emissions from three stage combustion, and less ash residue than coal. Disadvantages are the approach has not been demonstrated on a large scale, the whole tree requires significant drying time, and whole tree harvesting and handling operations are foreign to most farmers and power plant operators.

---

[77] This cost estimate is in 1992 $ and is for a dedicated wood-fired facility, although it is indicative of the cost estimate for a 250 MW coal-fired facility that co-fires with wood at a rate of 10%. Source: Strategic Analysis of Biomass and Waste Fuels for Electric Power Generation, Appel Consultants, Inc., Electric Power Research Institute, 1993, page 2-43.

[78] The Minnesota Wood Energy Scale Up Project currently has over 1,800 acres of hybrid poplar trees planted on CRP lands near Alexandria, Minnesota, with the purpose to track and monitor economic costs associated with planning and developing large commercial plantings of hybrid poplar.

Because most types of wood have low sulfur, nitrogen, and ash content, co-firing wood is environmentally advantageous compared to burning 100% coal. Where wood and wood waste have been co-fired in major power plants, wood material has made up 10% or less of the heat input to the boiler. Co-firing of wood has been successfully demonstrated in fluidized bed, cyclone, stoker-grate, and some pulverized coal systems. Fluidized bed and stoker grate systems are better suited for co-firing wood with relatively high moisture content, while cyclone and pulverized coal systems require relatively dry wood for co-fire. Co-firing wood in cyclone and pulverized coal facilities requires the most attention to fuel handling and processing as the size of wood particles must be consistent with the size of coal particles to permit proper introduction into the furnace/boiler, suspension, and completeness of burn.

Municipal Solid Waste and Waste Tires

The use of municipal solid waste as a boiler fuel in dedicated, waste-to-energy (WTE) facilities is relatively common in the US, particularly where high costs of waste disposal are encountered and where municipal governments are responsible for both waste disposal and power production. As of 1996, there were 102 WTE plants operating in the US, mostly in the eastern US where landfill space is less available. To consider use of municipal solid waste as a primary boiler fuel, the amount, cost, and composition of local MSW needs to be assessed. Also, recycling can decrease the amount and types of MSW and change its composition. Recycling paper only decreases the combustible content of MSW and decreases its heating value. Yet most communities engaged in recycling also recycle plastics, glass, and metals, so the overall heat content of MSW subjected to recycling may not change significantly relative to MSW not subjected to recycling.

Even if municipal solid waste is a zero cost fuel or a tipping fee is paid to the utility, combustion of municipal solid waste may not be economical because of other technical considerations. Refuse handling and processing is high maintenance. Additional emission control equipment may be needed due to increased emissions of particulates, chlorine, and trace metals. Municipal solid waste does not store well, and may therefore create a health risk and an odor problem.

Mass burn plants, which on the average use 850 tons per day of municipal solid waste without any significant material processing, represent 85% of WTE plants in use in the US.[79] A truck entering a waste-to-energy plant is weighed before and after depositing its load of waste directly onto an enclosed tipping room floor or refuse pit. The storage capacity of the tipping room floor or refuse pit is usually two to four days of required boiler fuel. All the material received at the plant (except large, non-combustible items) is transferred to a feed table via crane or front end loader and feed chutes where a series of hydraulic rams push material into the boiler.

Refuse-derived fuel (RDF) technology is a newer approach to using MSW for power production. RDF involves processing MSW to improve its combustion characteristics by making the fuel more consistent in size and composition. RDF systems shred materials to predetermined particle sizes, magnetically separate metals, and screen other non-combustibles such as glass. The processing of MSW for fuel enables RDF boiler subsystems to achieve efficiencies around 75%-

[79] *Municipal Solid Waste Combustion in the United States: 1996-1997 Yearbook, Directory, and Guide,* Governmental Advisory Associates, 1997.

80%, a 10% improvement over mass burn units.[80] The average RDF-fired facility uses about 1,875 tons of waste material per day. Every ton of RDF produces 200 to 300 pounds of ash, which has been argued to be a hazardous material, thus potentially increasing its disposal cost.[81] Pollution control techniques have evolved to mitigate the concerns for dioxin emissions in RDF facilities.

The predominant boiler type in dedicated WTE boilers is stoker-grate, where mass burn or RDF feedstocks are partially burned in suspension, with remaining combustibles and non-combustibles dropping to a traveling or sloping grate. There the combustible portion of the refuse is burned off and non-combustibles drop into an ash pit for reclamation and disposal.

RDF used to supplement crushed coal in a cyclone boiler should be relatively low in ash, have minimum ferrous metal, aluminum, and other non-ferrous metal, and should be small enough to be fed pneumatically to the boiler. The processing system for such a fuel would generally be a low yield system, between 40% and 60% of the raw refuse.[82] RDF for dedicated traveling grate stoker boilers should be relatively low in ash, as free as possible of ferrous metal, aluminum, and other non-ferrous metals, and can be of a particle size considerably larger than required by cyclone boilers. The processing system for such a fuel will be a higher yield, around 70% to 85% of the raw refuse.[83]

In both mass burn and RDF facilities, sophisticated flue gas cleaning systems are required to remove sulfur, particulate, mercury, and dioxin emissions. Fluidized bed combustion systems, which can efficiently use a high ash fuel with variable particle sizes and moisture content characteristic of RDF, is also being used in new dedicated WTE facilities.

Most dedicated RDF boilers are new installations; however, it is possible to retrofit existing boilers to become dedicated RDF boilers. To be candidates for retrofitting, the existing boilers are typically conservative in design and are older units that are underutilized or used as standby units. These plants are usually located near large metropolitan areas, a source of large quantities or refuse.

Refuse derived fuel (RDF) can be used to co-fire with coal, usually 10% or less of heat input. RDF co-firing with coal has been demonstrated with cyclone and stoker grate units to which RDF receiving, handling, and boiler feed equipment has been added.[84] In retrofit situations, larger bottom ash systems may be required to accommodate the large volumes of ash produced from combusting RDF. In RDF co-firing, boiler efficiencies may drop up to 3.5% because of the lower heat content of RDF and associated efficiency degradation due to boiler slagging and

[80] Waste to Energy Screening Guide, Volume 1: Guidebook, EPRI, pages S-6 and S-7.
[81] Testing of ash from mass burn or RDF facilities using localized or regional MSW may be required to determine its composition and its disposal status.
[82] Babcock and & Wilcox, Steam: Its Generation and Use, page 27-11.
[83] Babcock and & Wilcox, Steam: Its Generation and Use, page 27-12.
[84] Co-firing RDF in a pulverized coal system is problematic, yet technically feasible. This combination has not been widely demonstrated. New fluidized bed combustion systems can readily accommodate RDF in a co-fire application with coal, although the newness and limited number of fluidized bed systems has restricted the number of co-fire demonstrations.

fouling.[85] To maintain proper operation of cyclone and stoker grate boilers, EPRI provides the following recommended guidelines for the characteristics and quality of RDF used in cofiring applications:[86]

Maximum particle size (inches)	2.5 (stoker-grate) 1 inch (cyclone)
Bulk density (pounds/ft^3)	4
% weight	
moisture	24
ash	12
volatile matter	54
fixed carbon	10
Heating value (Btu/pound)	5900

Where the disposal of existing and newly discarded tires is a problem, the use of tires as a feedstock for power production is a possible solution. Scrap tires have an energy content of around 14,000 to 16,000 Btu per pound (a value higher than coal), less nitrogen and sulfur content than some coals, moisture content is nil, and the ash component is less than 5%. Therefore, waste tires can be a good supplemental boiler fuel. However, since tires contain 1-1.5% sulfur, boilers burning waste tires need desulfurization equipment.

Tires can be processed into tire-derived fuel (TDF), where shredders produce small tire chips and magnets remove a significant portion of embedded belting wire. Tire processors have developed methods that can remove <99% of the heavy bead wire and <96% of all wire from tires. Firing whole tires in dedicated stoker boilers eliminates the requirement for chipping and wire removal, yet creates special design considerations in removal of by-products from the boiler ash pit. By-products include steel wire, zinc oxide, calcium salts, and other material.

Experience to date has shown that cyclone and stoker-grate boilers work best to co-fire tire-derived fuel (TDF) with coal since little or no modifications to the boilers are required.[87] Newer fluidized bed combustors can readily co-fire TDF with coal, especially ones designed with TDF fuel in mind. TDF is not commonly used in pulverized coal boilers due to problems associated with pulverizing tires. Although tires can be shredded into fine pieces, the pieces are still larger than their coal particle counterparts. Injecting larger tire pieces into a pulverized boiler and getting full burn has been problematic in certain field tests.

Herbaceous Crops and Agricultural Wastes

Because of their low heat content, seasonality and high alkali-content (and thus their potential for boiler slagging and fouling), herbaceous crops such as switchgrass and agricultural wastes such as wheat straw and corn stalks are generally not suitable as primary boiler fuels, nor have they been widely used as co-fire materials with coal. Only very limited field demonstrations have

[85] *Data Summary of Municipal Solid Waste Management Alternatives: Volume IV, Appendix B - RDF Technologies*, SRI International for National Renewable Energy Laboratory, NREL/TP-431-4988D, October 1992.

[86] Waste to Energy Screening Guide, Volume 1: Guidebook, EPRI, page 9-5.

[87] In *Steam: Its Generation and Use*, Babcock & Wilcox indicates that TDF in ½ to 1 inch particle sizes is near optimum for use in cyclone boilers. Smaller grinds can be made, but cost of the fuel increases.

been conducted to investigate the feasibility and effects of these materials in co-firing applications.

However, based on potential environmental benefits and favorable agronomic analyses of plantation switchgrass for Kansas (reported in Section 2), Iowa, Alabama, Oklahoma, and other locations, interest remains keen on using switchgrass as a fuel to co-fire with coal in utility boilers.

Madison Gas & Electric Company has co-fired switchgrass on a test basis in a 50 MW pulverized coal boiler. MG&E's short term test involved co-firing 10% switchgrass (on a heat basis) in a facility already modified to handle and process an alternate boiler fuel (waste paper). While MG&E did not discover any evidence of boiler slagging or fouling following the test, the duration of the test period (5-days) was not long enough to instill sufficient confidence that a 10% switchgrass ratio is a reasonable target. Researchers in Denmark have conducted experiments on slagging and boiler effects from co-firing a ratio of 10% waste straw (a material similar to switchgrass) with coal in a pulverized facility. Preliminary results for a short test period have also indicated little slagging and fouling impact, but longer duration tests are underway to remove technical uncertainties.[88] Danish experience indicates slagging and fouling increases as a function of difference between the flue gas temperature and the heat transfer metal surface temperature, so modifications of existing utility boilers may be required to ensure successful long term co-firing of switchgrass.

As a general guideline, NREL recommends using boiler fuels with alkali levels of 0.4 pounds/MBtu or less (the tendency to form deposits or slag increases between 0.4 pounds/MBtu and 0.8 pounds/MBtu, to definite fouling and slagging above these levels).[89] Black & Veatch, a power plant engineering and construction firm, concurs that the potential for boiler slagging and fouling is low when alkali content is less than 0.4 pounds/MBtu, and recently determined from an analysis of mineral ash that the alkali content of co-fired switchgrass (5%) and coal (95%) to be 0.39 pounds/MBtu.[90]

Based on the above information, it appears that a conservative upper limit for co-firing switchgrass with coal that minimizes the potential for slagging and fouling is on the order of 5% (on a heat basis). Using higher percentages of switchgrass input (say 10%) may be feasible in certain situations, but the likelihood of boiler effects increases.

While there are a number of conceivable options for handling and processing switchgrass in a co-fire application, two recent investigative efforts sponsored by the Chariton Valley RC&D have resulted in the following approaches for switchgrass management in a 700 MW pulverized coal facility in Ottumwa, Iowa:

---

[88] Co-firing Straw and Coal in a 150 MW Utility Boiler, I/S Midtkraft Power Company and Technical University of Denmark, 1998.

[89] Alkali Deposits Found in Biomass Power Plants: A Preliminary Investigation of Their Extent and Nature, National Renewable Energy Laboratory, et al, NREL/TP-433-8142, Volume 1, February 1996.

[90] *Biomass Energy Conversion Technology Study*, Black & Veatch Engineers, prepared for Chariton Valley RC&D, Inc. May, 1995.

Danish/RW Beck Approach (circa 1998)
Switchgrass is unloaded from trucks using overhead cranes. During unloading the bales are weighed and moisture determined using microwave technology. The bales may be stored or loaded on to conveyor belts for processing. After cords that hold the bales together are cut, the bales are shredded by heavy duty shredders. The shredded material is sucked through a trap that removes heavy materials (e.g. stones) and then is sent to a hammermill where the switchgrass is ground into pieces shorter than 1 inch. From the hammermill the switchgrass particles are pnuematically transported to the furnace.

B&V Approach (circa 1995)
Switchgrass is unloaded from trucks using forklifts. The bales may be stored or loaded on to conveyor belts for processing. The switchgrass is sized by using tub grinders. From the grinders the switchgrass particles are placed in a short term (5-minute) buffer bin before it is transported via a high pressure pneumatic system to a receiving bin in the boiler building. The receiving bin uses a screw feeder with four bottom discharge chutes to deliver switchgrass via a low pressure pneumatic conveying system to four fuel nozzles located approximately 10 feet below the top row of existing pulverized coal nozzles. Based on recommendations from the manufacturer of the boiler in the Ottumwa facility, Black & Veatch reports that 99% of switchgrass particles should be sized to be less than 1.5 inches and 90% less than 1 inch.

Although costs as low as $50/kW have been suggested as the capital requirement for the design, purchase and installation of equipment to handle and process swtichgrass in a co-fire application, costs of $100 to $200 per kW of switchgrass electrical capacity are believed to be a more representative cost range for retrofits of large coal-fired facilities using 5% switchgrass.

Significant Co-firing Field Tests

Wood and Wood Waste

Southern Company – Wood waste was successfully co-fired with coal in a 100 MW pulverized coal power plant at Georgia Power Company's Hammond Unit 1 in June 1992. Wood waste consisting of tree trimmings and sawdust were used in the test. Wood percentage in the boiler fuel averaged 11.5% by weight, or 6.5% by heat input. The test indicated that 14% wood loading (by weight) represented the maximum wood percentage without load reduction from the unit. Boiler efficiencies were little changed when wood was co-fired. Although not measured, a 5% reduction in SO_2 was estimated from wood co-firing. NO_x emissions from wood co-firing were unchanged compared to normal coal firing. Wood wastes were pre-ground before delivery to the plant, and the wood and coal were mixed at the plant's coal pile before delivery to the pulverizer and boiler.

Pennsylvania Electric Company – Penelec conducted wood co-firing tests at the Shawville plant in Johnstown in 1995. The test involved one 138 MWe wall-fired and one 190 MWe tangentially-fired pulverized coal boilers. The biomass co-firing level was 3% by mass. Four different fuels were used in the test: a reference coal and three biofuels. The three biofuels included mill waste sawdust, utility right-of-way tree trimmings, and hybrid poplar. The biofuels were processed prior to blending with coal grinding equipment (when necessary) to ensure a particle size of less than ¼ inch. Tree trimmings and hybrid poplar, with longer, stringier fibers, proved to be more difficult to handle during fuel preparation and blending operations than sawdust. Only small amounts of hybrid poplar were fired because of the inability to successfully handle the fuel during operations. Aside from fuel handling and processing, the only significant impacts of wood co-firing encountered were related to the ability of the boilers to achieve normal full capacity. The 138 MW boiler lost 8 to10 MW of capacity due to feeder limitations, and the 190 MW boiler lost 15 MW of capacity due to significant reductions in mill outlet temperatures. For both units, the 3% weight biofuel blend behaved like wet coal. Penelec concluded that wood fuel should be fed separately from pulverized coal. (Co-firing Biomass with Coal at Shawville, Prinzing, D.E., et al, Bioenergy 96)

Herbaceous Crops

Madison Gas & Electric – MG&E is the first utility in the US to co-fire herbaceous energy crops with coal on a large scale. MG&E co-fired switchgrass in a 50 MW wall-fired, pulverized coal boiler at its Blount Street generating station, a non-base load facility. A 5-day test burn in October 1996 used a ratio of 10% grass/90% coal (on a heat basis). Switchgrass harvested from Conservation Reserve Program (CRP) land from 5 farms 30 miles west of Madison was delivered in bales 5-foot in diameter weighing 750 pounds each. The bales were separated by hand and fed to a hammermill, pulled through a fan to a cyclone separator, and deposited in storage bunker. Twin augers fed the switchgrass to a conveyor belt tied into pneumatic transport lines. The switchgrass was blown into the boiler between two levels of coal nozzles. The heating value of the switchgrass was about 78% that of bituminous coal, with a moisture content of 5% (stored) to 10% (no storage). The ash content was about 4.6%, or half that of coal. The switchgrass had 40% the nitrogen but only 5% the sulfur contained in coal. Switchgrass ash contained 3.4 times more potassium and 50 times more phosphorous than coal ash. The test indicated that sulfur dioxide emissions were largely unchanged, nitrogen dioxide emissions decreased 12%, and opacity (a measure of visible smoke) was reduced 50% compared to burning 100% coal. Post co-fire inspections of the boilers indicated no slagging or other detrimental effects. MG&E is considering burning switchgrass on a regular basis as part of a green pricing program. (Co-firing Switchgrass in a 50 MW Pulverized Coal boiler, Ragland, K. and Aerts, D. Weiss, C., Bioenergy 96)

Waste Tires

Union Electric – In 1995 UE began co-firing waste tires at its Sioux Power Plant. The plant, which has two 480 MW cyclone boilers, uses 20,000 tons of tires (2 million tires) per year ground into one inch chips to co-fire (2%) with coal. The two million tires represents about the total number of tires discarded annually in the St. Louis metropolitan area. UE buys processed chips wholesale at $12 to $15 per ton ($0.40 to $0.50 per million Btu) delivered. As of July of 1995, eight US utilities were co-firing tires in their power plants on a regular basis.

Multiple Feedstocks

TVA – The Tennessee Valley Authority and EPRI evaluated co-firing wood waste with coal and tri-firing wood waste, tire-derived fuel, and coal at TVA's Allen plant in Memphis. Allen's three cyclone boilers each have a gross capacity of about 270 MW. A single boiler was used for the tests. The results of the co-firing tests indicated that co-firing and tri-firing can be practiced in large cyclone boilers with no impact on capacity or stability, minor loss in boiler efficiency, and with potential for significant improvement in airborne emissions. Slight efficiency losses did occur during co- and tri-firing. Efficiency losses exceeded 1% when wood was co-fired with coal at the 20% level. In tri-firing, the TDF provided a high BTU fuel to offset the reduced heat content and increased moisture of the sawdust. Wood fuel decreased the sulfur content of the all-coal test, and a blend of 15% wood waste/5% TDF contained about the same sulfur content the all coal test. (Tri-firing Wood Waste and Tire-Derived Fuel with Coal in a Cyclone Boiler, Tillman, D., et al, Bioenergy 96 - The Seventh National Bioenergy Conference)

Northern States Power – In Ashland, Wisconsin, NSP operates the 76 MW Bay Front coal fired facility. In 1991, the facility underwent a life extension project that also allowed the facility to use up to 40 tons per hour of waste wood. In 1994, Bay Front also added the capability to handle tire-derived fuel. Elsewhere, NSP uses refuse-derived-fuel from MSW to fire three other power facilities in Minnesota, two in combination with natural gas.

Table 4.1. Biomass-fired Generation Operated by US Electric Utilities (as of January 1997)

	Plant Type	Primary Fuel	Secondary Fuel	Plant Capacity (MW)
Connecticut				
Connecticut Light & Power Co.	Co-fire	Bit. Coal	Refuse	64
Maine				
Central Maine Power	Dedicated	Wood	--	32
Minnesota				
Northern States Power (Minneapolis)	Co-fire (Cyclone)	Coal	Waste Wood	560
Northern States Power (Redwing)	Dedicated	Refuse	Natural Gas	21
Northern States Power (Wilmarth)	Dedicated	Refuse	Natural Gas	22
United Power Association	Dedicated	Refuse	--	39
New York				
New York State Electric & Gas (Dresden)	Co-fire (Pulverized)	Coal	Waste Wood/Willows	108
New York State Electric & Gas (Big Flats)	Co-fire (Stoker)	Coal	Waste Wood/TDF	75
Niagara Mohawk Power	Co-fire (Pulverized)	Coal	Waste Wood/Willows	91
Ohio				
City of Columbus	Co-fire	Bit. Coal	Refuse	90
Oregon				
City of Eugene	Dedicated	Refuse	--	23
City of Eugene	Dedicated	Wood	--	12
Pennsylvania				
Pennsylvania Electric Company (Johnstown)	Co-fire (Pulverized)	Coal	Waste Wood	320
South Dakota				
Otter Tail Power	Co-fire (Cyclone)	Coal	RDF/TDF	440
Tennessee				
TVA (Kingston)	Co-fire (Pulverized)	Coal	Waste Wood	380
TVA (Memphis)	Co-fire (Cyclone)	Coal	Waste wood/TDF	272
Vermont				
City of Burlington	Dedicated	Wood	Natural Gas	50
Washington				
City of Tacoma	Co-fire (Fluidized Bed)	Sub. Coal	RDF/Wood	50
Washington Water & Power	Dedicated	Wood	Natural Gas	47
Wisconsin				
Madison Gas & Electric	Co-fire (Pulverized)	Coal	Switchgrass	50
Northern States Power (Ashland)	Co-fire (Stoker)	Sub. Coal	Wood	75

Sources: Inventory of Power Plants in the US, US Energy Information Administration and Renewable Energy Technology Characterizations, EPRI and US DOE, December, 1997.

4.3 Gasification

Gasifying biomass has several advantages over direct burning. One advantage is the ability of gasified biomass to fuel a new generation of high efficiency gas turbines or fuel cells. Another advantage is that problematic biomass and waste fuel feedstocks such as switchgrass, straws, and other agricultural residues that can clog steam-cycle boilers with ash and alkali deposits can be gasified and filtered for use as a boiler fuel or used in gas turbines or fuel cells.

Gasification of biomass and waste feedstocks involves heating of the feedstocks in a controlled chamber to drive off combustible gases without consuming them. A cyclone separator separates the char, which is used in a combustor vessel to heat sand. Circulating hot sand is transferred in a closed loop and is used to break down the feedstock material.

Several competing gasification technologies are now being promoted for utility applications, including the direct-fired (steam and air) high pressure fluidized bed Renugas® system developed by the Institute of Gas Technology (IGT) and licensed to Tampella Power; the indirectly-heated (steam only) low pressure fluidized bed system developed by Battelle Columbus Laboratory (BCL) and licensed to FERCO; the direct-fired (air only) low pressure system developed by Thermiska Processor AB (TPS); and small fluidized bed-based gasifiers from other vendors. While natural gas from the pipeline has a heating value of roughly 1,000 Btu/ft^3, air-based gasifiers produce less energy-rich gas, typically 100 to 200 Btu/ft^3. The BCL indirect gasifier produces syngas with an energy content around 350 Btu/ft^3. Fluidized bed gasifiers that introduce pure oxygen into the gasifier can convert feedstocks into 500 BTU/ft^3 gas.

A significant consideration of the use of biomass- and waste-derived gases is the presence of significant amounts of alkali metals, which, in the presence of sulfur, can cause hot corrosion of turbine blades. Ash and tars in product gas from gasifers can also cause corrosion, erosion, and deposition on blades. A number of strategies can be used to clean up the gas. The fluidized bed gasifier system developed by BCL first cools the product gas to remove condensable compounds. Particulates are then removed from the cooled gas with filters or via a catalytic process.

For power production, cleaned gasification product gases are fed directly to a boiler or to an industrial or aeroderivative turbine.[91] Gas turbines can achieve higher thermodynamic efficiencies because of higher cycle temperatures (above 1200 ^oC) which are far higher than that for steam turbines (about 540 ^oC). In addition, gas turbines are being steadily improved, where steam turbines are a very mature technology. Aeroderivative turbines (smaller turbines akin to jet engines) offer high efficiency and low unit cost at relatively small scales (< 50 MW), which is characteristic of much of the biomass power market (due to feedstock availability). Simple cycle aeroderivative gas turbines are available today with efficiencies between 40% to 45% and capital costs of $500 to $700 per kW. Gas-fired combustion turbines are now available in units ranging from several hundred kW to tens of MWs. Similarly, several US manufacturers of gasifiers offer a range of throughput capacities targeted for niche applications and the export market that match well with these small- to medium-capacity gas turbines.

[91] Due to their lower Btu content, consideration must be given to the potential effects of biomass- and waste-derived gas on boiler or gas turbine operation. Many gas turbines have rigid firing requirements that make them suitable for using high Btu gas (i.e. pipeline gas) only, while some smaller capacity gas turbines now available are designed to accommodate gas with varying heat content.

With a gas turbine, the exhaust temperature is high enough (620 ^{o}C or 1150 ^{o}F) to produce high temperature steam from a waste heat boiler to run a steam turbine. Combined cycle systems using heavy-duty industrial (rather than aeroderivative) turbines in conjunction with a steam cycle are the generating technology of choice for larger (> 100 MW) natural gas fired systems. However, the economies of scale for the steam generator portion of recent generation combined cycle systems make them less appropriate for use with dedicated biomass gasifier systems. Technical advances in combined cycle systems using aeroderivative turbines are expected to result in efficiencies exceeding 50% for systems which can be matched with biomass and waste gasifiers (75 MW or below).

Biomass gasification systems coupled with combined cycle (gas turbine and steam cycle boiler) power systems examined by DOE and EPRI have capital costs for a first-of-a-kind BGCC plant in the $1500 to 2000/kW range (comparable to the cost of new coal-fired capacity with flue gas desulfurization and particulate emission control, but up to 2 to 2.5 times the cost of new gas-fired combined-cycle capacity), with costs dropping to around $1400/kW for a mature plant.[92] Table 4.2 summarizes the operational and economic characteristics for a mature BGCC plant. Table 4.3 also provides operating and economic characteristics for current and future BGCC plants in comparison with current and future co-fired coal/biomass systems.

Wood and Wood Waste

Gasification of wood and wood waste involves similar steps as found in direct combustion. The wood materials must be gathered and processed to produce a relatively consistent particle size for introduction to the gasifier, although the use of fluidized bed gasifiers permits some size variability. Fluidized bed gasifiers also permit the use of wood and wood waste with varying moisture to be used. Since most wood species have relatively low ash content, ash disposal following gasification of wood and wood wastes is not a significant hurdle; however, the use of wood chips from fast growing trees (e.g. hybrid poplar) in gasifiers will require special attention to the fuel gas cleanup system since such trees typically have a high alkali content.

Municipal Solid Waste

MSW gasification is an emerging technology that may offer an alternative to mass burn and direct combustion of refuse derived fuel. MSW gasification starts similarly to direct combustion of MSW in that they both require front end processing to remove metal and other non-combustibles. Then instead of burning, the organic fraction of MSW is heated to drive off a fuel gas. This gas can be cleaned and burned in a gas turbine to generate electricity. A number of developers are readying new gasifier technologies for processing MSW.[93] Circulating fluid bed technology to gasify RDF has been adopted in several plants in Europe. While MSW gasification does not offer significant economic advantages over mass burn or direct combustion of RDF, MSW gasification does result in significantly lower air emissions that the other two combustion options. Disposal of relatively large amounts of ash and residual non-combustibles is still required following gasification of MSW.

[92] Renewable Energy Technology Characterizations, EPRI and US DOE, TR-109496, December, 1997, page 2-2.

[93] Evaluation of Gasification and Novel Thermal Processes for the Treatment of Municipal Solid Waste, Camp Dresser & McKee for the National Renewable Energy Laboratory, August 1996.

Significant Biomass and Waste Fuel Gasification Demonstrations

BCL Technology (low pressure, indirectly heated gasifier)

Vermont – A commercial-scale demonstration of thermal gasification of biomass is being funded by the US Department of Energy in partnership with Future Energy Resources Corporation (FERCO) and the joint owners of the McNeil generating station in Burlington, Vermont. The initial phase of the demonstration will be to provide fuel gas to McNeil's boiler. A subsequent phase will be to utilize the fuel gas in a 15 MW combustion turbine as part of a combined cycle system.. The project uses a high throughput circulating fluid bed gasifier developed by Battelle Columbus Laboratory (BCL) and licensed to FERCO. The McNeil station serves the New England power pool and is one of the nation's largest wood-fired power plants, capable of using 85 tons per hour of wood chips. The demonstration allows FERCO to its tests its gasification technology to process 200 dry tons per day of wood chips to produce fuel gas with a heating value of 450 to 500 Btu/ft^3.

The BCL/FERCO gasifier uses two separate circulating fluidized bed reactors: 1) a gasification reactor in which the biomass is converted into gas and residual char by circulating sand at 1800 to 1900 ^oF and 2) a combustion reactor that burns the residual char to provide heat for gasification. Once biomass is gasified, the resulting gas contains trace amounts of condensable materials called "tars" (about 0.5 to 1% of the weight of dry wood). Tars can coat downstream equipment surfaces fouling and damaging turbines and combustors. The BCL/FERCO gasifiers uses a catalyst called DN-34 which destroys the tars by "cracking" the hydrocarbons and chemically converting them into additional fuel gas for the turbine. After tar cracking, the product gas is cleaned of alkali. Once the system has conditioned the biogas and pressurized it, it is ready to fire a gas turbine. In plant performance estimates, the BCL/FERCO system's efficiency is about 36%. The BCL/FERCO process has been demonstrated on a 12 ton per day research unit to be effective on a variety of biomass materials including wood chips, sawdust, refuse derived fuel, and energy crops such as switchgrass and hybrid poplar. FERCO and BCL plan to use engineering data from the Vermont demonstration project to design standardized packaged biogas power plants in the 2 MW to 10 MW range. The gasifier system would be packaged in a single module approximately 14 ft. x 14 ft. x 40 ft., suitable for rail and limited road transport. A second module would contain the gas cleaning and gas compression equipment. The objective is to offer package simple cycle biogas power plants (turbine and gasifier) for a target of $750 per kW. (Commercial Demonstration of Biomass Gasification: The Vermont Project, Farris, S., Weeks, S., FERCO, Bioenergy 96)

IGT Technology (high pressure gasifier)

Hawaii – The Hawaii Biomass Gasifier project is a demonstration of integrating gasification and hot gas cleanup (HGCU) with gas turbines for power generation. The Hawaii project is a scale up of the Institute of Gas Technology (IGT) Renugas pressurized air/oxygen gasifier to an engineering development unit that can handle 50 to 100 tons per day of bagasse (sugar cane residue) and wood as gasifier feedstock.

Minnesota – The Northern States Power Company, University of Minnesota, Tampella Power Corporation, Westinghouse Electric Corporation, and Institute of Gas Technology have proposed an integrated gasification combined cycle (IGCC) demonstration project in Granite Falls, Minnesota using alfalfa stems as the biomass feedstock. In the Minnesota Alfalfa Project, alfalfa stems would be collected from 250,000 acres within a 50-mile radius of the Granite Falls project site. The gasifier technology proposed by Tampella Power (now Carbona) is the same pressurized, air-blown, fluidized bed technology used in the Hawaii bagasse project (the IGT RENUGAS technology under license). The product gas is to be cleaned via a hot gas clean up unit, where the gas stream is cooled to condense alkali metals (including sodium and potassium chlorides) which, along with particulate matter, are removed by the hot gas filter. Electricity is to be produced by two separately powered turbines/generators. In the first cycle, a 50 MW Westinghouse turbine would be powered by the combustion of low-BTU biomass-derived gas (150 BTU/ft^3) provided by the gasification of the alfalfa stems. The heat in the exhaust gas from the combustion turbine would be reclaimed as steam in a heat recovery steam generator. The steam would be used to produce an additional 29 MW in a steam turbine generator. The gasifier will be sized to process 1100 tons per day of alfalfa stems (at 9% moisture) to meet the design load requirements of the combustion turbine. The MAP project is entering a phase involving detailed engineering. Full-scale operation is targeted for 2001.

Iowa – Chariton Valley Resource Conservation & Development, Inc., IES Utilities, and others have proposed to pursue a project involving the establishment of 35,000 acres of switchgrass to provide approximately 35 MW of power from biogas at the IES Ottumwa Generating Station.

Herbaceous Crops and Agricultural Waste

Fluidized bed gasifiers can convert to fuel gas a wide range of herbaceous crops and agricultural wastes with varying moisture and ash/alkali content. As gas turbines are designed to operate on either natural gas clean and free of ash and alkali, gasifiers using herbaceous crops and agricultural waste feedstocks must be able to successfully filter ash and alkali from the product gas. Most fast growing herbaceous crops or agricultural residues have high proportions of inorganic compounds, which can be filtered and recycled back to croplands. At present, little is known about the physical and chemical characteristics of ash from grasses. Such information is valuable in developing advanced gasifier strategies and determining the potential markets for the ash and its value in overall system economics. Under sponsorship by the Southeastern Regional Biomass Energy Program (SERBEP), a study is now being conducted to characterize ash from the gasification of switchgrass.

Table 4.2 Operational and Economic Characteristics for BGCC Plants (n^{th} plant)

	IGTGasifier w/ Aeroderivative Gas Turbine (existing plant)	**IGTGasifier w/ Aeroderivative Gas Turbine** (greenfield plant)	**IGT Gasifier w/ Advanced Gas Turbine** (existing plant)	**BCL Gasifier w/ Advanced Gas Turbine** (existing plant)	**TPS Gasifier w/ Advanced Gas Turbine** (existing plant)
Gasifier Description					
Wood Flow Rate (lb/hr)	70,261	70,261	151,361	136,494	133,838
Air Flow Rate (lb/hr)	72,674	72,674	143,178	0	235,469
Steam Flow Rate (lb/hr)	20,044	20,044	43,181	61,346	0
Fuel Gas Output					
Fuel Gas Flow Rate (lb/hr)	182,520	182,250	378,360	114,734	347,040
Fuel Gas Heating Value-LHV (Btu/ft^3)	115	115	115	354	129
Power Production					
Gas Turbine	GE LM5000PC	GE LM5000PC	GE MS6101FA	GE MS6101FA	GE MS6101FA
Gas Turbine (MW_e)	50.3	50.3	93.1	82.1	72.9
Steam Turbine (MW_e)	9.0	9.0	46.6	55.1	47.6
Internal Consumption (MW_e)	3.8	3.8	8.0	15.2	15.1
Net System Output (MW_e)	55.5	55.5	131.7	122.0	105.4
Net Plant Efficiency %	36.7	36.7	39.7	35.4	37.9
Capital Costs ($1000)					
Wood Handling	2173	2173	4346	4400	3478
Wood Drying	2724	2724	5448	5448	4360
Gasification	20972	20972	44475	14185	33481
Gas Cleanup	2700	2700	5400	5400	
Tar Cracker	0	0	0	454	
Direct Quench	15	15	15	30	
Gas Turbine	13161	13161	17220	17850	17220
HRSG	2208	2208	8000	7686	8000
Steam Cycle	3133	3133	11675	12668	11900
Boost Compressor	590	590	1180	5691	w/ gasifier
Char Combustor	1215	1215	2282	w/ gasifier	w/ gasifier
Balance of Plant	9778	9778	20011	14672	15688
Substation	0	3958	0	0	0
Land	0	1000	0	0	0
Other	29484	31323	60585	46435	48683
Total Capital Requirement	88112	94951	180653	135211	141810
TCR ($/kW)	1588	1696	1371	1108	1350
Ann. Oper. Cost ($1000)					
Wood ($42/dry ton)	9198	9198	19794	20087	16250
Water ($0.60/ton)	49	49	105	211	53
Ash Disposal ($8/ton)	9	9	19	822	16
Maintenance	1660	1772	3398	2507	2664
Other	2516	2647	5456	9011	4459
Net Operating Cost	13433	13675	28702	32638	23442
Levelized Cost of BGCC					
Cost of Energy: Current ($/kWh)	0.079	0.082	0.070	0.066	0.070
Cost of Energy: Constant ($/kWh)	0.061	0.063	0.054	0.051	0.054

Source: Cost and Performance Analysis of Three Integrated Gasification Combined Cycle Power Systems, K. Craig and M. Mann, National Renewable Energy Laboratory, undated. "Other" capital costs include general plant facilities, engineering fees, project contingency costs, prepaid royalties, startup costs, spare parts, and working capital. "Other" operating costs include labor, insurance, taxes, royalties, and miscellaneous.

Table 4.3 Operating and Economic Comparison of Co-firing and BGCC Systems

	Coal/Biomass Co-fired System			**IGT-based BGCC System**		
	Year			**Year**		
	2000	**2005**	**2010**	**2000**	**2005**	**2010**
Plant Description						
Plant Capacity (MWe)	100	150	200	75	100	100
Capacity Factor (%)	85	85	85	80	80	80
Cofire System						
Coal Moisture (%)	7.2	7.2	7.2			
Biomass Moisture (%)	21.5	21.5	21.5			
Coal Thermal Eff. (%)	32.9	32.9	32.9			
Biomass Thermal Eff. (%)	32.5	32.5	32.5			
Biomass Co-fire Rate (%)	15	15	15			
Coal Usage (tons/yr)	261,465	392,195	522,930			
Biomass Usage (d-tons/yr)	71,165	106,750	142,330			
BGCC System						
Thermal Efficiency (%)				36	37	37
Capital Costs ($/kW)						
Co-fire System						
Conveyors	41.8	39.4	37.7			
Controls	9.9	9.3	8.9			
Hogging Tower	20.0	18.9	18.1			
Wood Silo	5.2	4.9	4.7			
Other	0.6	0.5	0.5			
Total Equipment	77.5	73.0	69.9			
Total Capital Requirement	255	240	230			
BGCC System						
Fuel Preparation				113	101	101
Gasifier				450	377	346
Gas Turbine				216	216	198
Steam Turbine				48	48	44
Hot Gas Cleanup				39	34	31
Balance of Plant				472	402	332
Total Equipment & Facilities				1338	1178	1052
Total Capital Requirement				1892	1650	1464
Operating Costs ($/kWh)						
Co-fire System (Incremental)						
@ $8.32/d-ton biomass $35.57/ton coal	(.00844)	(.00848)	(.00851)			
@ $46.85/d-ton biomass $35.57/ton coal	.01608	.01604	.01601			
@ $8.32/d-ton biomass $25.52/ton coal	(.00464)	(.00468)	(.00470)			
@ $46.85/d-ton biomass $25.52/ton coal	.01989	.01985	.01982			
BGCC System						
@ $2.63/MBtu				.0362	.0355	.0355
Cost of Energy ($/kWh)	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported

Source: Renewable Energy Technology Characterizations, Electric Power Research Institute and US Department of Energy, TR-109496, December 1997. TCR = Equipment + Engineering + Installation + Contingencies

4.4 Landfill Gas

Municipal solid waste contains significant portions of organic material that produce a variety of gaseous products when dumped, compacted, and covered in landfills. Anaerobic bacteria thrive on the oxygen free environment, resulting in the degradation of the organic material and the production of primarily carbon dioxide and methane. Landfill gas (LFG) can be explosive, toxic, and an odor nuisance and is also a potent greenhouse gas, so it must be controlled.

Landfill gas can be cleaned, dried, and used as a fuel for power generation. As of 1996, 133 landfill gas collection facilities operated in the US, mainly in California, New York, Pennsylvania, Michigan, Wisconsin, and Illinois. About 75% of the LFG facilities generate electricity with an average capacity of 3 MW; other LFG facilities use the gas as a boiler fuel for nearby industries. Internal combustion engines or small gas turbines are used to convert the medium Btu gas (about 500 Btu/ft^3) to electricity, although their overall system efficiencies are relatively low. In locations where LFG has not been economical to use, it is typically collected and flared.

In the future, fuels cells may become an attractive approach for using LFG because of their high conversion efficiency, negligible emissions, and suitability for all landfill sizes. A product gas cleanup system is critical to the use of fuel cells in off-pipeline applications. The gas cleanup system removes contaminants such as sulfur and halides and destroys them by incineration. However, at present the high cost of the fuel cell itself and the high cost of LFG cleanup systems to provide a fuel cell-compatible feedstock have hindered their application. The first commercial fuel cell (200 kW) to operate on landfill gas was dedicated in 1996 at a 42-acre landfill in Groton, Connecticut. The landfill project is a partnership among the town of Groton, Northeast Utilities, International Fuel Cells, and US EPA.

4.5 Waste Water Treatment Plant Gas

Methane is a major byproduct of the operation of a wastewater treatment plant. Many sewage treatment plants flare methane, while some methane is released directly.[94] Methane gas can be collected, stored, purified, and used in several useful ways, including power generation. Using two stage digesters, waste sludge is broken down into methane, carbon dioxide, trace gases, and stabilized sludge.

4.6 Pyrolysis

Pyrolysis is the breaking down (lysis) of a material by heat (pyro). Pyrolysis is performed by applying heat to prepared biomass feedstocks that are usually less than 2 mm thick and have low (less than 10%) moisture content. When biomass is heated in the absence of air it forms gases, char particles, pyrolysis oil vapors, and water vapor. After a very brief residence time (less than 2 seconds) in the reaction chamber, the various constituents of the process flow through a cyclone separator where char particulates are removed. The pyrolysis oils are then condensed to form a black, viscous, medium Btu material. Sixty-five to eighty percent of the feedstock is converted to biomass fuel oil. The residual gases and char can be collected and burned to provide process heat to dry the incoming feedstock or heat the reactor chamber. There are three

[94] Methane in the atmosphere is believed to be 20 to 30% more effective as a greenhouse gas than carbon dioxide, and is thus an undesirable emission.

primary types of pyrolysis reactor designs are vortex (~65% pyrolysis oil yield), tubular transport (~75% pyrolysis oil yield), and fluidized bed (~65 to 80% pyrolysis oil yield).

Pyrolysis oils can be used in gas turbines or for co-firing in existing pulverized coal- or oil-fired boilers. Using liquid fuels derived from biomass and wastes in power production have several advantages. Biocrude can be handled like diesel fuel, eliminating the need for special drying, storage, and conveyor systems at a power plant. Biocrude can be transported over long distances, and therefore can be used in power plants removed from the source of biomass and waste production. Biocrude also contains little sulfur, less than 0.1% by weight, and can be used in co-firing and turbine generator applications or as a substitute for heavy, No. 6 fuel oil. With respect to the ash/alkali problem associated with direct combustion of some biomass and waste materials, the production of liquid biocrude permits the removal of ash and alkali from the biomass prior to combustion.

Ensyn Technologies, a Canadian engineering company, has developed a process to convert biomass feedstocks into chemicals and liquid fuels (biocrude) via its Rapid Thermal Processing™ approach. RTP™ involves the liquification of biomass by the addition of heat at atmospheric pressure in the absence of air or oxygen. In effect, wood, grasses, refuse, or other biomass and waste feedstocks are liquified and made pourable, and have approximately the same heating value as the feedstock entering the conversion unit. Ensyn Technologies summarizes the system economics of the RTP process as follows:

If wood or other biomass feedstocks are available at zero cost, an RTP fuel oil price of about $5 per MBtu is required to render a 100 ton (wet) per day RTP plant economically viable.[95,96]

There are currently a handful of RTP plants in commercial production in Wisconsin including two cogeneration facilities with an average processing capacity of 30 dry tons per day and one co-firing project. A Wisconsin public utility is co-firing RTP biocrude with coal in a 20 MW grate-type boiler. The biocrude provides about 5% of the input fuel demand, and is believed to be the first commercial production of power using a fuel derived from thermochemical conversion.

In other areas of the country, pyrolysis is being used to produce energy and other usable products from 100% post-consumer tire stockpiles. Carbon black can be sold back to several industrial markets, pyrolysis oils can be sold for use as diesel fuel or as a chemical feedstock, pyrolysis gas can be used to produce electricity, and scrap steel can be sold to steel recyclers.

Pyrolysis liquids are more difficult to use as a fuel in gas turbines than biomass- and waste-derived gases. Compared to light and middle distillates, pyrolysis liquids are very viscous, have high densities, and high tar, alkali, and moisture content (thus are potentially corrosive). Further, they are not thermally stable so they can't be heated to reduce viscosity. The relative yield and

[95] The Commercial Conversion of Wood to Liquid Fuels via RTP for Fuel Chemical and Power Applications, Ensyn Technologies, Inc., The Seventh National Bioenergy Conference, September, 1996.
[96] This suggests that negative cost feedstocks (associated with tipping fees) are needed for the process to be competitive with other power technologies in Kansas.

quality of pyrolysis oils depends on the reactor type and the feedstock material. The alkali content of pyrolysis oils developed by NREL from varying feedstocks far exceed the acceptable limits of commercially-available gas turbines, with pyrolysis oils from grasses found to be of lower quality (higher alkali content and viscosity) fuel for gas turbines than pyrolysis oils from wood.[97] For pyrolysis oils to be used as a fuel for gas turbines, removal of alkali and ash during pyrolysis or in post-processing must be proven, and viscosity-related technical issues must be solved.

4.7 Anaerobic Digestion

Animal wastes can be converted to biogas by anaerobic digestion. Biogas from animal waste has a heating value of around 600 Btu per cubic foot. Anaerobic digestion involves a two-phase process, where animal wastes are biologically converted to a gas in the absence of oxygen. In the first phase, acid-forming bacteria convert carbohydrates, fats, and protein in the waste to simple acids. In the second phase, organic acids are converted by bacteria to methane and CO_2. Digesters are airtight containers that can be batch or continuously loaded. The process starts with the flushing of manure into a holding pit and mixed into a slurry. The resulting slurry is pumped to a reactor chamber where anaerobic conversion takes place in temperatures above 60^oF. Biogas is then filtered prior to combustion. The remaining waste product can be treated and used as fertilizer. Because of their high capital costs, anaerobic digesters are not currently economic for bulk power generation. However, digesters can provide cost effective fuel for localized thermal and micro-generation energy needs.

4.8 Summary

Table 4.4 provides a side-by-side comparison of the fuel characteristics of coal, biomass, and waste fuels based on recent literature. Coal and waste tires have higher heating values than other fuels, yet have higher sulfur content. Biomass fuels such as switchgrass and agricultural residues have high alkali content. Municipal solid waste and refuse-derived fuels have high ash content and relatively high levels of chlorine.

Table 4.5 provides a side-by-side comparison of performance and cost estimates of a range of electric power options. Dedicated, direct combustion biomass power plants typically cost $1,500 to $2,000 per kW, operate at 20-25% thermal efficiencies, and exhibit non-fuel O&M costs near $0.01 per kWh. Biomass electric power plants using conventional boiler steam turbine technology are seldom economic below 15 MW. Dedicated, direct combustion power plants using waste fuels can cost $4000 or more per kW.

Efficiency advantages and pollution profiles favor new gas-fired systems for capacity expansion. Natural gas combined cycle power plants typically cost $500 to $750 per kW, operate at 40-45% efficiencies, and non-fuel O&M costs are about $0.005/kWh. Gas turbine generator sets as small as 1.0 MW are now available with efficiency ratings as high as 35%. Installed packaged gas turbine generator sets (simple cycle) in the 1.0 to 10 MW range cost $450 to $750 per kW; gas turbines in the 25 to 50 MW range cost $300 to 400 per kW. Based on very limited plant applications, BGCC plants presently cost around $1500 to $2000 per kW. Given likely cost

[97] Impact Study on the Use of Biomass-Derived Fuels in Gas Turbines for Power Generation, C. Moses and H. Bernstein, Southwest Research Institute for National Renewable Energy Laboratory, NREL/TP-430-6085, January 1994.

reductions and advances in conversion efficiencies for combined cycle gas systems and the relatively low cost of current gas supplies, the cost of delivered biomass fuels must be less than about $1.00 per MBtu for BGCC power systems to compete with such systems.[98] [99]

In general, co-firing in an existing coal boiler represents the most competitive use of biomass or waste fuels for electric generation. Fluidized bed, cyclone, and stoker grate boilers are most suited for co-firing biomass or waste fuels. Pulverized systems, which are the predominate design of coal-fired capacity in Kansas, can be modified to use biomass feedstocks that are properly sized for delivery to the boiler. Switchgrass, which has emerged as an attractive biomass feedstock option in Kansas, can be cofired with coal on a limited basis (~5%). Results from on-going co-fire trials around the country may provide evidence that higher percentages of switchgrass are possible without detrimental boiler effects. The economic and environmental effects of cofiring switchgrass in Kansas coal-fired power plants are evaluated in the following section.

---

[98] Biomass for Electric Power in the 21st Century, C. McGowin, Biomass and Bioenergy, Volume 10, No. 2-3, Pergamon Press, 1996, page 70.

[99] The cost of synthesis gas (syngas, or biogas) from current gasifier equipment is on the order of $4 to 5 per mmBtu, well above the cost of pipeline gas. (Source: Phone conversation with Kevin Craig, NREL, June 1998)

Table 4.4 Thermal and Chemical Characteristics of Coal, Biomass, and Waste Fuels

	Western Coal			Urban Wood Waste		Wood Waste (sawdust)		Black Locust		Hybrid Poplar		Switch Grass		Ag. Residue (straw)		MSW (As Is)		RDF		TDF	
	Dry (6)	Dry (2)	AU (3)	Dry (4)	AU	Dry (4)	AU (3)	Dry	AU	Dry (4)	AU	Dry (1)	AU (1)	Dry (4)	AU	Dry (2)	AU (6)	Dry (2)	AU (6)	Dry (5)	AU (3)
Proximate Analysis (%)																					
Moisture	0.0	0.0	9.6				40.8					0.0	5.9			0.0		0.0		0.0	3.0
Ash	5.7	9.2	7.3	5.5		3.6	3.7			2.7		4.9	4.6	9.6		36.0		12.0		4.8	4.8
Volatile Matter	43.1	44.7	39.1				46.4					85.1	80.1					74.7		67.1	60.8
Fixed Carbon	51.2	46.1	44.0				9.1					10.0	9.4					13.3		28.1	31.4
Ultimate Analysis (%)																					
Moisture	0.0	0.0	9.6				40.8					0.0	6.0			0.0	31.3	0.0	20.2	0.0	3.0
Ash	5.7	9.2	7.3	5.5		3.6	3.7			2.7		5.7	5.3	9.6		36.0	16.0	12.0	6.0	4.8	4.8
Carbon	70.3	68.8	66.9				28.5					46.8	44.0			32.6	27.9	45.6	36.1	84.4	81.6
Hydrogen	5.0	4.9	4.9				3.3					5.6	5.3			4.3	3.7	6.4	5.1	7.1	7.0
Nitrogen	1.0	0.9	1.2				0.1					0.5	0.5			0.6	0.2	0.7	0.8	0.2	0.5
Sulfur	0.4	0.7	0.6				0.1					0.1	0.1			0.2	0.1	0.4	0.1	1.1	2.0
Oxygen	17.7	15.5	9.6				23.5					41.2	38.7			25.7	20.7	34.5	31.6	2.4	1.1
Chlorine	~0.0	~0.0	~0.0	<0.1		~0.0	~0.0			~0.0		0.1	0.1	1.8		0.6	~0.1	0.4	~0.1	<0.1	<0.1
Ash Composition (% by weight ash)																					
SiO_2	32.6			55.1		57.6				0.9		66.0		37.1							
Al_2O_3	13.4			12.5		12.2				0.3		1.4		2.7							
TiO_2	1.6			0.7		0.5				0.2		0.0		0.2							
Fe_2O_3	7.5			4.5		5.6				0.6		1.3		0.8							
CaO	15.1			13.5		13.9				44.4		7.0		4.9							
MgO	4.3			2.9		3.3				4.3		4.1		2.6							
Na_2O	7.4			3.2		2.4				0.2		0.6		9.7							
K_2O	0.9			4.8		3.8				20.1		8.5		21.7							
SO_3	14.6			1.9		1.0				4.0		1.9		4.4							
P_2O_5	0.4			0.9		0.5				0.2		8.2		2.0							
CO_2										19.5											
Alkali (lb./MBtu)				0.5		0.2				0.4		1.3		3.9							
HHV (1000 Btu/lb.)	12.1	11.5	12.0	8.4		8.7	4.7			8.2		8.0	7.5			6.4		8.1		16.3	15.3

Note: AU = As used during combustion.

Sources:

1 *Co-Firing Switchgrass in a 50 MW Pulverized Coal Boiler*, Univ. of Wisconsin and Madison Gas & Electric.
2 *Strategic Analysis of Biomass and Waste Fuels for Electric Power Generation*, EPRI
3 *Tri-Firing Wood Waste and Tire-Derived Fuel with Coal in a Cyclone Boiler*, TVA and EPRI.
4 *Alkali Deposits Found in Biomass Power Plants*, NREL et al.
5.*Characteristics of TDF*, Waste Recovery Inc.
6. *Steam: Its Generation and Use*, 40th Edition, Babcock & Wilcox.

Table 4.5 Technology Performance and Cost Estimates

Conventional, Biomass, and Waste Fuel Power Technologies[100] (1994 $)					
	Net Capacity MW	**Net Heat Rate Btu/kwh**	**Thermal Efficiency %**	**Total Capital $/kW**	**Levelized Cost $/kwh**
Dedicated Facilities: Solid Fuel					
New Coal/PC w/ FGD	200	10,020	34.1	1,960	0.063
New Coal/FBC*	200	9,350	36.5	1,600	--
Wood Fired Stoker	50	13,894	24.6	1,829	0.078
Wood Fired FBC	50	13,864	24.6	2,147	0.085
Whole Tree	50	10,661	32.0	1,740	0.063
MSW Mass Burn	50	16,373	20.8	4,324	0.083
RDF-fired Stoker	50	16,460	20.7	4,457	0.085
Dedicated Facilities: Gaseous Fuel					
Natural Gas CC	120	7,900	43.2	725	0.039
Wood GCC	100	9,598	35.5	1,765	0.069
Co-Fired Facilities					
Coal Only	200	10,127	33.7	--	0.030
Coal/Wood	200	10,288	33.2	90	0.036
Coal/RDF	200	10,300	33.1	119	0.037
Coal/TDF	200	10,133	33.7	24	0.031

Assumptions				
	% Moisture	**Btu/lb.**	**$/ton**	**$/MBtu**
Fuel Costs				
Natural Gas	--	--	--	2.50
Coal	12.0	10,100	26.25	1.18
Wood	33.2	5,554	24.80	2.22
Whole Trees	45.0	4,840	17.40	1.80
RDF	24.0	5,852	25.00	2.14
TDF	8.0	12,420	25.00	1.01
Tipping Fees				
MSW	24.8	4,896	30.00	3.06
Scrap Tires	8.0	11,902	30.00	1.26

* Fluidized bed values not from main source for table.

[100] Data from *Strategic Analysis of Biomass and Waste Fuels for Electric Power Generation*, C. McGowin and G. Wiltsee, Biomass and Bioenergy, Volume 10, No 2-3, Pergamon Press, 1996, pgs. 170 and 172.

5.0 CASE STUDIES

5.1 Kansas Utility Plant Characteristics

It is anticipated that specific opportunities may emerge for using biomass to generate electrical power in Kansas, if Federal tax credits are extended and environmental and economic benefits are full accounted. This portion of the assessment looked at the potential of specific biomass project opportunities in the State to document their competitiveness relative to other competing options.

In order to relate biomass resources and conversion technologies to the actual infrastructure of Kansas utilities and to answer basic questions about the potential for biomass power in Kansas, the type, vintage, and operational profile (e.g. efficiency, heat rate, fuel handling, etc.) of existing and proposed fossil-fired electrical capacity for each utility were identified and characterized. This information was gathered from power operations and planning personnel at KEURP-member utilities, Edison Electric Institute and Energy Information Administration publications, and recent MOKAN Power Pool reports.

5.1.1 Existing Power Plants

Coal is the predominant fuel used today in US power plants. Coal-fired power plants represent nearly 60% of all fossil-fired power plants in operation at the end of 1995, with natural gas-fired and oil-fired plants representing 27% and 13%, respectively.[101,102] In Kansas, coal-fired power plants in 1995 produced 92% of all fossil-derived electricity in the state, compared to nearly 8% from natural gas turbines and engines, as shown in Table 5.1. Table 5.2 provides a profile of the major fossil-fired power facilities operated by KEURP member utilities.

Table 5.1 Fossil-Fired Electric Production and Fuel Cost for Kansas Electric Utilities[103]

(1995, All Kansas Utilities)				
	Coal	Natural Gas		Petroleum
		Steam	GT/IC	
Electricity Generated (million kWh)	25,897	1,808	390	74
Electricity Generated (%)	91.9	6.5	1.5	< 0.1
Average Fuel Cost ($/MBtu)	1.02	1.61		3.69

[101] US DOE Energy Information Administration, Electric Power Annual, 1995 Volume I, page 10.
[102] Due to the advantages of efficiency, relatively low natural gas prices, positive prospects for plentiful natural gas supply, lower environmental emissions, and smaller capacities, natural gas-fired power plants accounted for nearly 66% of new capacity additions in 1995, compared to 18% and 15% for coal- and oil-fired power plants, respectively.
[103] US DOE Energy Information Administration, Electric Power Annual, 1995 Volume I, pg. 18.

Table 5.2 KEURP Member Power Plants in Kansas

(>25 MW - peaking units excluded)

Utility/Plant/County	Rated Capacity (MW)	Fuel	Unit Type	Year of Start-Up	Heat Rate (Btu/kWh)	Coal Firing Method
Empire District						
Riverton (Cherokee)						
Unit 7	37.5	Sub. Coal	ST	1950	11,973	Front[1]
Unit 8	50	Sub. Coal	ST	1954	11,973	Tangential[2]
Kansas City Power & Light						
LaCygne (Linn) **						
Unit 1	682	Bit. Coal	ST	1973	10,962	Cyclone[3]
Unit 2	662	Sub. Coal	ST	1977	10,962	Opposed[3]
Midwest Energy ***						
Sunflower Electric Power						
Garden City (Finney)						
Unit S4	50	NG	GT	1976	12,976	--
Unit S5	50	NG	GT	1979	11,686	--
Holcomb (Finney)	325	S. Coal/NG	ST	1983	10,280	Opposed[3]
Western Resources						
Gordan Evans (Sedgwick)						
Unit 1	150	NG/Oil	ST	1961	11,103	--
Unit 2	367	NG/Oil	ST	1967	11,103	--
Gill (Sedgwick)						
Unit 1	46	NG/Oil	ST	1952	11,974	--
Unit 2	75	NG/Oil	ST	1954	11,974	--
Unit 3	114	NG/Oil	ST	1956	11,974	--
Unit 4	114	NG/Oil	ST	1959	11,974	--
Hutchinson (Reno)						
Units 1/2/3/4	321	NG/Oil	GT	1974	12,994	--
Unit 4	172	NG/Oil	ST	1965	NA	--
Jeffrey Energy Ctr. (Pottawatomie)*						
Unit 1	698	Sub. Coal	ST	1978	11,104	Tangential[2]
Unit 2	735	Sub. Coal	ST	1980	11,104	Tangential[2]
Unit 3	703	Sub. Coal	ST	1983	11,104	Tangential[2]
Lawrence Energy Center (Douglas)						
Unit 3	56	S. Coal/NG	ST	1954	11,531	Tangential[2]
Unit 4	113	S. Coal/NG	ST	1960	11,531	Tangential[2]
Unit 5	370	S. Coal/NG	ST	1971	11,531	Tangential[2]
Tecumseh (Shawnee)						
Unit 7	88	S. Coal/NG	ST	1957	12,028	Tangential[2]
Unit 8	148	S. Coal/NG	ST	1962	12,028	Tangential[2]
WestPlains Energy						
Cimarron River (Seward)	58	NG	ST	1963	--	--
Clifton (Washington)	71	NG/Oil	GT	1974	--	--
Judson (Ford)	137	NG/Oil	ST	1969	--	--
Arthur Mullergren (Barton)	92	NG/Oil	ST	1963	--	--

Sources: Kansas Corporation Commission, *Directory of Electric Utilities*, DOE/EIA *Inventory of Power Plants in the US, 1997.*
* Jointly owned with WestPlains Energy ** Jointly owned with Western Resources *** Midwest Energy purchases most of its electricity from others. Its generation facilities are primarily small peaking units. All coal-fired units in Kansas use pulverized or crushed coal. Manufacturers of these units are 1 = Foster Wheeler 2 = ABB Combustion Engineering 3= Babcock & Wilcox.

5.1.2 Planned Power Plants

No new base load electric capacity is projected in Kansas for the foreseeable future. Kansas utilities are planning expansion of peak electric capacity using simple cycle gas turbines. Just recently Western Resources, Inc. announced plans to build three combustion turbines (totaling 300 MW) at its Gordon Evans Energy Center. Cost considerations aside, given the lack of need for new baseload capacity, the prospects for new, dedicated biomass facilities in Kansas are not favorable. In contrast, co-firing biomass in existing utility boilers where biomass fuel is substituted for coal with no new capacity added appears to a more favorable for using biomass in the near future.

5.2 Overview of Case Studies

The economic and environmental effects of using biomass feedstocks to generate power in Kansas were modeled using BIOPOWER 1.01 developed by the Electric Power Research Institute. BIOPOWER generates process information and power plant and cost estimates for a range of power technology and fuel combinations. Process information includes energy and material balances, fuel consumption, stack emissions, and waste material production. Performance estimates include boiler efficiency, gross and net capacity, and gross and net plant heat rate. Cost estimates use total capital requirement (TCR) and fixed and variable operation maintenance costs to predict levelized cost of electricity.

Due to the relatively high cost to develop dedicated biopower facilities and the sizable installed base of coal-fired facilities in Kansas, the modeling effort focused on the performance and cost of co-firing biomass feedstocks with coal in utility boilers. Using spatial analysis to determine the location of low cost and high availability biomass feedstocks in close proximity to Kansas power plants, two coal-fired power plants – Jeffrey Energy Center Unit #1 in Pottawatomie County (Western Resources) and LaCygne unit #1 in Linn County (Kansas City Power & Light Company) were modeled (using the "Co-fire" module within BIOPOWER) in a co-fire mode using switchgrass.

For their respective plants, Western Resources and KCP&L personnel provided data on boiler efficiency, plant thermal efficiency, annual capacity factor, coal heat content, and coal cost. In some cases these data served as inputs to BIOPOWER; in others the data served as a check against the general accuracy of BIOPOWER outputs. The characteristics of the two power plants are shown in Table 5.3.

Table 5.3 Characteristics of Power Plants for Co-Fire Analysis

	Jeffrey Unit 1		LaCygne Unit 1	
Boiler Type	Pulverized (tangential)		Cyclone	
Net Capacity (MW)	734		688	
Boiler Efficiency (%)	84		89	
Plant Thermal Efficiency (%)	32		33	
Annual Capacity Factor (%)	69		64	
Coal Type	Sub-bituminous		Blend (sub-bituminous/bituminous)	
Fuel Composition (%)	Coal	Switchgrass	Coal	Switchgrass
Carbon	47.67	41.72	49.90	41.72
Hydrogen	3.51	5.23	3.70	5.23
Nitrogen	0.78	0.51	1.10	0.51
Oxygen	11.83	33.95	9.00	33.95
Sulfur	0.38	0.03	1.30	0.03
Chlorine	0.00	0.10	0.00	0.10
Moisture	30.19	12.50	27.00	12.50
Ash	5.65	5.96	8.00	5.96
HHV Btu/lb (wet – combusted)	8,340	6,930	8,785	6,930
HHV Btu/lb (dry)	11,946	7,920	12,034	7,920

For each of the power plants, the following two co-firing scenarios were investigated: 2% switchgrass/98% coal and 5%switchgrass/95% coal.104 Based on the volumetric requirements for each of the co-fire scenarios, the cost of switchgrass feedstocks costs grown on "CRP" and "conventional" lands and delivered to the power plant gate were determined from spatial analysis. Since the volumetric requirement for switchgrass feedstocks is greater for the 5% co-fire scenario than the 2% co-fire scenario, the feedstock costs for the 5% scenario are slightly higher (due primarily to greater haul distance).

Two capital cost scenarios were also investigated based on two cost levels recently estimated for a proposed coal/switchgrass project in Iowa. Total capital requirements (TCR) values used in the analysis are based on capital requirements to accommodate a 5% co-fire of switchgrass in a 700 MW pulverized coal boiler, therefore they are considered directly appropriate for Jeffrey Unit 1, which is a 734 MW pulverized system. Slightly lower switchgrass-related TCR values may be possible for LaCygne Unit 1 since it uses a cyclone boiler with less precise fuel sizing requirements. Further, co-firing switchgrass at a 2% rate may result in lower TCR values than for a 5% co-fire rate, but the difference is not 40% as the ratio (2%/5%) would suggest. Capital requirements for a 2% co-fire may be as high as 85-90% of the capital requirements for a 5% co-fire. For this analysis, capital requirements are the same for the 2% and 5% co-fire scenarios, which may be indicative of a transition period where the infrastructure at the power plant to accommodate a 5% co-fire of switchgrass is readied and the infrastructure outside the plant gate (switchgrass plantation development) is ramping up to deliver sufficient feedstock to realize a 5% co-fire. However, a distinction was made in the number of personnel required to handle and process switchgrass at 2% and 5% co-fire rates, and BIOPOWER internally accounts for variances in processing cost differences (i.e. electricity consumption of switchgrass-related processing equipment).

[104] Co-firing switchgrass in utility boilers at percentages higher than 5% heat input may cause fouling and slagging. Co-firing switchgrass in utility boilers at percentages of 5% heat input or less minimizes the potential for fouling and slagging.

5.3 Case Study Results

Table 5.4 provides a summary of the levelized cost of power reported by BIOPOWER for the coal-only case and the two co-fire scenarios with varying total capital requirements (TCR) associated with handling and processing switchgrass. Table 5.4 also provides the breakeven cost of switchgrass reported by BIOPOWER to yield an equivalent levelized cost as the coal-only case.

From Table 5.4 the following observations are made:

- Co-firing switchgrass results in an increase in the levelized cost of electricity of 2.2% to 8.4% compared to levelized costs for coal only cases, depending on power plant, cost of boiler feedstocks, and switchgrass-related capital requirements;

- The breakeven cost for switchgrass to be competitive (on a levelized cost basis) with coal-only scenarios ranges from $1.34 to $33.24, indicating switchgrass would need to be delivered at virtually no cost or negative cost to the power plant to offset the upfront capital requirements and the recurring O&M costs associated with switchgrass co-firing; and

- While the costs of switchgrass delivered to the LaCygne plant are lower than costs of switchgrass delivered to the Jeffrey plant, the breakeven costs of switchgrass are higher (better) for the Jeffrey plant due to the higher cost of coal used at Jeffrey.

Table 5.5 provides a summary of environmental emissions associated with the coal-only case and the two co-fire scenarios. From Table 5.5 the following observations are made:

- Co-firing switchgrass reduces SO_x emissions proportionately with the percentage of switchgrass used, but the sulfur-related benefits of switchgrass co-firing are not as pronounced for Jeffrey and LaCygne as for power plants elsewhere due to the relatively low sulfur content of the coals used;[105]

- Co-firing swichgrass reduces NO_x emissions on the order of 15%; and

- Co-firing switchgrass results in comparable levels of CO_2, particulates, and total ash (bottom ash and fly ash).

Output results for each case modeled by BIOPOWER are presented in Appendix C.

[105] When SO_x emission credits were modeled in BIOPOWER, little impact was made on system economics.

Table 5.4 Summary of Power Cost from Two Kansas Utility Plants (1998 $)

	Coal Only	**Co-Fire (2% Switchgrass/98% Coal)**				**Co-Fire (5% Switchgrass/95% Coal)**			
		Switchgrass-Related TCR of $4.2 Million **($283/KW – Jeffrey)** **($302/KW – LaCygne)**		**Switchgrass-Related TCR of $6.5 Million** **($441/KW – Jeffrey)** **($470/KW – LaCygne)**		**Switchgrass-Related TCR of $4.2 Million** **($113/KW – Jeffrey)** **($121/KW – LaCygne)**		**Switchgrass-Related TCR of $6.5 Million** **($177/KW – Jeffrey)** **($189/KW – LaCygne)**	
	Levelized Electricity Cost $/kWh	Levelized Electricity Cost $/kWh	Breakeven Cost of Switchgrass $/ton	Levelized Electricity Cost $/kWh	Breakeven Cost of Switchgrass $/ton	Levelized Electricity Cost $/kWh	Breakeven Cost of Switchgrass $/ton	Levelized Electricity Cost $/kWh	Breakeven Cost of Switchgrass $/ton
Jeffrey Unit #1 (734 MW)									
Coal Required – 2,805,595 dt/y									
$26.64/d-ton	0.0277								
Switchgrass Required – 59,110 dt/y									
$28.31/d-ton (CRP)		0.0283	(13.66)	0.0284	(21.45)				
$47.78/d-ton (conventional)		0.0287		0.0288					
Switchgrass Required – 147,860 dt/y									
$28.87/d-ton (CRP)						0.0289	1.34	0.0290	(1.77)
$48.22/d-ton (conventional)						0.0297		0.0298	
LaCygne Unit #1 (688 MW)									
Coal Required – 2,342,797 dt/y									
$18.60/d-ton	0.0250								
Switchgrass Required – 52,000 dt/y									
$26.00/d-ton (CRP)		0.0258	(24.39)	0.0259	(33.24)				
$38.50/d-ton (conventional)		0.0260		0.0262					
Switchgrass Required – 130,102 dt/y									
$26.09/d-ton (CRP)						0.0264	(7.33)	0.0266	(10.87)
$38.83/d-ton (conventional)						0.0270		0.0271	

Notes:

TCR is total capital requirement (equipment+engineering+installation+contigencies) to handle and process switchgrass. $/KW values are for switchgrass-fired capacity.

Delivered switchgrass feedstocks costs vary for the 2% and 5% co-fire cases due to varying land characteristics and haul distances.

TCR values are consistent with data reported by Chariton Valley Resource Conservation and Development, Inc. for a switchgrass co-fire project (5%) proposed for a 700 MW pulverized coal facility in Ottumwa, IA. A TCR of $4.2 million is generally consistent with cost data reported in *Biomass Energy Conversion Technology Study* prepared for Chariton Valley RC&D by Black & Veatch, 1995, which includes a truck scale, storage barns for seven day supply of switchgrass, forklifts, two movable conveyors, two tub grinders for feedstock sizing, a high pressure and low pressure pneumatic conveyor system for boiler feed, short-term buffer storage bins, and indirect costs. A TCR of $6.5 million is generally consistent with cost data prepared for Chariton Valley RC&D by RW Beck, 1998, which includes a truck scale, storage barn for three day supply of switchgrass, two overhead building cranes, conveyors, switchgrass shredding equipment, pneumatic conveyors, buffer storage bins, and indirect costs.

Table 5.5 Environmental Emissions from Two Kansas Utility Plants (1000 Tons per Year)

	Coal-Only					Co-Fire (2% Switchgrass/98% Coal)					Co-Fire (5% Switchgrass/95% Coal)				
	CO_2	SO_x	NO_x	Part.	Ash	CO_2	SO_x	NO_x	Part.	Ash	CO_2	SO_x	NO_x	Part.	Ash
Jeffrey Unit 1	4870	21.3	14.0	0.7	166.1	4877	20.9	11.7	0.7	167.0	4887	20.4	11.7	0.7	168.4
LaCygne Unit 1	4257	60.9	12.3	0.6	194.1	4264	59.7	10.3	0.6	194.0	4275	58.0	10.3	0.6	193.8

Notes:
CO_2 = carbon dioxide; SO_x = sulfur oxides; NO_x = nitrogen oxides; Part. = particulates; Ash = bottom ash and fly ash.
CO_2 emissions of switchgrass are closed-loop in direct proportion to its total energy profit ratio (EPR).

6.0 Recommendations for Further Biomass Development Activities

6.1

6.2 The Conservation Reserve Program and the 2000 Farm Bill

Authorizing use of CRP enrolled land was promoted and considered during debate on the Federal Agriculture Improvement and Reform Act of 1996 which extended the CRP program, but not adopted. Some form of specific exemption for harvesting biomass energy crops from CRP enrolled land could reduce the market cost of biomass energy crops and significantly reduce the uncertainty regarding long term availability. If KEURP member utilities are interesting in maximizing the potential for biomass fueled generation, developing a strategy for promoting provisions for use of CRP enrolled land for biomass energy production as part of the year 2000 farm bill should be a prime consideration.

6.3 Continuation of the $0.015 Plantation Biomass Energy Tax Credit

The soon to expire renewable energy production tax credit for "closed loop" biomass is essential to reduce the incremental cost of biomass-fired generation to a level supportable with green pricing. If KEURP member utilities desire to further consider biomass energy development for power generation, they should consider supporting the proposed extension of the exisiting biomass tax credit.

6.3 Boiler Co-firing Trial Tests

If KEURP member utilities decide to further pursue co-firing switchgrass with coal, additional steps should be taken to evaluate the potential for boiler fouling and slagging. One basic step would be a review of forthcoming data on boiler effects that may be available from Madison Gas & Electric, ongoing research efforts in Denmark, the Ottumwa, Iowa co-fire field test scheduled for 1999, and other similar projects. Another step may include bench-scale testing of the chemical and combustion characteristics of coal and switchgrass feedstocks that would be used in Kansas co-fire facilities.

6.4 Rigorous Field Trials to Better Understand Production Cost, Optimized Harvest Methods, Energy Profit Ratio, and Environmental Impacts

A rigorous analysis of potential yields, costs, and area specific production of two promising biomass crops has been performed as part of this project, yet a great deal remains to be learned regarding the real potential for their profitable use in Kansas. While genetic research continues on switchgrass, primarily at Oklahoma State University, such work on black locust appears to have been discontinued. Field trials were conducted on black locust varieties by Geyer and others from the late 1970s to early 1990s, but only limited field trials have been conducted on new varieties of switchgrass. ALMANAC was used to estimate the impact of varying nitrogen application levels for switchgrass. These estimates should be varified with actual field trials. The field operations component of field operations was estimated based on the use of conventional agricultural and forestry equipment. Equipment specifically designed for harvesting energy crops would likely reduce these costs. Finally, most of the yield data available has been developed from relatively small managed test plots and the data does not generally reflect the diversity resulting from real world conditions.

An aggressive field trial program along the lines of the parameters outlined below should be considered:

- two sites, one in Region 2 or 3, the other in Region 4, or 5,
- two diverse soil types at each site based on lowest cost – highest yield predicted in this study,
- minimum land area for each soil type plot of 160 acres, EI >8,
- plant each soil type plot in four different promising switchgrass varieties,
- manage each variety with four different nutrient strategies (10 acre plots).

For each ten acre sub-plot, evaluate the following:

- yield and energy profit ratio,
- production cost by component,
- environmental impact, including erosion, nutrient migration, root system carbon sequestering, and wildlife density, diversity, and health.

Investigate the following specific strategies for achieving highest yield, lowest prodution cost, maximum environmental benefit:

- identify switchgrass varieties best suited for particular climate, soil, and management conditions,
- develop new harvesting and material handling method that minimize field to boiler mouth biomass energy cost.

In conjunction with field trials, work should be encouraged and supported to improve and validate the ALMANAC model for Kansas specific conditions.

Essentially the same scenario should also be considered for black locust.

6.5 Measure and Monetize Environmental Benefits

One strategy for reducing the actual cost of switchgrass and black locust is to determine the environmental benefits associated with their production and use, such as improved water quality through a reduction in soil erosion and nutrient runoff compared to conventional commodity crop production, and a monetary value placed on these benefits. The actual monetary value could be in the form of a payment to either the landowner or utility based on the number of tons of soil (sediment) saved or a percent reduction in nutrients or herbicide leached to groundwater.

6.6 Investigate Strategies for Improving the Energy Profit Ratio of Biomass Crops

Evaluate the potential for using biodiesel for field and transportation equipment.

Evaluate the potential for using animal wastes from large livestock confinement operations as an alternative source of nitrogen.

6.7 Rekindle Research on Genetic Improvement of Black Locust

The current ORNL Biofuels Development Program focus on hybrid poplar may represent the best SRWC opportunity for much of the US, particularly areas with higher annual rainfall than Kansas. However, black locust, a tree with consideable genetic diversity, may represent a more viable alternative for the central and eastern Kansas. Leguminous, it offers the potential for a higher energy profit ratio than other SRWCs or HECs. If KEURP wishes to keep a SRWC option active they may want to consider supporting further basic black locust genetic development focusing on yield, insect resistance, and plant form.