LNC 96-102

Appendix F

Economic Assessment of Conventional and Bioenergy Cropping Options for Saline Seep Remediation

Richard G. Nelson and Kyle R. Mankin

DRAFT – To be submitted to *Applied Engineering in Agriculture*

ECONOMIC ASSESSMENT OF CONVENTIONAL AND BIOENERGY CROPPING OPTIONS FOR SALINE SEEP REMEDIATION

R.G. Nelson, K.R. Mankin

ABSTRACT. *Saline seeps are an increasing concern throughout the Great Plains, including the dryland crop production areas of Kansas. Seep development has been shown to be related to the shift from native grass prairie to annually cropped winter wheat. To control saline seep recharge, higher water-use crops or rotations must be used. The search for alternative crops has led to the consideration of bioenergy crops to help address the saline seep concern as well as diversify production. A total cost analysis on the net present value of farmer's variable costs (NPVVC) was used to compare the economics of winter whea (the traditional crop), alfalfa (a widely used alternative crop), and switchgrass (a bioenergy crop). Alfalfa was a competetive cropping alternative to winter wheat in this area based on *. The NPVVC of switchgrass with a yield of 4 dry tons/acre would be competetive with the delivered price of natural gas (approx. $3.50/MMBtu in 199*), only when average annual yields of winter wheat were 25 bu/acre and alfalfa were 2.5 tons/acre, both considered to be very low. This analysis demonstrates the economic difficulty with farmers switching to biomass energy crop production, but suggests that alfalfa is an economical alternative to winter wheat for controling saline seeps.* ***Keywords.*** **, Alfalfa, Wheat, Switchgrass.*

INTRODUCTION

Saline seeps are an increasing concern throughout the Great Plains, including the dryland crop production areas of Kansas. The seeps, which range in size from a few square meters to 20 ha, are growing in number, area, and severity. Seep development has been shown to be related to the shift from native grass prairie to annually cropped winter wheat, which reduced the net plant water use in the region and resulted in increased water movement downward through the soil (Doering and Sandoval, 1976; Halvorson, 1988). As the percolating water encounters a less permeable layer, lateral movement occurs until an outcrop area is reached, where the water evaporates and leaves behind the various salts that were accumulated along the flow path (Figure 1). The seeps typically go unnoticed for many years, until the salt concentration in the topsoil influences crop production. Normal crop production is feasible in reclaimed saline seeps. However, once the seep area has been controlled and reclaimed, a return to previous production practices would quickly reactivate the seep. Soil water in the recharge area will need to be continually managed to prevent recurrence of the seep and allow sustainable production on the land.

Two general methods have been used to remediate saline seep areas. Subsurface drains installed up-gradient from the seep can intercept the lateral water movement and reduce the salt loading to the seep area. Adoption of this control practice is limited by the high initial cost and practical problems associated with locating an acceptable outlet for the drainage discharge.

The authors are **Richard G. Nelson, *ASAE Member Engineer*?***, Assistant Professor, Engineering Extension Service, Kansas State Univ., and **Kyle R. Mankin, *ASAE Member Engineer***, Assistant Professor, Dept. of Biological and Agricultural Engineering, Kansas State Univ. **Corresponding author:** (?either one of us – this is the information needed…) Kyle R. Mankin, Dept. of Biological and Agricultural Engineering, Kansas State Univ., 140 Seaton Hall, Manhattan, KS 66506-2906; telephone: 785-532-2911; email: <kmankin@ksu.edu>.

Alternatively, cropping practices can be modified to use the water before it percolates below the root zone. Use of the water by a crop in the recharge area while it is a relatively non-saline water resource is considered the better approach.

The traditional farming system in south-central Kansas is continuous-wheat, with winter wheat planted in September-October and harvested in May-June. The summer fallowing period is intended to store water for the next wheat crop. However, 30% of annual precipitation typically occurs during the last two months of wheat production (May and June) and 45% occurs during the fallow period (between July and September) in south-central Kansas. It is this water that the alternative practices are intended to utilize.

One alternative is to shift to a perennial cropping system (e.g., alfalfa). Here, the entire up-gradient area would be planted to a high-transpiration, perennial crop. This would maximize water use and allow close approximation of the native grass system while allowing profitable economic return from the land.

In addition to traditional food and feed crops, several crops show potential for production on lands recharging or affected by saline seeps. For example, switchgrass (*salinity toloerance?, ET?) has been demonstrated as a small-scale alternate energy source for schools, hospitals, and industrial processes. Use of such crops beyond their planned objective for saline seep control will increase the value of the reclamation process to the landowner.

The decision of which cropping practice to use for saling seep remediation depends on its effectiveness in reducing seep recharge, discussed in detail by Mankin and Koelliker (1999), and its economic viability. An economic comparison of switchgrass with the two major copping options in south-central Kansas, continuously cropped winter wheat and alfalfa, will help assess the economic risks associated with each option. In the case of using the lands for producing alfalfa hay or wheat, the net return per acre should be an adequate guide when determining which crop to plant over the next ten years and if it is possible to form a rotation between the two. But the production of switchgrass for energy purposes means that it will be competing with a conventional energy source such as natural gas; the delivered price of this conventional energy source must also be taken into consideration when analyzing whether to grow switchgrass.

OBJECTIVES

Evaluate and compare costs and profit potential for producing alfalfa, continuously cropped winter wheat, or switchgrass for energy purposes on saline seep-affected lands. Specifically, the net present values above a farmer's variable costs (NPVVC) were determined for all three crops grown on the recharge areas of saline seeps over multiple years for a range of yield predictions. The delivered cost of energy derived from the conversion of switchgrass was also assessed to determine the price at which the biomass energy source would be competitive with the current energy source, natural gas.

METHODS

In order to determine the multi-year effect of different cropping scenarios on the delivered price of energy derived from the conversion of switchgrass, the farmer needs to estimate, with reasonable accuracy, an expected annual net return associated with each cropping scenario. A farmer's net return is a function of his variable and fixed costs, crop yield and price, and any government payment. Variable costs are considered true "cash" expenses which must be covered each year, while fixed costs (e.g., depreciation on machinery) do not necessarily require a cash expenditure on an annual basis. Therefore, a farmer is more susceptible to changes in his variable costs because these have a greater impact on his cash flow and hence, his decision(s) on how best to manage his lands.

One simple but highly effective method to estimate and compare the effect of annual net returns associated with different cropping scenarios on an alternate crop production scenario is to calculate the net present value (NPV) of each cropping scenario based on projections of future expected costs and returns. Net present value is defined as the present (today's) value of a series of future costs and returns subject to a certain discount rate. Therefore, determining the net present value of each cropping scenario with respect to a farmer's variable costs, refered to as the net present value of variable costs (NPVVC, $/acre), provides a simple economic indication by which a farmer can make decisions. In this case, NPVVC will help determine how production of alfalfa or continuously cropped winter wheat on saline seep recharge acreages will influence the NPVVC of switchgrass and hence the delivered cost of energy produced on these same lands over an extended period of time.

DETERMINATION OF THE NPVVC

Determination of the NPVVC over an extended period of time for each of the three crops involved projecting variable and fixed costs, as well as returns, over a period of nine years beginning in crop year 1998, using accepted cost and price forecasts. Nine years was chosen because this is a typical growth and harvesting cycle associated with a single planting of switchgrass in Kansas. Forecasting future expenses and returns for each of the three crops involved establishing "base" year (crop year 1997) crop production costs and then multiplying these by accepted cost indices multipliers.

Crop production cost categories and base year costs. Crop production cost categories, both variable and fixed, include labor, seed, fertilizers and herbicides, fuel and oil, insurance, repairs, interest, and real estate taxes. Production costs for alfalfa and continuously cropped winter wheat were taken from KSU Cooperative Extension Service Farm Management Guides (KSU Cooperative Extension Service, 1995a; 1995b). These guides are widely accepted as a means of analyzing current farm production expenses and are also used to predict future expenses and returns for various agricultural crops produced within Kansas. Since the experimental portion of this project is being conducted in Rice and Harper Counties located in south central Kansas, Farm Management Guides for this portion of the state were used.

Actual production costs do not exist in published form for switchgrass production in Kansas and thus were derived from personal conversations with state hay production experts and agronomy personnel (Ohlenbusch and Fjell, 1998). Expenses associated with particular field operations were taken from the 1996 *Kansas Custom Rates* (Kansas Agricultural Statistics Service, 1996). Production expenses used for all three crops were updated to reflect current (1997) costs according to the methodology presented in the next section.

Prediction of future crop production expenses. The Food and Agricultural Policy Research Institute (FAPRI) forecasts future farm production expenses for eight years for a variety of farm-related categories (Food and Agricultural Policy Research Institute, 1997). In addition, they forecast expected supplies of various commodity crops. Farm production expense categories and expected total costs that would be incurred by United States farmers for each of these categories in 1997 were used.

Prediction of future expenses for each crop production cost category for the three crops involved determining cost indices multipliers using FAPRI expense forecasts of 1997. A cost indices multiplier is defined as the ratio of a projected farm production expense, such as petroleum and oil, in a future year divided by its base year expense. For example, the total expense for petroleum fuel and oil in 2000 is predicted to be 6.15 billion dollars while the base year (1997) is 5.89 billion dollars. This means that the cost indices for 2000 is 1.044 ($6.15/$5.89). Using this multiplier, the petroleum fuel and oil expense ($/acre) for alfalfa in 2000 is predicted to be $19.95, up from $__* in 1997. Similar calculations were made for all other expense categories.

CROP YIELDS AND RETURNS

Crop yield and price have a direct effect on a landowner's net return above variable costs. Predictions of future returns were made using FAPRI price forecasts for alfalfa and wheat. The impact of these returns on the farmer's net present value above variable costs, subject to varying alfalfa and wheat yields, were examined through the use of a sensitivity analysis.

Alfalfa.. Alfalfa yields can be expected to lie between 2.5 to 4.5 tons per acre on these particular lands (Schroyer, 1998). Future returns ($/ton) for alfalfa were estimated using a 1997 return of $70.00/ton for south-central Kansas, multiplied by the ratio of expected U.S. alfalfa prices in subsequent years to the 1997 U.S. alfalfa price, as predicted by FAPRI.

Wheat. Yields for continuously cropped winter wheat in Rice and Harper Counties can be expected to fall between 25 and 44 bu/acre, depending upon climate conditions, etc. (Schroyer, 1998). Future prices of wheat ($/bu) were predicted as the ratio of the average 1997 Kansas price ($4.94/bu) to the 1997 national price ($4.74/bu), multiplied by the FAPRI-predicted U.S. price.

If continuously cropped winter wheat is produced, it is eligible for a government payment. This payment is determined from a base yield for each county, as established by the United States Department of Agriculture, and is determined by multiplying the base yield in Rice or Harper Counties by the government payment per bushel. The average base yield for winter wheat is 34.4 bushels per acre for both counties. Government payments for continuously cropped winter wheat ($/bu) for 1998 through 2006 are given in Table 1.

Table 1. Government payments ($/bu) for wheat production from 1998 through 2006.

1998	1999	2000	2001	2002	2003	2004	2005	2006
$0.87	$0.62	$0.66	$0.64	$0.59	$0.48	$0.46	$0.46	$0.46

Switchgrass. While no historical yield data exist for dedicated switchgrass production in Rice and Harper Counties, over the nine-year period an average annual yield of 4 dry tons/acre was attainable in these counties on saline-affected lands subject to proper management and climatic conditions (Ohlenbush and Fjell, 1998). This average value was used in all cost/return analyses.

A total of 260 acres are being considered for alternative crop to remediate saline seeps in Rice and Harper Counties. (*how much is needed for optimal operation? From the last para. before Total Cost Analysis, it looks like these acreages are adequate?) Rice County has three separate areas of 40, 40, and 60 acres, while Harper County has two separate areas of 50 and 70 acres. Annual switchgrass production in Rice and Harper is estimated to be 560 and 480 dry tons, respectively.

USE OF SWITCHGRASS AS AN ALTERNATE ENERGY SOURCE

Switchgrass produced on saline seep-affected lands could be used as an alternative energy source to produce heat to raise the temperature of water or generate steam at a local enterprise such as a process industry. For switchgrass production to be profitable, 1) the NPVVC must equal or exceed that for production of competing crops such as alfalfa or continuously cropped winter wheat, and 2) the total cost associated with switchgrass production, transport to its end use, processing, and conversion into usable energy must be less than the cost of the competing conventional energy source, in this case natural gas.

The specific application for which the conversion of switchgrass into usable energy is intended is a function of the energy content of switchgrass and the total annual production of switchgrass. Both of these directly determine the required output of energy from the biomass energy conversion system, which in turn directly affects the cost and efficiency of the biomass energy conversion system.

Switchgrass energy content and total annual gross energy. The heating content of switchgrass is approximately 15.84 million Btu/dry ton (15.84 MMBtu/dton) (ORNL, 1998). The total annual gross heating content is about 8,870 MMBtu (560 dry tons × 15.84 MMBtu/dton) for Rice County, and 7,600 MMBtu for Harper County. Production between counties was not combined, since it was determined that transportation distances made a combined (multi-county) project infeasible.

Application of switchgrass as an energy source. The amount of energy required for a particular application, hence the size of the switchgrass energy conversion system, is a function of the application of use (production of hot water, steam, and/or electricity) as well as the number of hours used annually. The specific application for which the switchgrass would be used in this project is to heat approximately 17,500 gallons of water per day from 65 °F to 185 °F for cleaning purposes at a process industry in Rice County (*each county?). The conversion system associated with this particular application is to operate 10 hr/d, 6 d/wk, and 50 wk/yr (3,000 hr/yr). Natural gas is the primary competing energy source typically used in an existing burner/boiler systems, and costs an average of $3.50 per million Btu ($3.50/MMBtu).

The amount of heat required per hour (MMBtu/hr) for this particular application can be determined by a basic equation of heat transfer:

$$q = m \times c_p \times \Delta T \qquad (1)$$

where: q = required heat transfer rate (MMBtu/hr)
m = mass flow rate of water (lb/hr)
c_p = specific heat of water (1 Btu/($\mathrm{lb}_{\mathrm{water}}$ °F))
ΔT = temperature difference (°F)

Using this equation, approximately 1.75 MMBtu/hr is required to heat 17,500 gallons of water from 65 °F to 185 °F.

However, when switchgrass is converted from its solid form into a useable energy source by a burner system, not all of the 15.84 MMBtu/dton is usable due to thermal losses and incomplete combustion of the switchgrass. In general, most small-scale biomass energy conversion systems have a system efficiency of roughly 70%. This means that only 70% of the gross heating value of 15.84 MMBtu/dton (~ 11 MMBtu/dton) is usable energy. Therefore, in order to meet the requirement of 1.75 MMBtu/hr, nearly 2.5 MMBtu/hr (1.75/0.7) needs to be input into the conversion system. For this particular application, this equates to a total annual heat input of nearly 7,500 MMBtu (2.5 MMBtu/hr × 3,000 hrs) or approximately 470 dry tons of switchgrass. The available area for production is adequate in both counties.

TOTAL COST ANALYSIS

The total cost associated with using switchgrass as an alternative energy source is a function of the production, transport, and processing costs plus the amortized capital cost of the conversion system. Each of these costs needs to be converted into a cost per million Btu ($/MMBtu) in order to make a valid comparison with the delivered cost of natural gas.

Production costs. Since the lands affected by saline seep could readily be used to produce either alfalfa or continuously cropped winter wheat, the NPVVC associated with a range of yield scenarios for each crop must be determined. For this study, three scenarios were used for each crop: 2.5, 3.5, or 4.5 tons/acre for alfalfa; and 25, 33, or 44 bu/acre for continuously cropped winter wheat.

Transporation costs. After the switchgrass has been harvested and baled, it must be transported and processed before it can be used as an alternative energy source. The cost associated with transporting switchgrass is similar to transporting a baled hay crop such as alfalfa. Transportation costs were estimated to be approximately $3.00/dry ton ($0.19/MMBtu) based on 10, one-way transport miles (ORNL, 1995).

Processing costs. After the switchgrass has been unloaded, it must be processed into a smaller size before it can be converted to usable energy. To accomplish this, a tub grinder similar to the type employed for processing alfalfa hay, would be used. Typical rental rates for tub grinding hay are on the order of $50/hr and these grinders can usually process an average of 20 tons/hr. This equates to a total seasonal rental cost of $1,400, based on processing 560 tons of switchgrass per year ($0.16/MMBtu). For an application of the type considered in this project, purchase of a commercial tub grinder would cost approximately $12,000/yr, based on a 10-year amortization; therefore, renting is the most economical option.

Conversion system capital cost. The boiler being used in an existing natural gas conversion system can also be used in conjunction with the biomass conversion system (burner) with some retrofitting. The capital cost of the biomass burner needs to be converted into a cost per MMBtu to compare with the cost of the competing conventional energy source. A total cost for the burner system and required retrofitting to the existing boiler was determined by amortizing all expenditures associated with purchasing, delivering, and installing the burner over a nine-year period (same time period as for crop production forecast data) at a fixed loan rate of 7%. This cost was estimated to be approximately $75,000 for a 2.5 MMBtu/hr burner which equated to $1.53/MMBtu.

Delivered cost of energy. The delivered cost of energy ($/MMBtu) is the sum of the edge-of-field cost of production, transport, and processing costs, and an amortized conversion system capital cost.

RESULTS AND DISCUSSION

Production costs. The NPVVC's of each crop and yield scenario are presented in Table 2. Each NPVVC of alfalfa was compared to each NPVVC of continuously cropped winter wheat (nine different cases) and the higher of the two NPVVC's for each of the nine cases was chosen for use in setting the edge-of-field price per ton for switchgrass. This price was set as the price which equated the NPVVC of switchgrass to the higher NPVVC for either alfalfa or winter wheat production in each of the nine cases. These prices are given in Table 3. This was converted into $/MMBtu by dividing by 15.84 MMBtu/dry ton.

Table 2. NPVVC for selected yields of alfalfa (ton/acre) and winter wheat (bu/acre).

Code	Alfalfa yield	Alfalfa NPVVC	Code	Wheat yield	Wheat NPVVC
a1	2.5	$43.71	w1	25	$170.26
a2	3.5	$453.72	w2	33	$490.50
a3	4.5	$863.72	w3	44	$822.72

Table 3. Edge-of-field price for switchgrass ($/ton) needed to match the higher NPVVC of alfalfa or continuously cropped winter wheat for various scenarios. Underlined code has higher NPVVC of the two.

Code	NPVVC	$/ton	Code	NPVVC	$/ton	Code	NPVVC	$/ton
a1 w1	$170.26	$26.82	a2 w1	$453.72	$41.13	a3 w1	$863.72	$61.84
a1 w2	$490.50	$42.98	a2 w2	$490.50	$42.98	a3 w2	$863.72	$61.84
a1 w3	$822.72	$59.77	a2 w3	$822.72	$59.77	a3 w3	$863.72	$61.84

Delivered cost of energy. Table 4 presents a total cost analysis for the edge-of-field costs for each of the nine yield scenarios considered in addition to the delivered cost of energy from switchgrass ($/MMBtu). In all cases, the delivered cost of energy derived from switchgrass was higher than the competing conventional energy source, natural gas. Therefore, production of switchgrass as an alternative energy source on these lands for this particular application would be uneconomical and should not be pursued.

Table 4. Edge-of-field and delivered costs of switchgrass ($/MMBtu) needed to match the higher NPVVC of alfalfa or continuously cropped winter wheat for various scenarios. Underlined code has higher NPVVC of the two.

Code	Edge-of field cost	Delivered cost	Code	Edge-of field cost	Delivered cost	Code	Edge-of field cost	Delivered cost
a1 w1	$1.69	$3.57	a2 w1	$2.61	$4.49	a3 w1	$3.90	$5.78
a1 w2	$2.71	$4.59	a2 w2	$2.71	$4.59	a3 w2	$3.90	$5.78
a1 w3	$3.77	$5.65	a2 w3	$3.77	$5.65	a3 w3	$3.90	$5.78

The net return associated with a range of yield scenarios for each crop demonstrated the economic difficulty with farmers switching to biomass energy crop production. Further, the delivered cost of energy derived from the conversion of switchgrass was found to be significantly higher that the current energy source, natural gas. However, the economic analysis also indicated that alfalfa was a competitive cropping alternative to wheat in this area.

At this time, the analysis indicates that it will be highly unlikely that the current project lands will be used for producing switchgrass due to the small acreages at each site. This inevitably translates into a smaller scale-of-economy when the purchase of conversion equipment is taken into consideration. Of course, larger acreages and/or more favorable economics for energy crop production may alter this assessment.

CONCLUSIONS

*

REFERENCES

Doering, E.J. and F.M. Sandoval. 1976. Hydrology of saline seeps in the Northern Great Plains. *Trans. ASAE* 19:856-861, 865.

Food and Agricultural Policy Research Institute. 1997. *U.S. Agricultural Outlook.* FAPRI, University of Missouri-Columbia, Columbia, Missouri.

Halvorson, A.D. 1988. Role of cropping systems in environmental quality: Saline seep control. p. 179-191. In W.L. Hargrove et al. (ed.) Cropping strategies for efficient use of water and nitrogen. ASA Spec. Publ. 51. ASA, CSSA, and SSSA, Madison, WI.

Kansas Agricultural Statistics Service. 1996. *Kansas Custom Rates.* Topeka, Kansas.

KSU Cooperative Extension Service, Dept. of Agricultural Economics. 1995a. KSU Farm Management Guide, MF-363, *Alfalfa Costs and Returns in Central and Eastern Kansas.*

KSU Cooperative Extension Service, Dept. of Agricultural Economics. 1995b. KSU Farm Management Guide, MF-574, *Continuous Cropped Winter Wheat in Central Kansas.*

Mankin, K.R. and J.K. Koelliker. 1999. A hydrologic balance approach to saline seep remediation design. *J. Applied Eng. in Agr.* (in review).

Ohlenbusch, P.D. and D. Fjell. 1998. Dept. of Agronomy, Kansas State University, Manhattan, Kansas. Personal communication.

ORNL. 1995. Ribatran Transportation Model. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Schroyer, J.D. 1998. Dept. of Agronomy, Kansas State University, Manhattan, Kansas. Personal communication.

Table *. Total cost analysis for alfalfa, continuously cropped winter wheat, and delivered cost of switchgrass ($/MMBtu).

		wheat yield, bushels/acre				
	alfalfa yield, tons/acre	25		33		44
NPVVC, alfalfa	2.5	$43.71		$43.71		$43.71
NPVVC, wheat		$170.26		$490.50		$822.72
switchgrass, $/ton		$26.82		$42.98		$59.77
$/MMBtu, edge of field		$1.69		$2.71		$3.77
$/MMBtu, delivered		$3.57		$4.59		$5.65
NPVVC, alfalfa	3.5	$453.72		$453.72		$453.72
NPVVC, wheat		$170.26		$490.50		$822.72
switchgrass, $/ton		$41.13		$42.98		$59.77
$/MMBtu, edge of field		$2.61		$2.71		$3.77
$/MMBtu, delivered		$4.49		$4.59		$5.65
NPVVC, alfalfa	4.5	$863.72		$863.72		$863.72
NPVVC, wheat		$170.26		$490.50		$822.72
switchgrass, $/ton		$61.84		$61.84		$61.84
$/MMBtu, edge of field		$3.90		$3.90		$3.90
$/MMBtu, delivered		$5.78		$5.78		$5.78

* natural gas: $3.50/MMBtu, delivered