THE ROLE OF AGRICULTURAL LANDS IN TIMBER AND BIOMASS PRODUCTION

S. Arif Husain, Dietmar W. Rose, and Joan M. Nichols[1]

ABSTRACT. —The potential of certain agricultural lands to be converted to short rotation poplar production in order to reduce harvest pressure on commercial forests was examined. An optimization model, a transportation model, and a poplar production model were utilized to generate optimal management schemes. The output is the marginal cost of delivered timber, location, and quantity of agricultural lands harvested in each planning period. The results show that agricultural lands can play a critical role in meeting timber and fuelwood demands over time. The role of agricultural lands as sole providers of fuelwood was also analyzed.

INTRODUCTION

Increases in market and non-market demands for natural resources are compelling decision-makers to rethink current natural resource management policies. The demand for forest products has grown substantially in recent years and is expected to continue to grow well into the next century. Public concerns over forest industry expansion and its perceived negative impacts on the environment stimulated preparation of a Generic Environmental Impact Statement (Jaako Pöyry 1992), which indicated potential constraints in meeting existing and future timber demands in the state. There is a particular shortage expected in aspen production due to the unequal age class distribution of currently growing timber.

Electricity is traditionally produced from non-renewable resources such as coal, natural gas, petroleum, or nuclear energy. Since energy production from these fuels can result in environmental externalities such as emissions of sulphur and carbon, there is an increasing public interest in the possibility of using substitute fuels such as biomass. The use of biomass energy for large-scale electricity production is not a new idea. It was thoroughly examined, for example, during the oil crisis of the mid-seventies. The idea was rejected because it was considered cost ineffective when compared to fossil fuels or nuclear energy. Now, thirty years later, biomass energy production is again gaining public attention. The present study examines the relationship of the forest and electric power industries by focusing on the use of wood as either a biomass fuel or as a traditional timber product.

Increasing demand for wood has resulted in higher timber prices in recent years. Wood-fired power plants would add to this demand and thus further increase timber prices. In order to meet these increased demands, it is being advocated that short-rotation woody crops (SRWCs) be produced on marginal agricultural lands such as those set aside under the Conservation Reserve Program (CRP). These lands, it is argued, have the potential to provide both fuelwood and timber, thereby reducing harvest pressures on traditional forest lands. This could also provide farmers with an additional cash crop assuming that markets will exist. Soil erosion and water contamination concerns might be reduced because of the relatively long rotation periods associated with SRWCs and reduced reliance on pesticides and herbicides which contribute to water contamination.

Production of SRWCs on agricultural lands might permit some landowners to diversify their crop operations. This is particularly relevant in light of the 1996 farm bill which incorporates several reforms and structural changes in the United States agricultural policy. In short, agricultural subsidies are to be phased out by 2003. Most of CRP acres will come out of contract by 1999, perhaps to be returned to annual crop production. In the absence of price support programs, this increased production might result in lower crop prices which can have substantial national and

[1] S. Arif Husain is a research associate and Dietmar W. Rose is a professor, College of Natural Resources, University of Minnesota, St. Paul, MN 55108; Joan M. Nichols is an assistant professor, School of Natural Resources, The Ohio State University, Columbus OH 43210.

international consequences. Because some of the CRP acreage is highly erodible, its return to annual cropping could result in an increase in soil erosion and surface water contamination.

Proponents argue that growing SRWCs on agricultural lands, particularly those that are adjacent to the current forest lands and not highly erodible as energy or fiber plantations might have a positive impact on the economy as well as on the environment. However, before energy production plants are built and large investments into farm-grown woody biomass are made, it must be understood how such developments would fit with the existing economic and environmental conditions.

OBJECTIVES

In this research, we examine the role of marginal agricultural lands in Minnesota as potential fuelwood and timber suppliers. We assume that hybrid poplar produced on these lands can either be used as a substitute for timber or as fuelwood. Although, we considered traditional forest lands as well as agricultural lands, the focus of this paper is on the role of agricultural lands only. Expected future aspen demands at six aggregated forest markets and biomass requirements for two 100MW power plants are modeled.

A set of spatial and dynamic optimization models (DTRAN, GISTRAN) is used to estimate the delivered timber and fuelwood prices under different cost and production assumptions over ten 10-year planning periods (Hoganson and Rose 1984; Kapple and Hoganson 1991; Husain 1997). The combination of forest lands as well as agricultural lands in a location specific environment adds a new dimension to the previous planning efforts. Furthermore, the inclusion of transportation cost based on actual road distances between analysis areas and the market locations provides better estimates of delivered costs. The results of this study show the amount and location of agricultural lands best suited for poplar production under several management scenarios.

STUDY DATA

The forest markets considered in this study are Brainerd, Bemidji, Cook, Duluth, Grand Rapids, and International Falls. These locations represent the major concentration of forest industries in Minnesota. The power plant locations considered are Alexandria and Granite Falls. These locations were specifically chosen because they appear to meet the potential requirements for the establishment of biomass operated power plants, as spelled out by EPRI (1994) and are currently under consideration.

Agricultural Land Attributes

The farm land data set for this study was obtained from the Minnesota Department of Agriculture (MDA). This tabular database was created by each county's Farm Services Agency (FSA) office by running a standard query on county CRP records in September of 1994. According to FSA's summary statistics, there were 1,834,411 acres enrolled in the Minnesota before the implementation of the "Early Release Program" in 1995. The key attributes of the database included the legal description of the location of each land parcel, acreage, rent rate, current conservation practice, indication whether the land parcel is highly erodible or is a wetland, and the land capability class (LCC) and land capability sub-class (LCSC) as defined by the Natural Resource Conservation Service (NRCS).

Statewide totals for acreage in major land categories such as highly erodible lands and their distribution in wetlands and converted wetlands are presented in Table 1. The acreage reported as highly erodible (830,000 acres) was excluded from further analysis. Steep slopes or other severe soil limitations associated with these lands render them unsuitable for any type of farming activity, including tree growth. Those lands classified as unknown (90,000 acres) were not excluded from the analysis, except for wetlands. Wetlands are said to provide several environmental and economic benefits and their destruction can have significant long-term impact on the ecosystem itself. Therefore, acreage consisting of confirmed non-converted wetlands (420,000 and 22,000) was also excluded.

Table 1. —Major Agricultural Land Categories and Their Distribution (Acres)

Highly Erodible Lands (YES) 829,788 acres			
Attributes/Indicator	Yes	No	Unknown
Wetlands Indicated	468,289	265,054	96,445
Wetlands Converted	6,720		
Highly Erodible Lands (NO) 786,095 acres			
Attributes/Indicator	Yes	No	Unknown
Wetlands Indicated	419,800	286,173*	80,122*
Wetlands Converted	2,157*		
Highly Erodible Lands (UNKNOWN) 89,558 acres			
Attributes/Indicator	Yes	No	Unknown
Wetlands Indicated	21,765	8,383*	59,410*
Wetlands Converted	2,119*		

Notes: * indicates agricultural lands included in the analysis

These exclusions left the agricultural land database with 438,364 acres, about 26 percent of the original database. This portion of the agricultural land data was modeled in this study for possible planting to hybrid poplar.

Location of Agricultural Lands

The UTM coordinate system was used to represent the location of the aggregated land parcels within a township. Each parcel was treated as if it was located at the geographic center of the township. These coordinates provided the linkage between the land parcels and the transportation network used in this analysis. UTMs were calculated using software known as SECTIC-24K, developed by the Minnesota Land Management Information Center (LMIC).

HYBRID POPLAR

For this study, agricultural landowners are modeled as if they face a choice: (1) do not grow trees and rent the land or (2) grow hybrid poplar and sell it to potential power plants and/or to forest markets. Since hybrid poplar and aspen have similar product characteristics, it is assumed that they can be substituted for each other in all markets. In compliance with existing practices, an 8 X 8 spacing and an optimal rotation age of 10 years is assumed.

Ongoing research on intensively managed plantations provides some reliable information on the production potential of short-rotation hybrid poplar clones. In Minnesota, yield rates are expected to range between 2 to 5 dry tons/acre/year, according to soil and climatic conditions. These estimates are mostly derived from a network of research plantations which were established in a five-state region of the north central U.S. during the 1980s (Hansen et al. 1994). In the present study, yield rates are modeled as a function of NRCS land capability classes and subclasses, rainfall, and soil types. In general, soils with a higher productivity rating for agricultural crops will also be more suitable for hybrid poplar. However, this link is not expected to hold for soils with poor drainage conditions, because hybrid poplar tends to grow well under such conditions (Berguson 1994).

Production Costs

Estimates of variable production costs for hybrid poplar production were obtained from the Natural Resources Research Institute (NRRI), based on actual cost data associated with a network of plantations in Minnesota and Wisconsin. In general, most expenses incurred in the production of hybrid poplar occur during the establishment phase. After successful establishment usually there are no other significant costs until harvest. The only exception might be in case of disease, which may result in additional costs, but these are not modeled in this study. In addition to the traditional production costs, CRP land rents associated with each land parcel are used as the opportunity cost of the landowner participation.

Harvest and Transportation Costs

Harvest and transportation costs are extremely significant components of the timber production process. In general, transportation costs are approximately one third of the total costs associated with the procurement of timber. In some cases, these costs can be actually higher than the stumpage value of a given stand. Despite this, transportation costs are often not considered in the timber management and modeling studies.

Two separate estimates of harvest costs for hybrid poplar were generated. One reflects the traditional harvesting technology, and the other represents the whole tree harvesting systems which avoid expensive operations such as wood chipping and partial skidding. In Minnesota, data on hybrid poplar harvesting costs are rare because most of the large scale plantations are still below harvesting age. Therefore, this study utilized harvesting cost estimates generated by the Oak Ridge National Laboratories (ORNL) for the Great Lakes region (Walsh 1994). Appropriate adjustments were made to reflect the regional conditions and specific assumptions of this research. The adjusted harvest costs for hybrid poplar in Minnesota given (1) Conventional Harvest are $450 per acre with an additional loading and processing cost of 4.75 per dry ton. (2) Whole Tree Harvest is $270 per acre with an additional loading and processing cost of 4.75 per dry ton. In addition to these charges, a 0.15 cent per dry ton per mile charge was also applied to cover hauling costs. The model is further calibrated so that hybrid poplar sold as pulpwood in the forest markets will be harvested conventionally because these markets generally require additional on-site processing. Hybrid poplar sold to power plants will be harvested and processed with the whole tree harvesting technology.

RESULTS

The results for fuelwood demands using only agricultural lands for Alexandria and Granite Falls are presented in Table 2. These results are based on the assumption that whole trees are delivered to the power plants and that farmers use CRP rent rates as their opportunity cost of participation. Approximately 95–100 thousand acres of land capable of producing about 3.5 million dry tons of wood are required to fuel each power plant for each 10 year planning period (350,000 dt/year). Table 2 also shows the maximum and the minimum costs per dry ton. The maximum cost can be interpreted as the marginal cost of delivered fuelwood because it is the cost associated with the last unit of fuelwood delivered to a given power plant. The minimum costs are simply the cost of fuelwood delivered from a location with the lowest overall cost.

Table 2. —Final Results for All Independent Fuelwood Supply Scenarios

Scenario	Acres	Dry Tons	Total Cost ($)	Average ($/dt)	Minimum ($/dt)	Maximum ($/dt)	Average ($/MBtu)
1[A]	94,546	3,501,769	112,071,938	31.86	20.73	35.68	1.85
2[B]	98,809	3,502,947	127,014,242	36.25	23.56	39.99	2.11

Notes: [A] indicates Alexandria power plant with unchipped wood and CRP payment rates.
[B] indicates Granite Falls power plant with unchipped wood and CRP payment rates.

The delivered fuelwood costs at Alexandria are on average about $5/dt lower than Granite Falls. This is simply because those agricultural lands closer to Granite Falls generally fall into the category of good agricultural lands with relatively higher opportunity costs. These high land rents translate into higher production costs, which make it more cost effective to transport fuelwood from lands that are further away but have lower rents. The yields on lands closer to Granite Falls are not so high that they can off-set their higher opportunity costs. The average distance between production sites and Alexandria is approximately 60 miles.

The weighted average delivered fuelwood costs for all townships supplying to Alexandria were also calculated. The cost estimates associated with each yield rate in a given township were weighted by the number of acres to determine the total average costs for a given township. In most townships, delivered costs ranged between $28/dt and $36/dt ($1.98/MBtu). Townships in the west and north-central part of the state deliver the majority of the fuelwood. No fuelwood is supplied from the southern part of the state primarily because of the higher land rents in that area. The range of fuelwood traveling distance is between 4 and 188 miles, with an average distance of 62 miles.

The weighted delivered fuelwood costs for the majority of townships supplying to Granite Falls are between $31/dt and $40/dt and a few townships have costs within $25/dt and $31/dt. Again, higher land opportunity costs result in most of the fuelwood being shipped from the central and west-central part of the state, in spite of the fact that other agricultural lands are closer to Granite Falls. The transportation distances vary by as much as 7 to 211 miles, with an average distance of 91 miles.

While the aspen demand for the initial 4–5 decades cannot be met using only forest lands, the introduction of hybrid poplar produced on agricultural lands changes the results substantially. Since there is little difference between the physical and chemical properties of aspen and hybrid poplar, they can be modeled as if their markets were identical. Figure 1 depicts the discounted aspen shadow prices when agricultural lands are added to the forest lands. The inclusion of agricultural lands substantially reduces aspen shadow prices and the demand targets for all markets and planning periods are satisfied. Shadow prices generally rise for the first four periods before they begin to steadily decline, but their patterns are not uniform across markets.

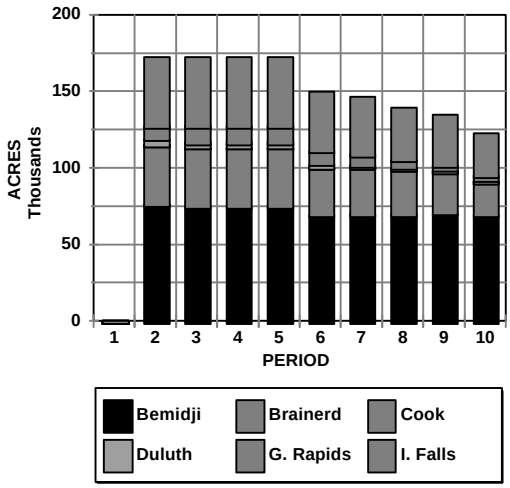

Figure 1. —Aspen Shadow Prices ($/cord) and Agricultural Lands Harvested (acres)

Those markets that bought wood from agricultural land generally exhibit the lowest shadow prices. As a rule, these markets are located closer to agricultural lands with low opportunity costs and high yield rates.

Figure 1 also shows the acreage of agricultural lands utilized to meet aspen demands for all planning period and markets. No agricultural land is harvested in the first planning period because the rotation for hybrid poplar is ten years and therefore it will not be available for harvest until the beginning of the second planning period. The lowest shadow prices are associated with Bemidji, primarily because it is located closer to large acreage of agricultural lands with relatively low opportunity costs. About 70–80 thousand acres of these lands are used to meet the demands at the Bemidji market in each planning period. The highest shadow prices are associated with Duluth and Grand Rapids markets, which receive most of their aspen supply from commercial forest lands. The wood from agricultural lands allocated to Duluth and Grand Rapids markets is relatively insignificant. The only market that does not receive any supply from these lands is Cook. This market is located in the north-eastern part of the state. There are very few agricultural lands near this market and therefore, all its aspen requirements are met by the commercial aspen stands located nearby.

It is interesting to note that after the first four periods the harvested acreage of agricultural lands starts to decline, reflecting the fact that the age class imbalance of aspen stands will begin to improve in about 40 years. Therefore, its ability to provide industrial quality aspen becomes more stable. Because hybrid poplar produced on agricultural lands is generally more expensive than aspen produced on forest lands, the model always picks aspen stands over poplar provided that aspen is physically available. This is the main reason for the reduction in agricultural acres harvested during the later planning periods.

The acreage of agricultural lands harvested to meet fuelwood requirements was not substantial when forest lands were also available for harvest. The main reason for this is that relatively abundant stands of northern hardwoods with relatively higher Btu content than hybrid poplar are available for harvest and therefore, it is economical to supply northern hardwood to the power plants. Furthermore, since there is a shortage of aspen, the model allocates most of the poplar produced on agricultural lands to the traditional forest markets, not to the power plants. Figure 2 illustrates that for both power plants only eight thousand acres were allocated in the initial planning periods and approximately eleven thousand acres in the later planning period. This increase in acreage harvested during the later periods reflects the restricted supply of hardwoods from the forest lands. Most of the fuelwood produced on these lands goes to Granite Falls because it is relatively distant from the forest lands and closer to the agricultural lands. About eight thousand acres are harvested in each planning period for Granite Falls. In comparison, the allocation of agricultural lands to Alexandria is insignificant at least in the first five planning periods. But as the fuelwood supply from the forest lands begins to tighten, the acreage of these lands increases to a little over three thousand acres in the remaining planning periods.

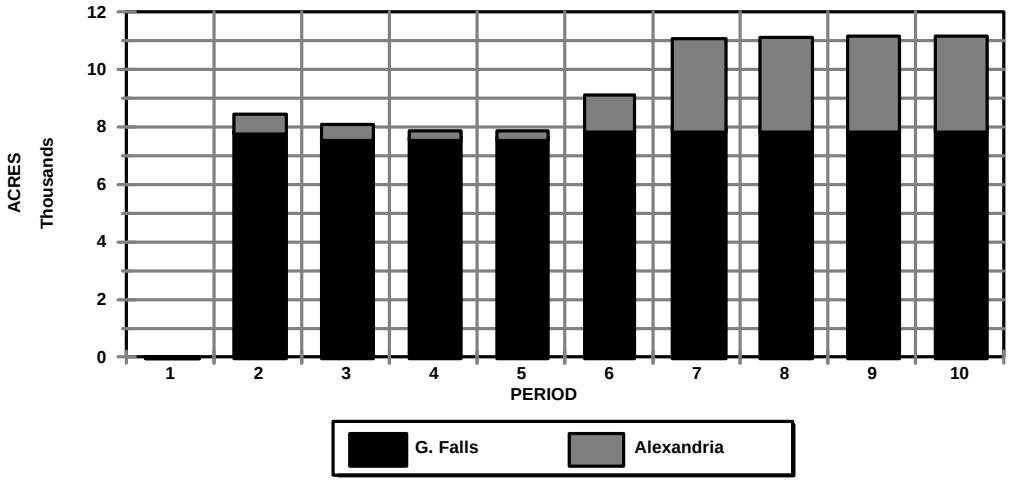

Figure 2. —Agricultural Lands Harvested for Fuelwood when Forest Lands were Available (acres)

CONCLUSION

Modeling timber and fuelwood supply from traditional forest lands and agricultural lands managed under short-rotation production alternatives adds a new dimension to previous Minnesota forest planning efforts. The present study's use of location specific information and realistic estimates of production, harvesting, and transportation costs can provide decision makers with reliable estimates of marginal costs for delivered timber and biomass products.

This research assumed that whenever necessary, the forest industry can use short-rotation hybrid poplar produced on agricultural lands as a substitute for aspen. The results indicate that the inclusion of these lands allows the aspen demands at all markets to be satisfied over all planning periods.

The use of agricultural lands particularly in the initial planning periods has a significant impact on aspen prices and the acreage of forest lands harvested. Production of hybrid poplar results in large quantities of wood in relatively short time and thus significantly reduces the harvest of traditional forest lands. At most about two hundred thousand acres of these lands provide hybrid poplar to the timber markets in each planning period. It should be noted that not every township

with agricultural acreage is allocated to timber production. The combination of landowner opportunity cost, the transportation costs to timber demand markets, and the soil productivity influence the economics of timber production and determine the relative advantage of one township versus another.

Estimates of fuelwood costs were also computed under the assumption that forest lands will also be able to provide fuelwood. The role of agricultural lands significantly decreased in this case because of the apparent differences in the energy contents of hybrid poplar and other forest species such as northern hardwoods. The fuelwood marginal costs rise in each subsequent planning period indicating that fuelwood supply from forest lands becomes constrained over the planning horizon. The role of agricultural lands as fuelwood supplier becomes relatively significant in these later planning periods, particularly for Alexandria.

Since it turns out that the power plants modeled in this study would most cost effectively acquire fuelwood from existing forest lands, substantial savings could be achieved if the plants are located in the northern part of the state where major concentrations of the forest lands exist, rather than the currently proposed southwestern locations.

The results of this study also indicate that poplar produced on agricultural lands has a better chance of being used in the forest industry than in the power plants. This is because forest markets can pay more for poplar than the power plants. In comparison, the power plants can use northern hardwoods, which are available at relatively lower costs and have a higher energy content.

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