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Wood-ethanol plantations: Implications for sustainable forest management

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Highlights

- Access to wood waste and/or land that can be converted to ethanol plantations provide development opportunities for wood-ethanol production.
- Distance to processing plants and transportation infrastructure are two critical factors in the economic viability of wood-ethanol production.
- Impacts of plantations on biodiversity, soil and water quality may be mitigated through management practices designed to reduce fertilizer and erosion impacts and planting tree species mixes.
- Foresters and land-use planners should consider how wood-ethanol production strategies could fit into a sustainable forest management framework.

Ethanol is gaining market share in North America as an alternative fuel. Consequently, some forest and land managers are becoming more interested in diversifying their operations to produce wood-ethanol, either from wood residues or by establishing short-rotation forest plantations.

This note looks at short rotation wood-ethanol plantations, and reviews the economic, ecological and social implications for sustainable forest management and the local economy. It is the companion note to the SFM Network Research Note # 22, *Wood-ethanol in Canada: production technologies, wood sources and policy incentives.*

The economics of wood-ethanol plantations

The cost of wood-ethanol plantations is influenced by several factors, including the costs of raw materials, land, management activities, transportation and the ethanol production process.

The cost of raw materials

An important economic element of ethanol production is the source of the raw material or feedstock. For wood feedstock from short-rotation plantations, the costs of establishment and maintenance of plantations influence the final market price of ethanol. Hardwoods are the preferred tree type, as softwoods have a high lignin content which hinders the ethanol conversion process.

Wood waste from existing pulp, paper or sawmills is often less expensive as it does not carry the cost of plantation management. The demand (and therefore, the cost) for wood waste increases with the number of secondary forest product industries using this material (e.g. OSB plants). Imported wood waste has additional financial considerations including the cost of importing the wood waste and the long-term stability of that import cost.

Residue fibre from harvest or silviculture operations (e.g. thinnings, branches, low-value trees, beetle-killed timber, etc.) has been identified as a potential fibre source for ethanol. However, inconsistent availability, transportation cost and ecological implications of removing the fibre, tend to make this source a less attractive option.

The cost of land

If the feedstock for wood-ethanol plants is derived from short-rotation plantations grown on non-forested lands (such as marginal farmlands), then the cost of land or land rental is another consideration. A survey of Western Canadian farmers found that they would have to be paid a minimum of $100/ha ($40/acre) in rent—a figure that would increase with the productivity of the land—to convert their land to short-rotation tree plantations. Furthermore, on land with low productivity the costs of fertilization and irrigation need to balanced with the return in plantation productivity.

The cost of plantation management

A 2002 economic analysis of plantation production, using an ethanol price of $0.40/L, showed there was potential for profit from plantation-grown wood. The average yield of a hybrid poplar plantation on a 12-year rotation was estimated at approximately 500 m^3/ha—a yield that varies with species, site productivity and management. The cost of establishing a plantation was estimated to be nearly $1600/ha, again depending on the site and management intensity (i.e. type of site preparation and fertilizer/irrigation need). Harvesting costs were estimated to be $12/$m^3$ for a total plantation management cost of approximately $6000/ha.

In that study, ethanol yield was estimated at 44KL/ha based on a conversion efficiency of 242 L/oven-dry ton of biomass for the same hypothetical hybrid poplar plantation. This could translate to nearly $10 000/ha profit without the costs of transportation and ethanol production factored in.

The cost of transportation

Transportation costs are an important factor in the economic viability of wood-ethanol production. Research shows that transport distances over 50 km in length, to a moderately-sized production facility, would be uneconomical. Indeed, truck transportation—the main mode of transport for ethanol feedstock—comprises 30-40% of the total cost of production. This is particularly true for wood waste, which has low bulk density, high moisture content and is highly dispersed. An increase in the price of oil may affect the cost of feedstock transportation but may simultaneously increase the market demand for wood-ethanol production.

The cost of ethanol production

The 2006 cost of producing ethanol from woody materials—either wood waste or woody biomass—is around $0.30/L and $0.35/L and is expected to drop to $0.22/L within the decade, increasing the economic feasibility of wood-ethanol ventures.

The distance to the processing plant and the transportation infrastructure in the area are critical factors in the economics of wood-ethanol production. For high-lignin woody biomass such as softwoods, a market for the lignin co-product also affects the financial viability.

The global oil market will continue to play a large role in the economic viability of any ethanol venture. An increase in oil prices and resulting demand for ethanol and alternative fuels will make wood-ethanol production more financially feasible.

Carbon market economics

Depending on the forest type, discount rates, energy conversion efficiency and the fossil fuel being replaced, the use of wood-ethanol as a transportation fuel could save between 1.7 to 9.0 tons of carbon/ha annually. While the hypothetical carbon benefit of substituting ethanol from biomass plantations for coal and gasoline is significant, the higher cost of wood-ethanol production is currently overriding any economic benefits. Once cost-effective bioconversion technologies are available most scientists agree that wood-ethanol production may become a viable strategy to counter global warming.

In Southern Minnesota, the conversion of cropland to a 5-year rotation hybrid poplar plantation was estimated to consume a total of about 40 GJ/ha of energy and produce approximately 650 kg carbon/ha in emissions through establishment, maintenance and harvest. This value is considerably less than that for fossil fuel production. The calculated annual return of converting cropland to short-rotation woody plantations was estimated to be US$44–96/ha.

The market value of carbon emission offsets may also contribute to the economic feasibility of establishing short-rotation forest plantations for wood-ethanol production. Depending on the market value for carbon offsets, carbon sequestration by trees and fuel emission reduction are likely to be the most "market valuable" environmental benefits. Short-rotation forest plantations may become more economically feasible than wood waste as a raw material for wood-ethanol production due to the added benefit of financial compensation for the carbon storage in the plantations.

Socio-economic aspects

The ethanol industry, in general, has the potential to generate some socio-economic growth, particularly in rural areas. Many analysts forecast a boost in rural employment and economy with the establishment of biomass plantations and the operation of bio-fuel production systems. The year-round availability of wood feedstocks for ethanol production, compared to seasonal grain crops, may translate into more consistent employment at ethanol production facilities. As part of an economic diversification strategy, wood-ethanol production may generate additional profits for pulp and paper mills and sawmills.

Environmental aspects

Wood plantations grown for ethanol production have several potential ecological effects, in terms of carbon storage and climate change, soil and water quality and biodiversity.

Carbon storage and climate change

Since ethanol production is seen as a favourable greenhouse gas mitigation strategy under the Kyoto Protocol, many of the environmental benefits attributed to wood-ethanol are in terms of carbon (Figure 1).

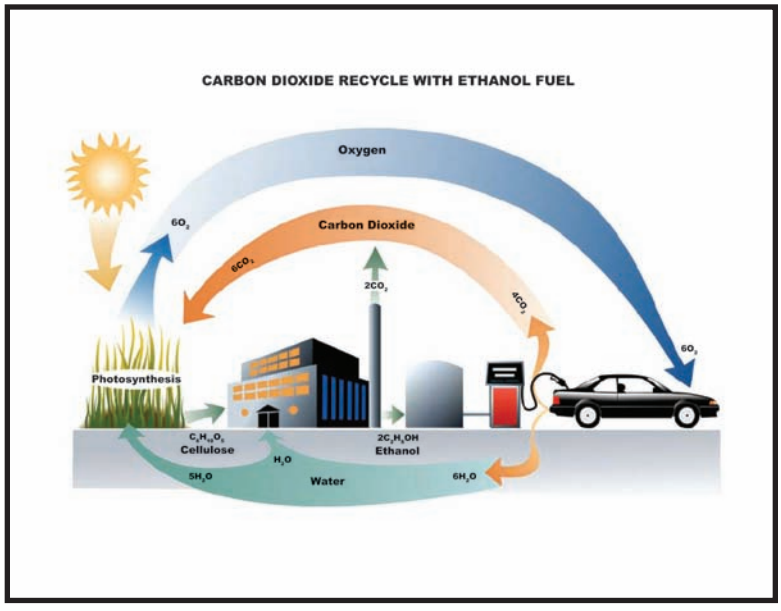

Figure 1: Carbon cycle for ethanol.
(Source: CANMET, Natural Resources Canada)

In general, trees are more efficient carbon sinks than annual agricultural crops. Researchers have analysed carbon sinks and sources for wood-ethanol production in a complete life cycle analysis that included: storage in soil organic carbon; below- and above- ground carbon in fast-rotation wood-ethanol plantations; emissions from bioconversion plants; and emissions avoided by using ethanol rather than gasoline. It was estimated that a small-scale plant that produces 122 megalitres of ethanol annually would divert approximately 350,000 tonnes of carbon dioxide per year. This would be the equivalent of about 2% of Canada's commitment to the Kyoto Protocol.

In addition, the lignin co-product of ethanol production can also be used to generate power, thus further reducing reliance on fossil fuels. However, some studies from the United States indicate that wood-ethanol production consumes 57% more energy than it produces. If there is truly a negative energy balance associated with ethanol production, then its potential may be more limited than expected—further research is required to confirm this.

Ecological comparison of tree plantations and annual crops for ethanol production

Wood-ethanol plantations have potentially different ecological effects than grain-ethanol crops, particularly for soil and water quality, biodiversity and site productivity. Much of the information on the ecological advantages and disadvantages for wood-ethanol production comes from studies of grain-ethanol production. Most of these data originate from the United States; however, conditions are likely to be similar in Canada.

Soil and water quality

Adverse effects on water quality can be minimized through a reduction in fertilizers and pesticide use in wood-ethanol plantations. In the case of pasture or hayland where few, if any, agrochemicals are used, conversion to plantations will likely have a negligible effect on water quality.

The table below presents average fertilizer requirements for wood-ethanol plantations and switchgrass. For plantations, fertilizer is usually applied during the first one or two years after establishment, depending on specific site characteristics (e.g., soil fertility and texture). Switchgrass is an annual cellulose-ethanol crop. Agricultural crops like corn require considerably more fertilizer than either of these two bio-energy crops.

	Nitrogen	Phosphorous	Potassium
Wood-ethanol plantation	60 kg/ha/year	15 kg/ha/year	15 kg/ha/year
Switchgrass	50 kg/ha/year	60 kg/ha/year	60 kg/ha/year

Table 1. Average annual fertilizer requirements for wood-ethanol plantations and switchgrass crops.

Adverse effects on water and soil quality, similar to those associated with clearcut harvest systems, may result during harvest of short-rotation plantations. Best management practices for operations associated with the construction of roads and other infrastructure linked with harvest activities (landings, bridges, etc) should minimize soil erosion and compaction , as well as mitigate impacts on aquatic systems (i.e., increased sedimentation).

Researchers have predicted an improvement in water quality and less topsoil erosion in tree plantations, in comparison to row-cropped farmland, leading to reduced expenditures on culvert and ditch maintenance.

Site productivity

Long-term site productivity under woody bio-energy crops is likely to improve compared to annual grain-ethanol crops since biomass and nutrients are not removed on an annual basis.

Biodiversity

Short-rotation plantations may lead to a decrease in the biodiversity of the shrub layer and an increase in bacterial and fungal parasites and pathogens—a potential issue in any monoculture crop.

Other researchers suggest the possibility of changing the genetic make-up of wild tree species through cross-breeding with the plantation species. The use of non-reproductive clones could address this issue.

Summary

There is significant potential for wood-ethanol production if the conversion process of woody materials to ethanol becomes cost-effective. The market demand for wood-ethanol is substantial and relatively underdeveloped. Most analyses indicate that the carbon balance sheet for wood-ethanol is favourable compared to the production and consumption of fossil fuels as well as compared to the production of agricultural-based ethanol.

If there is company interest in market diversification, then wood-ethanol production could provide another revenue source. This may increase employment opportunities in rural areas, both in plantation establishment and at the ethanol production facility.

Wood ethanol has many environmental benefits over fossil fuels and other types of ethanol. It can provide an alternative market for wood products and therefore may be of interest to forest companies. Forest managers and land-use planners will want to consider the effect of wood ethanol production and its implications for sustainable forest management on their land base.

Management Implications

There are several factors to consider when establishing plantations for ethanol production, including:

- Access to wood waste and/or marginal farmland
- Economic and ecological trade-offs between alternative land and fibre uses
- Proximity to a wood-ethanol production plant or economic feasibility of plant construction (perhaps developed in partnership with other industry)
- Market supply and demand for ethanol, and the cost of alternative fuels
- Government incentive programs
- Technical and economic refinement of the ethanol bioconversion process
- Off-site environmental impacts of management practices in short-rotation plantations, particularly soil and water quality. Ground cover is recommended in situations where groundwater contamination or soil erosion is a concern.
- Tree species mixes, if practical, to address ecological concerns over biodiversity and pest and disease incidence. Heterogeneous plantations (for example, with willows, alders and poplars) would increase biodiversity and may maintain some wildlife habitat.

Further reading

CANMET, Natural Resources Canada. *Factsheet: Ethanol, the green gasoline.* http://www.nrcan.gc.ca/es/etb/cetc/cetc01/htmldocs/Publications/factsheet_ethanol_the_green_gasoline_e.htm

Graham, P.J., Gregg, D.J., and J.N. Saddler. 2003. *Wood-ethanol for climate change mitigation in Canada.* Appl. Biochem. and Biotech. 105-108: 231-242.

Ranney, J.W. and L.K. Mann. 1994. *Environmental considerations in energy crop production.* Biomass and Bioenergy 6(3): 211-28.

Saddler, J.N. 2002. *The potential of short rotation forestry on marginal farmland in BC and Alberta to provide a feedstock for energy generation and to reduce greenhouse gas emissions.* Sustainable Forest Management Network Project Report 2002-5.

Skog, K.E. and H.N. Rosen. 1997. *United States wood biomass for energy and chemicals: possible changes in supply, end uses and environmental impacts.* For. Prod. J. 42 (7): 63-69.

Updegraff, K., M.J. Baughman and S.J. Taff. 2004. *Environmental benefits of cropland conversion to hybrid poplar: economic and policy considerations.* Biomass and Bioenergy 27: 411-428.

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