Opportunities for Woody Biomass Fuel Crops in Interior Alaska

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1.0 Introduction

As the price of traditional fossil fuels escalates, there is increasing interest in using renewable resources, such as biomass, to meet our energy needs. Biomass resources are of particular interest to communities in interior Alaska, where they are abundant (Fresco, 2006). Biomass has the potential to partially replace heating oil, in addition to being a possible

Robbin Garber-Slaght in a Conservation Reserve Program field near Delta Junction, Alaska. Photo by Stephen D. Sparrow.

School of Natural Resources & Agricultural Sciences source for electric power generation (Crimp and Adamian, 2000; Nicholls and Crimp, 2002; Fresco, 2006). The communities of Tanana and Dot Lake have already installed small Garn boilers to provide space heating for homes and businesses (Alaska Energy Authority, 2009). A village-sized combined heat and power (CHP) demonstration project has been proposed in North Pole. In addition, several Fairbanks area organizations are interested in using biomass as a fuel source. For example, the Fairbanks North Star Borough is interested in using biomass to supplement coal in a proposed coal-to-liquids project, the Cold Climate Housing Research Center is planning to test a small biomass fired CHP unit, and the University of Alaska is planning an upgrade to its existing coal-fired power plant that could permit co-firing with biomass fuels. The challenge for all of these projects is in ensuring that biomass can be harvested on both an economically and ecologically sustainable basis.

One method of ensuring long-term sustainable production and harvest of biomass may be by growing short rotation woody biomass crops, such as willows (*Salix* spp.) and poplars (*Populus* spp.). This concept has generated interest locally, and has been demonstrated with some success in other locations around the world. Programs in Sweden and New York have been studying and cultivating willows as a biomass resource for the past thirty years (Nordh, 2005; Volk, et al., 2006.). While their information does not necessarily apply to the subarctic conditions of interior Alaska, their studies can be used as a starting point for local projects.

Interior Alaska has several potential plant genera that could be used as biomass energy crops, including willow, alder (*Alnus*), and poplar. Previous studies conducted on willows and alders in interior Alaska examined succession of these shrubs on river flood plains (Viereck, 1970; Van Cleve and Viereck, 1981; Krasny et al., 1988) while others investigated the use of shrubs to revegetate areas impacted by development (Densmore et al., 2000; McKendrick, 2005; Walter and Hughes, 2005). There is very little information on the growth rate and biomass production of native shrubs and trees in short rotation plantations in the subarctic, but such information is needed in order to assess the feasibility of growing them as an energy crop.

2.0 Existing Short Rotation Biomass Programs

There are many programs worldwide that are actively engaged in growing short rotation willow crops for use in biomass heat and power generation (Volk et al., 2004). The programs in Sweden and New York are among the longest running and provide a wealth of information about how to best manage short rotation woody species as agricultural crops for their particular geographic regions. While their experiences are very important and many aspects are relevant to crop production in other parts of the world, neither system is designed for subarctic conditions. Even in Sweden, most biomass crops are cultivated at latitudes significantly south of those of interior Alaska, and in a climate heavily influenced by the North Atlantic Current. This creates a warmer and wetter climate than is found in interior Alaska, resulting in longer growing seasons.

2.1 Willow Research and Production in Sweden

Swedish researchers have been studying short rotation willow coppice (SRWC) systems since the 1960s (Nordh, 2005). Originally the research focused on biomass for paper and pulp mills. As energy prices have increased, more research has gone into SRWC for use in energy production. Between 1990 and 1996 a huge expansion in the planting for SRWC brought approximately 37,000 acres (15,000 hectares) into cultivation for SRWC. This boom in SRWC plantings was fueled in part by government subsidies. Many of the plantations started in this period were on marginal land and were not well managed; their yields have been low and some were plowed under after 1996 when subsidies decreased (Helby et al., 2006). More recent research is looking into the use of willows for environmental applications such as phytoremediation (use of plants to decontaminate soils and water) (Nordh, 2005).

The plantation system for growing biomass in Sweden has a well-established, fully mechanized protocol for planting and harvesting. During the fall prior to planting, the field is treated with an herbicide and the field is plowed to prepare the soil for planting the subsequent spring. Cuttings are harvested from one-year-old shoots during winter when they are dormant and stored at temperatures slightly below freezing until planting time, in late April to early June. Cuttings are planted in double rows. Up to three double rows can be planted at a time, using a specially designed planting machine. The machine cuts the shoots into 6–8 inch (15–20 cm) lengths and pushes them into the soil. Controlling weeds is very important in the first year, and mechanized weed control is often used. During the winter of the first year the shoots are coppiced (cut back) to encourage the development of lots of shoots. During the second year the crop is fertilized and additional fertilization is recommended after the first harvest occurs. The plantations are harvested every three to five years in the winter when the soil is frozen. The harvester cuts and feeds the plants into a chipper. The chips are shipped green to a local user, usually a district heating plant. Well-maintained plantations can produce 4–5 oven-dry tons (odt) /acre/year (9–11 metric tons /hectare/year) or about 30–45 MWh (102,000–153,000 Btu) of energy (Nordh, 2005). A plantation can last about 25 years and sustain 6–7 harvests before it must be replanted.

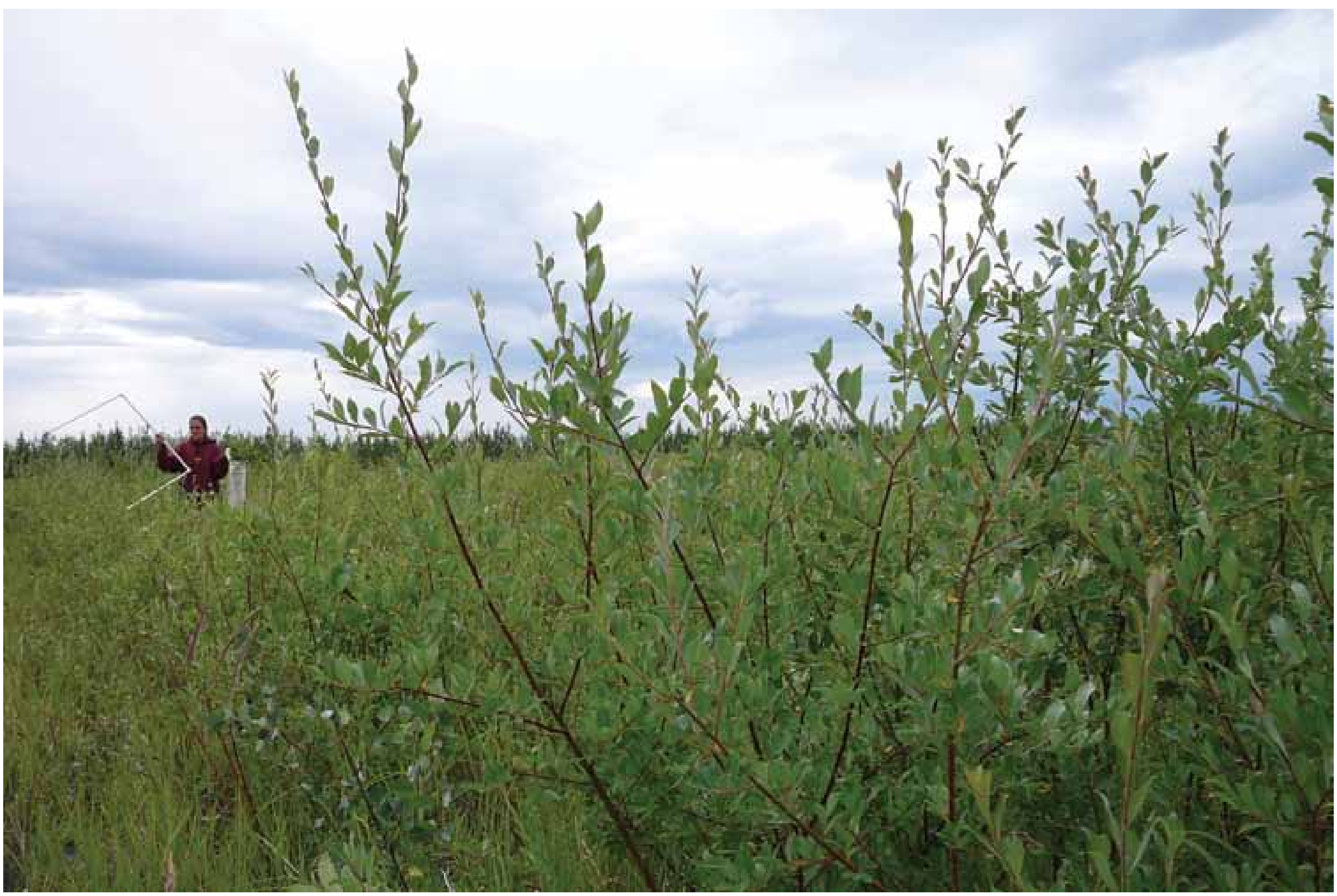
Much of the research in Sweden has gone into determining which willow species to plant and developing fast-growing clones and hybrids. Years of study have produced several willow clones which were chosen for particular characteristics such as fast growth rates, disease resistance, and other adaptations to their environment.

2.2 Willow Research and Production in New York State

The State University of New York, College of Environmental Science and Forestry (SUNY-ESF) began intense study and cultivation of willows as a renewable feedstock for bioenergy and bioproducts in the mid-1980s. In the mid-1990s SUNY-ESF and twenty other organizations banded together to form the Salix consortium with the goal of creating a way to commercialize willow production in the northeastern and the midwestern regions of the United States. By 2000 the consortium had 690 acres (280 ha) of land planted in willow biomass crops. These plots were studied for adaptability of clones, management of diseases and weeds, as well as planting, harvesting, and transportation logistics (Volk et al., 2006).

SUNY-ESF researchers have created a willow producers' handbook, which was first issued in 1997 and was revised in 2002 (Abrahamson et al., 2002). The recommended methods are similar to those used in Sweden. Recommendations call for mowing, spraying with herbicide, and plowing during the summer prior to planting the field. In the spring just before planting, the field is cultivated to kill any germinating weeds and to loosen the soil for planting. Dormant cuttings are planted 2.5 feet (0.76 meters) apart in double rows spaced 5 feet (1.5 meters) apart. SUNY-ESF has modified a step planter to push the cuttings into the soil. A pre-emergent herbicide is applied right after planting. Mechanical weed control is often necessary during the first growing season. The plants are coppiced during the first winter after the leaves have fallen. Fertilizer is applied during the second growing season. The first harvest occurs at the end of the fourth growing season once the willows are dormant. The harvester cuts and then chips the willows. The field is fertilized the year after harvest. One planting should last approximately 23 years (Abrahamson et al., 2002). SUNY-ESF's unirrigated research fields yield 4–5 odt/acre/year (9–11 metric tons/hectare/year) while their fertilized and irrigated fields yield up to 12 odt/acre/year (27 metric tons/hectare/year).

Researcher darleen t. masiak harvesting willows in a CRP field near Delta Junction. Photo by Stephen D. Sparrow.



2.3 Lessons Learned

The following lessons from Sweden and New York are important to potential biomass crop production in Alaska:

- Planting procedures and harvesting are similar in the temperate climates of Sweden and North America.
- Early weed control is important for establishing a good crop, as willows do not compete well with grasses and broad-leafed weeds.
- Fertilization is important for highly productive biomass systems.

While browsing by wildlife has not usually been mentioned as a factor in the Swedish and New York studies, it could reduce productivity in Alaska if steps are not taken to minimize it.

3.0 Alaska Studies

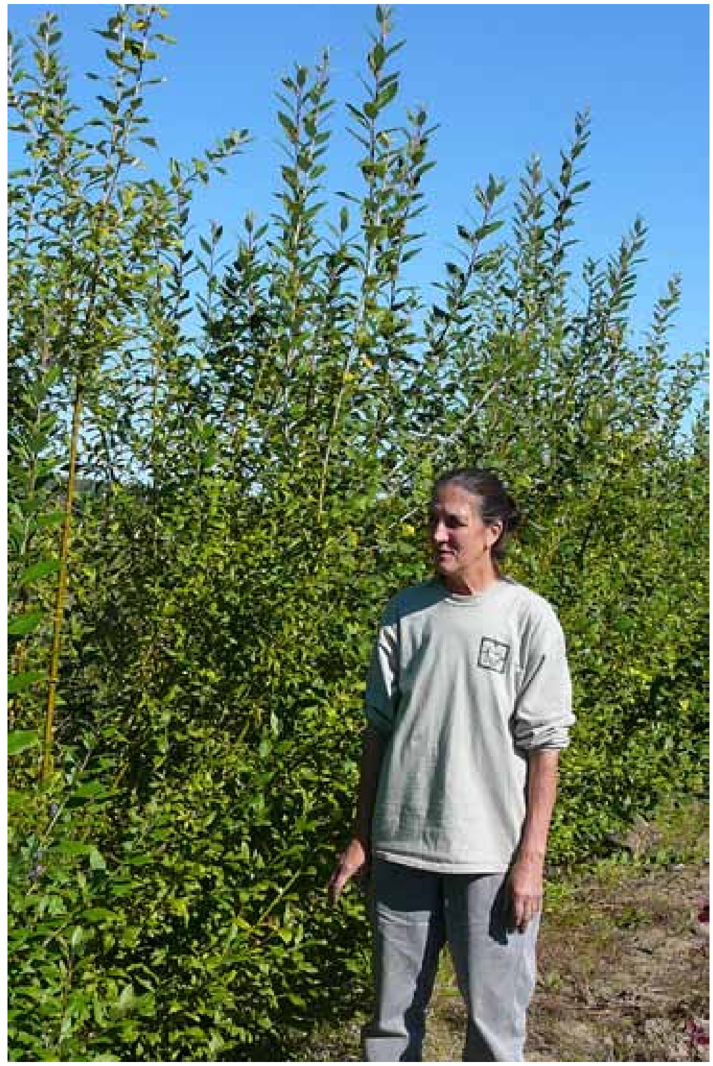
Willows are pervasive in Alaska (Argus, 1973), and quite a bit of study has gone into them. The more pertinent studies deal with species succession and revegetation. Successional studies provide information on the type of conditions where Alaska shrubs thrive. The revegetation studies provide knowledge about how to plant Alaska willows and which ones survive best.

3.1 Flood Plain Succession

Willows are among the first woody species to colonize newly created or freshly washed flood plains (Viereck et al., 1993). They grow prolifically for the first four to five years. Willows are followed by alders, which dominate for five to ten years. Balsam poplar mixes with the alder and the forest persists for approximately 100 years after flooding. If there is no new flooding, white spruce are dominant for 200 to 300 years and are followed by black spruce (Viereck et al.,1993).

3.2 Forest Fires

Vegetation recovery after severe fire tends to be slow in Alaska and often starts with non-woody plants, such as fireweed and grasses. If grasses get well established, willows or other woody species do not really take over for several years. After approximately seven years willow and alder can be well established (Knapman, 1982). Zasada et al. (1987) planted spruce, aspen, alder, and willow following a prescribed burn. The spruce had the best survival rate, but the broad-leafed species grew taller and faster. Planted seedlings survived better than unrooted cuttings.



Researcher darleen t. masiak by a two-year-old stand of feltleaf willow at the Fairbanks Experiment Farm, on the UAF campus. Photo by Stephen D. Sparrow.

3.3 The Trans-Alaska Pipeline

Following the construction of the trans-Alaska oil pipeline there were several large studies to determine how best to revegetate affected areas. Many of the studies researched revegetating with grasses, which tend to out-compete willows. In 1977 Alyeska Pipeline Service Co., operator of the pipeline, began a program to plant 1.5 million willow cuttings on 890 acres (360 ha) of disturbed willow habitat in the areas of the Sagavanirktok, Atigun, and Dietrich River valleys. The program was an expensive failure, which led Alyeska to commission a study to determine the best ways to revegetate willow habitat in the Arctic (Zasada et al., 1981). That study provides the most comprehensive look at planting willows for revegetation in Alaska.

Feltleaf willow (*Salix alaxensis*) cuttings were planted on a variety of different sites for three years. The cuttings were harvested from the local area while they were dormant and kept frozen until their planting. Planting consisted of placing a shovel in the ground, opening a hole, and putting the cutting in the hole at an angle to get as much of the cutting below ground as possible. The plots were treated with a variety of different fertilizer treatments (Zasada et al., 1981).

The pipeline study found that feltleaf willow responds well to high fertilization levels, but can survive with low nutrient conditions provided there is not much competition (Zasada et al., 1981). Grasses are detrimental to the growth of willows. The grasses limit the light the willows receive, hindering growth, and may kill the willows if grass stands are thick enough (Zasada et al., 1981). Cuttings will survive the best of any planting system when in competition with grasses; however, seedlings have a higher survival rate overall.

The study indicated feltleaf willow survives best when planted early in the summer; mid-to-late summer plantings do not survive well. Also, plants cut back in the summer do not recover and often die. However, taking cuttings in early April when they are dormant does not seem to affect their growth the following summer (Zasada et al., 1981).

Densmore et al. (1987) studied the establishment of willow for moose browse along the pipeline and concluded that cuttings needed to be .25 to .5 in (0.6 to 1.5 cm) in diameter and 12–15 inches (30–38 cm) long for best survival.

These studies were put to good use when the pipeline was vandalized in 2001. The resulting oil spill clean-up required the use of revegetation techniques. The revegetation started with two short-lived grass species (*Puccinelliu borealis* and *Lolium temulentum*) to prevent soil erosion followed by the planting of 11,500 willow cuttings and 200 spruce trees. The entire area was well fertilized with 10-10-20 fertilizer at about 360 lb/acre (400 kg/hectare). Three years after planting the willow cuttings were 4 to 5 feet (1.2 to 1.5 meters) tall and had an 80–88% survival rate (McKendrick, 2005).

3.4 Revegetation Manuals

In the past twenty years, state and federal organizations in Alaska have published several manuals for revegetation of disturbed sites, particularly streambanks. Introduced grasses were a major part of most revegetation projects, but more and more agencies are looking to use local plants. Seeding local grasses and legumes is not very difficult when the seeds are readily available. However, willows are ideal because they are found locally, are easy to harvest and plant, and they establish rapidly.

Revegetation using willows is simple but takes some advanced planning. The revegetation manuals for Alaska present the same basic steps for revegetating with willows (Miller et al., 1983; Alaska Department of Fish and Game, 1986; Densmore et al., 2000; Walter and Hughes, 2005) and all provide detailed information on collecting, storing, and planting cuttings.

3.5 Lessons Learned

The following lessons from prior experience cultivating willows in Alaska are important to establishing biomass crops:

- Local Alaska willows (particularly feltleaf willow) can easily be grown from cuttings if proper handling procedures are used and field conditions are conducive to cutting survival.
- Moist soil conditions are important for dormant cutting survival. Watering for the first several weeks is important.
- Fertilizers will increase growth during the first few growing seasons.
- Weeds and grasses can severely stunt the growth of willows in the first year. Competition from grasses can even kill willow plantings.
- Cuttings should be harvested during the dormant season and planted as early as possible in the spring.

3.6 Non-Willow Woody Species

Willows are among the fastest growing woody shrubs in interior Alaska, but there are other species that may have potential as biomass crops. Balsam poplar (*Populus balsamifera* L.) and quaking aspen (*Populus tremuloides* Michx.) are two relatively fast-growing trees in interior Alaska. Researchers in other regions have studied both species as potential biomass crops. Aspen requires longer rotations between harvesting; at least eight years, but ten is better to minimize die-off following harvest (Perala, 1979). Balsam poplar is much more likely to succeed in a short rotation coppice system similar to the willow system, as it can survive the three-year harvest cycle better than aspen. Poplar can yield 3 to 8 tons/acre/year (7 to 18 metric tons/hectare/year) (Dickmann et al., 2001).

Alder is another woody shrub that may have potential as a biomass crop. Alders, particularly black alder (*Alnus glutinosa* L.) and gray alder (*Alnus incana* (L)), have been studied in Europe and the Lower 48 states as potential biomass crops. Both species can compete successfully with willows as potential short rotation coppiced crops, and alders are also nitrogen fixers so they enhance the soil where they grow.

Because of their nitrogen-fixing ability alders have been studied in Alaska as potential revegetation species for abandoned mines. Mitchell and Mitchell (1981) did an extensive study of green alders (*Alnus crispa*) for mine land restoration and found with the proper planting techniques alders can thrive on marginal land. However, alders are more difficult to plant than willows; transplanting seedlings produced the highest survival rates.

Alders do not seem to grow well from cuttings like many willow species do, and thus must be established from seeds. This means that alders are more labor intensive to plant, but alders fix nitrogen and produce slightly more energy per pound than willows: 8820 to 8460 Btu/lb (4900 cal/g compared to 4700 cal/g) for five-year-old plants (Van Cleve, 1973). The revegetation manual for Denali National Park and Preserve provides steps for the successful large-scale planting of alder (Densmore et al., 2000). It recommends collecting seeds in the late fall, being sure to collect a root nodule as well, and growing the seeds in a greenhouse for at least three months before planting. The seedlings will require fertilizer during this time, as well as when they are first put in the ground. The Denali process has had 95% survival rates and the alders grow about 1 m (3 ft) in the first three years (Densmore et al., 2000).

3.7 Growth Rates and Biomass Production on Non-intensively Managed Land

Very few Alaska studies investigated growth rates and biomass production of woody shrubs. Moose forage studies measured the number of twigs per acre (Weixelman et al., 1998), and some other studies weighed individual plants (Cole et al., 1999), but there is no published information on biomass yield per unit area over time. To establish a baseline, we conducted five biomass surveys on unmanaged fields of known and unknown ages.

A field which had been mowed three years before sampling and a four-year-old field near Delta Junction were chosen for the initial survey. Twenty-four randomly selected 1m^2 (10.8 ft^2) plots were sampled in each field. All of the standing woody species in each square were cut at ground level. The woody samples were oven-dried and weighed. The three-year-old field averaged 1045 lb/acre (1171 kg/ha), and the four-year-old field averaged 1000 lb/acre (1125 kg/ha). The fields are part of the federal Conservation Reserve Program (CRP), a program which pays farmers to place acreage aside to conserve topsoil and wildlife habitat. The fields are not treated in any way except that they are mowed, usually on three-year rotations. The small difference in biomass yields in the three- and four-year-old fields could be the result of many factors: soil quality, grass and weed competition, wetness of the area, and the large variability of the CRP lands. The yields in sample plots ranged from 0 g/m^2 to 478 g/m^2 (0-0.1 lb/ft^2). Three samples were collected from another CRP field that was on wetter soils and yielded 1600 lb/acre (1790 kg/ha) (due to the small sample size the results may be misleading). In any case, allowing willows to grow with little to no management will likely yield less than 1 ton oven-dry biomass/acre (2.24 metric tons/hectare).

Three similar surveys were conducted at the Chena River Lakes Flood Control Project. One field, judged to be at least five years old from growth rings, yielded about 1047 lbs/acre (1173 kg/ha). Two other fields, each estimated to be two years old, yielded 464 lbs/acre (519 kg/ha) and 590 lbs/acre (660 kg/ha). It would be worthwhile to conduct a study of the same fields next year to determine the actual increase in biomass over the course of a year.

4.0 The Potential

Yields of about a half-ton of biomass per acre (1.1 metric tons/ha) after three or more years growth are disappointing compared to about 5 tons/acre (12 metric tons/ha) or more over three years in the New York biomass energy program. A yield of half a ton of willow wood per acre contains an energy yield of about 8 million BTU which is equivalent to about 1.4 barrels of crude oil.

A biomass burner power plant capable of producing 200 KW power has been proposed near North Pole, Alaska. This would produce enough electricity to power about 150 average American homes (Energy Information Administration, 2009). The amount of willow biomass required in a year to power a 200 kW power plant at 30% efficiency is about 1100 tons (1000 metric tons) or about 2200 acres (900 ha). There are 25,000 acres (10,000 ha) of CRP land in the Delta Junction area, and a third of it is mowed every year. That is potentially 8000 acres (3,000 ha), which could produce 4000 tons (3,600 metric tons) of biomass in any given year. Current rules for CRP holders do not allow for the harvest of biomass as a fuel crop, but there is the possibility of changing the federal laws to allow for this type of harvest; New York state has such an exemption (Timothy Volk, SUNY-ESF, personal communication, 2008). While a thorough economic analysis would be required to determine how much biomass is needed per acre to be profitable, low yields on CRP land in Alaska likely make use of biomass uneconomical because cost of harvest may exceed the value of the woody biomass.

The Chena River Lakes Flood Control Project may also provide a potential source of biomass near Fairbanks. In the past it has had contracts with farmers to plant and harvest hay; this could easily be transferred to harvesting woody biomass. The flood plain is also mowed on a three-year rotation and it produces similarly to the CRP land. The flood control project is probably not large enough to be the sole source of biomass, only maintaining about 3000 acres (1200 ha) in shrubs. Again, low yields may limit the use of this resource without management to improve yields.

In addition to the CRP land and the Chena flood control project, there are other areas that could be harvested or are currently harvested in some fashion. The Golden Valley Electric Association (GVEA) spends time each summer clearing its power lines of trees and shrubs that could potentially be turned into a biomass resource. The actual biomass production along the power lines will need to be studied with the help of GVEA. The Fairbanks area also has new firebreaks or defensible-space clearings that could provide up to 100,000 green tons (90,000 metric tons) of biomass (Nicholls et al., 2006). These defensible-space clearings are expected to cover 3000 acres (1200 ha) and will be completed by 2010, so they are only a short-term solution unless they are managed for biomass production.

Harvesting and transporting biomass from natural stands can potentially be logistically intensive. Harvesting 2200 acres (890 ha) will require a lot of energy in the form of mowers and chippers. If biomass species could be farmed in a fashion similar to the New York program, 1100 tons (1000 metric tons) of biomass could come from 220 acres (90 ha), assuming yields similar to those produced in New York. However, it is unknown whether the New York system will work in interior Alaska. Most likely the willow clones that have been established for New York will not survive well here. The growing season in Alaska is much shorter than New York's and the harvest rotations may have to be extended. Before starting a short-rotation coppicing program in interior Alaska, the following questions need to be addressed:

- Which species will grow the fastest and produce the largest amount of biomass?
- How long should the plants grow before coppicing?
- How much biomass will they produce in 3, 5, 8 years?
- What types and levels of fertilizers will they need?
- What is the best way to plant the chosen species?
- How much weed control is required? Which weed control systems will not harm the biomass species?
- When is the best time to harvest the biomass? In the fourth year? During the fall or winter?
- How much is a power plant willing to pay per ton? Is it cost effective to grow?

We have begun looking into some of these questions on small test plots at UAF's Fairbanks Experiment Farm. Very preliminary results with a few plants in single row plots on highly productive soil showed average yields of about 4.5 odt/acre/yr (10 metric tons/ha) with feltleaf willow and about 1 odt/acre/yr (2.2 metric tons/ha) with other indigenous species (unpublished data). Thus, feltleaf willow looks promising; but it is too early to recommend it for use as a bio-energy crop. Several growing seasons will be required before conclusive information can be obtained.

5.0 Conclusion

Use of farmed biomass for power generation in interior Alaska may be feasible, but more research is needed on biomass production potential and costs of production, harvesting, transportation, and processing before a full assessment of the feasibility of biomass power generation can be determined. While woody shrubs may not produce as fast in Alaska as they do in New York, Alaska has much more space to harvest from. Natural growth of a half-ton per acre (1.1 metric ton/ha) is not spectacular, but it is expected that managed biomass would produce much more per acre. In an area of the world where solar power is seasonal, wind power is intermittent, and geothermal power is localized, biomass may be a viable option for interior Alaska.

Acknowledgements: Support for Garber-Slaght for this project was provided by an Alaska EPSCoR Undergraduate Research Grant.

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