Willow Biomass: An Assessment of the Ecological and Economic Feasibility of Growing Willow Biomass for Colgate University

Jeremy Bennick
Andrew Holway
Elizabeth Juers
Rachel Surprenant

ENST 480
Spring 2008
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Acknowledgements

We would here like to acknowledge and thank Professor Ian Helfant, our main advisor for this project. Professor Helfant was instrumental in guiding our group on the initial research goals to pursue, providing us with professional contacts and advising us over the source of the semester. Similarly, we acknowledge the other two course professors, Professors Beth Parks and Bob Turner. We thank Dr. Timothy Volk of the State University of New York, school of Environmental Science and Forestry, for providing us with his expertise in the willow biomass field and for answering all of the questions posed to him. Thanks also goes to Peter Babich, Michael Jasper, and Dr. Stephen Bick, the Associate Director of Facilities and Manager of Engineering Services, Associate Director of Facilities and Manager of Lands and Grounds, and Professional Forester and Consultant to Colgate University, respectively.
1. Executive Summary

Over the past four months, our group has worked to determine the environmental and economic feasibility of growing willow biomass on Colgate-owned property for our steam-generating wood-burning facility. This feasibility analysis is to be used primarily by the Environmental Council and president in determining the future of Colgate’s heating needs, as well as by members of Buildings and Grounds, and finally by potentially interested growers of willow biomass, such as local farmers.

Our primary methods of data collection include both primary and secondary resources. The willow biomass field is still young, however; therefore, in order to supplement this research, we also rely heavily on personal communications with several key experts in the science behind growing willow biomass, Colgate’s landholdings, sustainable forestry practices and the processes of the wood-burning facility.

This document contains a detailed description of the methods of preparing, planting and harvesting willow for biomass. The first crop of willow can be harvested five years after the initial preparation of the field. Willow stems can be planted at a density of 4,000 – 8,000 plants per acre and can produce around 3.7 – 5.1 oven dried tons per acre per year. In this way, Colgate could feasibly plant and maintain a small willow plantation with the aid of an experienced farmer.

Additionally, a Geographic Information Systems suitability analysis is carried out, which consider five criteria: road-access, land cover, favorable soil, stream buffer, and low slope. Ultimately, 485 acres of Colgate landholding are found to be suitable under these constraints; however, much of this land is not available for growing willow due to aesthetic and tract size concerns.

Furthermore, an economic analysis concludes that it would not make sense to buy or lease the farm equipment because of the small scale on which Colgate would be operating. Colgate should instead look to hire out the farm work. For it to be cost-effective for Colgate to grow its own willow on 200 acres, at the current price of woodchips, the cost of this service would have to be no more than $48,000 per year. At this time it is unknown whether the farming work for 200 acres can be hired out for less than $48,000 per year, however, as the price of woodchips increases, so does the maximum price that can be paid for this service. Even if it is not cost-effective today, it could be cost-effective in the future.

Overall, we recommend the following action:

Colgate should experiment with farming willow biomass on a small-scale, which GIS analyses indicate is the 10-acre Hamilton Street tract. This would ensure familiarity with the process should the prices of woodchips continue to rise as predicted.
2. Rationale

The importance of renewable energy is becoming increasingly important as we move into the second decade of the twenty-first century. One major concern on the global scale is the availability of the fossil fuels on which our modern society is dependent. Renewable energies represent one possibility for reducing our dependence on foreign oil for the U.S.; this is significant because currently this country spends billions of dollars annually in imports of fossil fuels such as oil and petroleum (NRDC, 2004). Two-thirds of the oil consumed globally comes from the Persian Gulf region, a region from which the U.S. imports $25 billion dollars worth of oil annually (Lugar and Woolsey, 1999; NRDC, 2004). Relying so profoundly on this one source leaves the U.S. in a precarious position because of the intense international competition for these oil reserves as well as the historical and current political and social unrest experienced in the region. This dependence is associated with a U.S. military presence in the Middle East, thus leading to other foreign policy conflicts (Lugar and Woolsey, 1999). Renewable energy could presumably placate this dependency and the foreign policy issues with which it is associated. Furthermore, it has been calculated that substantially integrating renewable energy into the national economy could save the U.S. $10 billion dollars annually by 2015 (Romm and Curtis, 1996).

Although Colgate University is ahead of many of our peer institutions with our use of renewable energy (our wood-chip powered steam producing facility, and our use of hydroelectricity), the University still pays a sizable amount for fossil fuels annually. In the 2006-2007 academic year (June 1st-May 31st), Colgate paid $299,151.95 for oil. It is expected that this number will increase in a substantial amount for the 2007-2008 academic year because of the expansion of Colgate’s facilities with the completion of the Ho Science Image 1: Woodchips at Colgate’s biomass burning facility
Center (121,200 gross square feet) and the additions to the Case Library (51,000 gross square feet added; 101,000 gross square feet renovated) (“Ho Science Center”, 2008). The construction of a second wood-burning facility would be able to provide heat for these additions to Colgate’s campus.

Nevertheless, the importance of renewable energy for the purposes of our study is its potential to mitigate human-influenced climate change. Climate change, or global warming as it is alternatively known, has become widely accepted by scientists and the public alike upon the release of the review in 2001 Intergovernmental Panel on Climate Change, a collection of hundreds of international scientists established by the United Nations. Much has been predicted about the consequences of global warming, both by this panel and other independent researchers. Climate change could result in an irreversible damaging of earth’s fragile ecological homeostasis. The IPCC hypothesizes the following: increases in the frequency and intensity of extreme weather events, increases in sea levels which will effectively displace millions of coastal dwellers and destroy ecologically necessary habitat and the organisms that depend on them, a disruption of crop patterns to the effect that hunger and famine would result, political instability as a result of dislocations and social, health and economic failures (IPCC, 2001; Climate Change and Human Health, 1997).

Using renewable energies, such as biomass, which are by definition carbon neutral, could drastically reduce Colgate’s greenhouse gas emissions. The U.S. is the number one global contributor to these greenhouse gases, emitting 1,650,020 thousand metric tons of C, or alternately, 3,851,420 thousand metric tons of CO2 (Marland et al., 2006). Colgate emits an estimated 41 tons of CO\(_2\) per year, a value comprised of residential heater emissions, oil burner emissions and woodchip emissions (Hornung, et al., 2002); though, approximately 95% of these emissions are considered carbon neutral as they come from the renewable energy source of wood chips.

However, these numbers do not factor in the transportation emissions associated with trucking the tons of woodchips to Colgate’s campus daily. The sources supplied to Colgate come from as many as 75 miles away from campus, thus significantly adding to the campus’s total greenhouse gas emissions. Growing our own willow biomass, or using logging residuals from well-managed logging operations on Colgate-owned land as will be discussed further on, would be a much more sustainable way of supplying this renewable energy source for our campus’s needs. In the climate change context, agricultural greenhouse gas sinks can be instrumental in the removing of carbon from the atmosphere by changing vegetation cover and improving management, switching from conventional agricultural crops to forests, and less intrusive and damaging till practices (Schneider and McCarl, 2003). Specifically, woody biomass crops, such as willow, represent a significant method to sequester carbon in two ways: first, reforestation and afforestation yields a carbon sink in the growing trees or shrubs; second, forest products act as substitutes to politically, socially and environmentally insecure fossil fuels (Baral and Guha, 2003). Because as trees reach maturity their potential to sequester decreases (in conjunction with a decrease in their growth rate), willow biomass is a particularly good method to sequester carbon because of its short growing time; effectively making the willow shrubs always young, and thus at their optimal sequestration capacity (Volk et al., 2004). Short rotation woody crops, such as willow shrubs, could sequester 4.5-8 tons of carbon per hectare per year (Baral and Guha, 2003). The planting and harvesting of willow biomass on Colgate-owned land if justified if:

\[
C_B + C_{Siw} \geq C_B + C_{Sout} + C_F - C_O
\]
Where $C_B$ is the carbon sequestered in the biomass harvested in one production cycle; $C_{Sin}$ represents all other carbon captured during the production cycle as a result of the short rotation woody crops (e.g. carbon in the root biomass and leaf litter); $C_{Sout}$ is the carbon released back into the atmosphere when the crops are harvested—this value is impacted by sustainability of the management practices; $C_F$ represents the carbon emitted over the course of the production of the biomass crop—the machinery emissions, the out gassing fertilizers, transportation; finally, $C_O$ is the amount of carbon prevented from being released into the atmosphere by the burning of the biomass as opposed to conventional fossil fuels (Satori et al., 2006). Essentially, if the amount of carbon sequestered is greater or equal to that generated in the production and burning of the biomass, it is logical, at least from an environmental perspective, to pursue this means of energy supply. Other studies (Volk et al., 2004; Heller et al., 2003) have concluded that the amount of carbon emitted during the entire production cycle of biomass equals that sequestered by the plants; thus it seems likely that this will prove to be the case for Colgate University as well, making biomass an environmentally viable option.

3. Agriculture

3.1 Site Preparation

After an appropriate site in which to plant the willow has been selected, the site must be prepared for planting. Site preparation begins on a fallow field the summer before the planting is scheduled. In the July before planting, this field must first be mowed and excess vegetation should be consolidated into hay bales and removed from the site. When the vegetation begins to grow after mowing, the site should be treated with herbicides in order to control competitive weeds. Weed competition is the most common cause of willow crop failure. As a result, it is necessary to spray the field with a broad-spectrum herbicide. Dr. Volk, a leading researcher on willow in the region, recommends the use of glyphosate, a post-emergent, translocated herbicide (Abrahamson et al., 2002). While Dr. Volk recommends the use of glyphosate after vegetation has begun to grow back, studies have successfully used Simazine, a pre-emergent herbicide, immediately after mowing (Kopp et al., 2001).

Following the successful application of herbicide, the site must be plowed to a minimum depth of 10 inches, which loosens the soil and mixes in fertilizer and plant material. Upon the completion of the initial plowing, cross-discing, a tillage technique that produces finer soil, can take place on the field (Abrahamson et al., 2002). Additionally, large rocks that project more than 2 inches from the ground should be removed to ensure that machinery would not be damaged later on during the harvesting process. The plowing, which should be completed by mid-September, is the final stage of field preparation in the fall.

In the following spring, all crop cover must be removed. Before planting, a cultimulcher should be used on the field. The cultimulcher is used to break surface crust, crush clods, firm loose soil, eliminate large air pockets, and leave the ground ready to plant. In this way, willow-planting equipment can be most effectively employed.
3.2 Planting

The design of a willow field should be carefully considered in order to ensure unproblematic and efficient planting, harvesting, and movement of machinery throughout the field. For use with existing planting and harvesting equipment, a double-row configuration should be implemented. This double-row design allows for a density of 4,000-8,000 plants per acre (Volk et al., 2004). While rows should be as long as possible, it is recommended that a 20-foot break should be inserted every 500-600 feet along the row. This break in the row will allow agricultural equipment to freely move between different sections of the willow crop (Kopp et al., 1997). For this same reason, 20 feet should be left at either end of the field. Additionally, willow rows should be designed to run across slopes where possible in order to mitigate the threat of soil erosion.

Image 2: Double-row spacing layout for short-rotation woody crops allows for the continued use of traditional agricultural equipment. The willow plants featured here are the new growth after one coppicing. Image source: Volk et al., 2004, Willow Biomass Producer’s Handbook

Within days after the cultimulching has taken place, the planting of the willow should begin. Although planting can take place as late as June, it is best scheduled to occur between late April and the end of May. In this way, the soil will be sufficiently moist to allow for rapid root development and frost will not pose a threat to the sprouting willow stems. With average field conditions Central New York, willow shoots can begin to sprout within 3 days to two weeks of the initial planting depending on the soil and air temperature. Willow planting material consists of dormant sections of willow stem. The willow stem sections come in two lengths, stem cuttings and stem whips, which require different machinery for planting. Both whips and cuttings can be transported over great distances when frozen, 25° - 30°F, and should not arrive on site until just before planting.

The willow cuttings are 8 to 10 inches long and have a diameter of 3/8 to 3/4 inches (Kopp et al., 1996). The Fröebbesta planter, which is produced in Sweden, is designed to work with willow cuttings. The Fröebbesta planter first cuts a thin, 8 to 10 inch hole in the soil. Willow cuttings are then manually fed into the machine’s planting tube, which is thrust into the open hole. Once the cutting has been inserted into the hole, a pair of packing wheels compacts the soil around the cutting (Abrahamson et al., 2002).

The willow whips are 4 to 7 feet long and have a diameter of 3/8 to 3/4 inches (Kopp et al., 1996). The Salix Maskiner’s Step planter, which is also produced in Sweden, is a slightly more automated process, which is designed to use willow whips as planting stock. The Maskiner’s Step planter requires the operator to feed whips into a set of mechanized belts, which convey the whips to the planting device. Then, a coulter, a vertical blade on the front of the machine, cuts a thin hole in the soil, while whips are simultaneously cut to a length of 8 inches. The machine then pauses as the cut whips are fed into the freshly created holes (Abrahamson et al., 2002).

The Maskiner’s Step planter is a more efficient machine, which is able to plant an average of two acres of willow per hour and is capable of planting two double rows of willow at once. In comparison, the Fröebbesta is only able to plant a single double row and is capable of planting around half an acre of willow in an hour. While the Step planter is more efficient in terms of planter stock and operator-hours required, the Fröebbesta is a nimble machine that can be more easily used on smaller tracts of land in conjunction with a smaller tractor.

Furthermore, it is recommended that a second round of pre-emergent herbicide be applied to the field after the planting has taken place. This second course of herbicide will ensure that weeds are sufficiently controlled during the important first year of growth (Volk et al., 2004).
Within two weeks of planting, the willow stems will have begun to sprout shoots and roots have begun to form. During the first season it is important to ensure that weeds do not become competitive with the willow and that an acceptable percentage of the planted cuttings survive to grow to trees. On average, 90% survival rates can be expected. If survival rates are lower than 75%, it may be necessary to replant cuttings and employ mechanical weed control, such as cultivators or rototillers. These machines are capable of removing weeds between rows without damaging the willow shoots.

By the end of the first growing season, the cuttings will have sprouted 1 to 4 stems and will have grown to be between 3 to as much as 8 feet tall, depending on the clone, rainfall and specific site conditions (Abrahamson et al., 2002). In November after the first growing season, the young willow trees should be cut back to a height of around two inches. This practice is known as coppicing and is used to encourage the sprouting of additional stems and faster growth during the second season (Kopp et al., 1997). While the excess willow stems can be left in the field to reduce nutrient removal, these cuttings have the potential to serve as the planting material for another crop of willow.

Coppicing can be performed by a sickle bar mower, which can be mounted to the back of a tractor. The sickle bar mower consists of a stationary guide bar and a second bar with sharp sickle sections, driven back and forth across the guide bar. In this way, the mower can cleanly cut the stems and coppicing can be performed without damaging the root structure of the willow (Kopp et al., 1997).

In the June of the second season after the willows have resumed growth, the field should be fertilized in order to ensure fast growth and to encourage newly sprouted roots to absorb the nutrients. Dr. Volk recommends that fertilizer be applied at the rate of 100 pounds of nitrogen per acre of willow (Abrahamson et al. 2002). The fertilizer can be applied by a variety of means providing that willows are not damaged by bending below the bottom third of the stem.

By the end of June of the second growing season, the willow should begin to close the canopy. With willow plants standing around 6 feet high, the closed canopy will prevent any further competition by weed species. The growth rate of the willow is fastest during the third and fourth growing seasons (Volk et al., 2004). During these last two seasons the willow should not need to be tended. After the fourth growing season, the willow will have reached a height of around 15 – 20 feet high and should be ready for harvesting.
Four years after the initial planting, the willow should be ready to harvest. This harvest can occur during anytime in the winter season, after the leaves have fallen but before growth resumes in the spring. Harvest can take place with snow cover, of up to a foot, on the field. The harvested willow stems can be transported as either whole stems or chipped on site. The advantage of chipping translates to more efficient handling and transport of the willow biomass. In contrast, whole stems offer the advantage of longer storage life, but increase the cost of transport and handling. Current technology allows willow to be harvested at a rate of around 1 – 2 acres in an hour (Abrahamson et al., 2002).

There are several harvesting machines available specifically for willow biomass crops. Due to the popular use of willow biomass in Sweden and other European countries, most of the willow equipment is developed and sold in Europe (Abrahamson et al., 2002). The most popular and effective harvesters are the modified Claas Jaguar corn harvester and the Bender harvester (Abrahamson et al., 2002). These corn harvesters can be easily modified by replacing the corn harvesting head with a head designed for cutting willow. The Claas harvester has two large saw blades, which are spaced to align with each row in the double-row configuration of willow plantations. In contrast, the Bender uses a single long chain-saw cutting chain to cut two rows simultaneously, which allows the Bender is not restricted by the location of the rows and can be used to cut across rows, if necessary. Both harvesters cut the stems at around 3 – 6 inches above the ground and chip them after cutting. These chips are then deposited into a container, which is towed behind the harvester or by a tractor along side of the harvester. While these harvesters cut and chip on site, there are harvesters that bundle whole stems.

### Agriculture Summary

- Willows are planted in a double row configuration
- Density of around 4,000-8,000 plants per acre
- 3.7 - 5.1 oven dried tons per acre per year
4. Soil

4.1 Optimal Soil Conditions

In choosing an appropriate site for growing willow biomass one must consider soil properties. Like all agriculture, shrub willows grow best in nutrient-rich soils; however, they are hardier than many crops and can also grow well on marginal soils (Abrahamson et al., 2002). With willow, there is a direct relationship between nutrient levels of the soil and the biomass yield harvested, until eventually a threshold is reached. The ideal pH range is between 5.5 and 8.0, which is found in the landholdings discussed as possible site locations for willow biomass in this paper (USDA, 2006). Willow can be grown on all types of loamy soil: sandy, clay or silt-dominated soils are all acceptable. One study concludes that coarser grained soils are preferable to finer, silty soils (Schaff et al., 2003). Willow biomass crops also prefer averagely well-drained sites, to those that are habitually too dry or too wet from

**Soil Characteristics**

- Optimal pH is greater than 5.5, less than 8.0
- High moisture gradient is necessary
- Loamy soil is preferable
- Depth of at least 18 inches required for roots

Image 5: Evidence of coppicing and root structure, Canastota plantation
improper drainage patterns. A depth of 18 inches is required for appropriate rooting and nutrient intake (Abrahamson et al., 2002). Also, a previous study has indicated that biomass crops perform relatively better at lower elevations, corresponding directly with a higher moisture gradient present in those soils as they are closer to the water table (Schaff et al., 2003).

### 4.2 Erosion

There have been concerns regarding willow biomass causing erosion. This is an important factor to consider when exploring the efficacy of willow biomass because erosion decreases the continuing productivity of soils (Kort et al., 1998). These apprehensions are the result of the normal agricultural processes associated with biomass, not evidence of atypical erosion in the harvesting of biomass (Volk et al., 2006). However, several studies conclude that groundcover crops virtually eliminate this worry (Arevalo, 2005; Volk et al., 2006). Cover crops are alternatively called green manure because of their utility in the agricultural process: adding different organic matter to the soil structure, increasing soil microbes and nutrients, maintaining soil moisture, and decreasing competition by weeds (Arevalo et al., 2005). One study uses the common Dutch white clover for this end, ultimately concluding this cover crop greatly reduces soil erosion but may not increase willow yield as predicted (Arevalo et al., 2005). The process involves planting a cover crop immediately after harvest in the fall, allowing it to protect the integrity of the soil during willow’s dormant winter phase, and then destroying it with an herbicide in the spring when more willow is ready to be planted.

Despite these concerns, woody biomass crops are associated with much less wind and water soil erosion than traditional agriculture (Kort et al., 1998; Volk et al., 2004). Once the underground root system has been established, after two-three cycles, there is virtually no erosion (Volk et al., 2004). There is also the threat of soil compaction from harvesting and planting machines. Overall, the degradations associated with short rotation forestry crops can be avoided through proper sustainable management (Mitchell, 1992). However, there has yet to be much research done on the sustainability of biomass production (Kort et al., 1998).

### 4.3 Nutrient Cycling and Fertilizers

It is necessary to keep logging residues within the ecosystem to replenish the nutrients after each cycle (Ledin, 1996). This can easily be accomplished by harvesting in late fall, after all leaves have fallen from the shrubs (Volk, et al., 2004). One study indicates that one to two thirds of the nitrogen and phosphorous in leaves can be reutilized by the next year’s plants (Ericsson, 1992). It has been recommended to add nitrogen to the already growing plants in the spring, to minimize the amount of fertilizer taken up by competing plants (weeds) or lost through runoff (Volk et al., 2004). Increased soil aeration with agricultural machines may also increase productivity by allowing the roots of the willow plants to extend
to a much larger volume of soil and thus gain access to more nutrients (Mitchell, 1992). However, with proper means of sustainable agriculture, such as ground cover crops and maintenance of leaf-litter, it seems that the amount of external fertilizers needed for the optimal productivity of the willow is minimal (Ericsson, 1992).

There are two philosophies regarding fertilizing fields for short rotation crops. One advocates using only minimal fertilizer in order to maximize the plant’s natural ability to seek out nutrients present in the environment and also to minimize costs and thus make the process economical. Of course, the drawback to this minimalist approach is limited yields. The other philosophy involves using economies of scale: very high levels of fertilizers act to guarantee the proper amounts of nutrients will be available to the plants. However, this approach is costly and brings with it the risk of leaching the soil of naturally-occurring nutrients (Mitchell, 1992). The ideal situation for Colgate would likely be a compromise between the two management styles just described.

4.4 Health of Soil after Willow

Short rotation forestry crops even have the potential to leave the soil in better condition than previous to their planting, especially if they are growing on land previously used for intensive traditional agriculture. For example, at first the biodiversity of microarthropods found in soils of fields growing biomass are equal to those of other agricultural products. After several cycles following sustainable methods of forestry both the density and biodiversity of these species increases to levels found in untouched fallow fields (Volk et al., 2004). Another study has shown that the deep and extensive root system of willow shrubs can actually improve the state of the soil by loosening previously compacted soil, returning nutrient-rich organic matter to depth from the roots, and reintroducing nutrients back into the nutrient cycle (Mitchell, 1992).

This soil improvement lends well to converting the land to grow another agricultural crop after several harvesting cycles have been completed and the soil is no longer suitable for willow. One study used corn as the conversion crop—an agricultural product already well-established in the Central New York region—to much success (Devine et al., 2004). This study is the first of its kind to measure the productivity of the conversion crop on a time scale of several years: several years after the last short rotation forestry crop was harvested, the concentration of carbon in the soil still increases. This nutrient increase is likely caused by the decomposition of the woody crops’ roots. Also, soil aggregate stability—the ability of the soil to resist disruption, typically water erosion—was improved by the forestry crops to the advantage of the corn crop (Devine et al., 2004). These improvements are important for Colgate when considering growing willow biomass because it means that the landowners to whom we currently lease land, and who would potentially manage the forestry crops, would

**Nutrient Requirements**

- Logging residues should remain in system
- Biomass requires fertilization of N and P prior to planting
- Soil condition is improved in comparison to traditional agriculture practices
not only be unaffected by the conversion to growing willow, but would in fact benefit from this adaptation with improved soil health and productivity.

5. Ecology

5.1 Sustainability

All too often these days, “sustainability” is used just as a buzz word. It is a term that is tacked on to indicate to promote an environmentally-friendly or progressive image. In reality, the concept of sustainability is complex. There is no easy way to classify actions as either sustainable or not sustainable; there is a continuous gradient of degrees of sustainability.

Figure 1: Environmental Sustainability.
This conceptualization of the three components of sustainability highlights the interactions between these three seemingly independent systems.
5.2 Biodiversity

On a national scale, a significant switch to biomass as a fuel source would lead to massive changes in land use. With increased demand, biomass would compete with for arable land with agricultural crops and also increase the pressure to clear new farm land. Some fear this habitat conversion would result in a loss of biodiversity. However, these concerns must be balanced against the threat of global warming and the need to develop alternative energy sources. This is an incentive for conservationists and biomass researchers and producers to work together to develop biomass systems in a sustainable manner. Maximizing the biodiversity in biomass plantations might require a compromise in terms of yield. However, protecting the soil and the health of the surrounding environment will increase the longevity of any agricultural or silviculture project. (Cook et al. 1991)

General principles of conservation biology should be applied when designing willow plantations. It is best to preserve large areas of natural habitat, or at the very least allow for “corridors” of suitable habitat between breeding populations. By using a mixture of willow clones and maintaining a variety of ages since coppicing, land managers can maximize the spatial complexity of the environment, and thereby create the greatest diversity of habitats and the greatest potential for biodiversity.

5.3 Bird Diversity

Studies by Dhondt et al. (2004 and 2007) of the Cornell Lab of Ornithology, surveyed avian species richness and nesting success in short rotation willow and poplar plantations in Central New York. The authors observed birds at 15 SRWC plots at six locations from 1999 to 2002 (2007) and 12 of these plots were used to determine nesting preferences (2004). They observed 79 species of birds utilizing the SRWC plots, of which 39 species were sighted regularly and 21 species were found nesting (Dhondt et al. 2007). Six other species had consistent territories, and so were most likely nesting for total of 27 species (Dhondt et al. 2007). Nesting preferences were highly non-random. Particularly popular clones were S25 and S365, while S301 appeared to be avoided (Dhondt et al. 2004). However, clones were not statistically correlated to nesting success. Plot size and age of the crop since coppicing were the only significant factor related to species diversity (Dhondt et al. 2007). Overall, the diversity observed was not significantly less than comparable natural habitats and neither
were breeding success rates (Dhondt et al. 2004 and 2007). These results indicated that willow plantations are not “ecological traps”; areas which attract many species but result in low reproductive success rates, making them population sinks.

Figure 2. Comparison of species richness in large SRWC plots (growth-years 4–5) and a selection of other habitats drawn from the Breeding Bird Census. Sample sizes above bars. (See text for description of BBC samples and statistical tests.) Filled rectangles span the inter-quartile range and show the median number of species. Vertical ‘whiskers’ indicate the range. SRWC species richness was not significantly different from any of the other habitat types, except the ‘upland pasture’ sample (Bonferroni adjusted tests, \( \alpha = 0.05 \)). The ‘old field’ category included a diverse array of sites (abandoned fields, clear-cuts, shrublands) that would be most comparable to the SRWC plots. ‘Upland’ sites were 9–14-year-old abandoned upland pastures. ‘Suburban’ sites included woodlands and wooded reserves in relatively populated areas. ‘Deciduous’ sites were mature forests (primarily beech–maple).

Figure 2. Box plots showing that bird species richness in willow plantations is not significantly different from most other habitat types. From Dhondt et al., 2007.
5.4 Sustainable Forestry

In addition to willow plantations, Colgate’s own forested lands present another possible local source of woodchips. Since our focus is on willow silviculture, we only will briefly touch upon the ecological concerns associated with forestry. We recommend reviewing the “additional reading” suggestions below for more detailed information.

In general, sustainable forestry maintains uneven ages of trees to promote structural diversity of habitat. It is also ecologically beneficial to leave occasional snags (dead trees) for their unique habitat contributions. Resource managers must be aware of the export of nutrients when any organic material (like timber) is removed from a forest (Perry 1998). Still, it is quite possible to selectively harvest trees for either timber or woodchips and maintain most of the long-term productivity and biodiversity of the landscape (Hilborn et al. 1995). Sustainable forestry is a broader concept than sustainable yield, because it includes the perpetuation of forest resources other timber harvests, such as recreational opportunities and wildlife habitat (Floyd et al. 2001). This follows from the notion of multiple use, Floyd et al. (2001) highlight the following five necessary components of sustainable forestry:

1. Maintaining the forest
2. Concern for future generations
3. Reasonable estimates of future needs
4. Estimates of current rates of use and regeneration
5. A widely accepted view of appropriate rates of use

Colgate currently has recommendations for sustainable logging of its forested lands in the “Colgate University Forest and Open Lands Stewardship Plan”. We hope that Colgate continue to pursue sustainable forms of forestry.

Additional Reading:


6. GIS Suitability Analysis

We performed a GIS suitability analysis to calculate the total area of Colgate land that is theoretically suitable for growing willow. The following five criteria were selected for on Colgate-owned land parcels:

1. Road access: Land parcels must border a road for planting and harvesting machinery access
2. Land cover: We selected agricultural or easily converted land cover types (52, 71, 81, 82)
3. Soil: We selected soil types which USDA (2006) SSURGO data classifies as well or moderately-suited for mechanical planting and harvesting of wood crops. This takes into account many factors such as slope, impervious layers, and erosion potential.
4. Streams: 10 meter buffering to protect riparian zone
5. Slope: Created Slope raster from DEM, and selected locations with less than 10 degree slopes

A total of 485 acres of Colgate land meet the criteria we used. However, some of the areas included in this total are too small for a cost effective willow plantation, and others would probably not be used for aesthetic reasons. This analysis was not meant to conclusively determine the feasibility of all possible sites, but instead to give a general idea of where we might find large areas suitable for this kind of crop. Particularly large and promising sites include the Parker Farm tract (245 acres), Bewkes Center (40 acres), and Hamilton Street tract (8 acres) (Fig. 6). These acreage calculations are also not meant to be taken as absolute figures. The area that appears suitable within the Hamilton tract has been relayed to us as approximately 12 acres, which is the figure we use in our economic analysis. Due to the low spatial resolution of some GIS data, these figures should be treated as estimates. Next, we examine soil characteristics at these three sites in depth, and found no evidence contrary to their classification as suitable.
Figure 3. Madison County roads and Colgate land parcels with road access.

Figure 4. 2001 NLCD land cover classifications.
Figure 5. Slope gradient calculation based on USGS DEM, used to select relatively flat sites.

Figure 6. Stream distance calculation on Chenango watershed hydrography network, used to create stream buffer zones.
Figure 7. Soil classified as moderately or well suited for mechanical planting and harvesting of wood crops based on data from the USDA soil survey geographic database.

Figure 8. Calculation of total suitable land (485 acres). Three main sites of interest are indicated.
Figure 9. The Bewkes Center, one possible willow location contains about 40 acres of suitable land according to this GIS analysis.

Figure 10. The Parker Farm tract contains the largest area of suitable land we found, at about 245 acres.
Figure 11. The Hamilton Street Tract was determined to contain about 8 acres of suitable land in GIS analysis. Other sources have given slightly larger estimates.

Figure 12. Distribution of soil types within the suitable area of the Hamilton Street Tract. The characteristics of these soils, and the major soils in suitable areas of the Bewkes Center and Parker Farm Tract are described in Table 1.
<table>
<thead>
<tr>
<th>Map Symbol</th>
<th>Soil Description</th>
<th>Sites</th>
<th>pH at 18 inch depth</th>
<th>Suitability for Mechanical Planting</th>
<th>Suitability for Mechanical Harvesting</th>
</tr>
</thead>
<tbody>
<tr>
<td>AsB</td>
<td>Arnot channery silt loam, 3 to 8 percent slopes</td>
<td>Parker</td>
<td>3.6 - 6.0</td>
<td>Moderate</td>
<td>Good</td>
</tr>
<tr>
<td>LwB</td>
<td>Lordstown channery silt loam, 3 to 8 percent slopes</td>
<td>Parker</td>
<td>4.5 - 6.0</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>LwC</td>
<td>Lordstown channery silt loam, 8 to 15 percent slopes</td>
<td>Parker</td>
<td>4.5 - 6.0</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>MaB</td>
<td>Mardin channery silt loam, 3 to 8 percent slopes</td>
<td>Hamilton</td>
<td>4.5 - 7.3</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>MaC</td>
<td>Mardin channery silt loam, 8 to 15 percent slopes</td>
<td>Hamilton</td>
<td>4.5 - 7.3</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>PgA</td>
<td>Palmyra gravelly loam, 0 to 3 percent slopes</td>
<td>Parker</td>
<td>6.1 - 7.8</td>
<td>Moderate</td>
<td>Good</td>
</tr>
<tr>
<td>PgC</td>
<td>Palmyra gravelly loam, rolling</td>
<td>Parker</td>
<td>6.1 - 7.8</td>
<td>Moderate</td>
<td>Good</td>
</tr>
<tr>
<td>VoA</td>
<td>Volusia channery silt loam, 0 to 3 percent slopes</td>
<td>Bewkes</td>
<td>5.1 - 7.3</td>
<td>Good</td>
<td>Moderate</td>
</tr>
<tr>
<td>VoB</td>
<td>Volusia channery silt loam, 3 to 8 percent slopes</td>
<td>Bewkes</td>
<td>5.1 - 7.3</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Wn</td>
<td>Wayland silt loam</td>
<td>Hamilton</td>
<td>5.1 - 8.4</td>
<td>Good</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

Table 1. Soil types found at the three most promising locations for a willow plantation, the Parker Farm tract, Hamilton Street tract, and Bewkes Center, with pertinent characteristics from the USDA (2006) SSURGO data. Ratings for suitability for mechanical planting of woody crops are based on slope, depth to a restrictive layer, content of sand, plasticity index, rock fragments on or below the surface, depth to a water table, and ponding. It is assumed that typical site preparation will take place. Possible ratings were: well suited, moderately suited, poorly suited, or unsuited. For this table, “well suited” was transcribed as “good”.

Ratings for suitability for mechanical harvesting of woody crops are based on slope, rock fragments on the surface, plasticity index, content of sand, the unified classification, depth to a water table, and ponding. The soils are described as well suited moderately suited, or poorly suited to this use.

More detailed information about the criteria used in the ratings is available in the "National Forestry Manual," which is available at: http://soils.usda.gov/technical/nfhandbook. (USDA, 2006)
7. Economic Feasibility Analysis

Colgate burns biomass, in the form of woodchips, to provide heat to most of the campus. Over the past six years, burning woodchips as the primary fuel, rather than oil, has saved Colgate around $2.5 million. There is no doubt that burning biomass has been a good option for Colgate, as it is cleaner and less costly than oil, but there are some economic concerns for the future that may threaten just how much money burning woodchips can save Colgate.

7.1 The Current and Future Woodchip Market

In the past few years, the price of woodchips in central New York has consistently increased. Colgate purchases woodchips to be burned in the biomass heating plant which is used to heat most of upper campus. The rising price of woodchips is increasing Colgate’s heating costs each year and it is important to start exploring alternative solutions.

The rising price of woodchips can be attributed to two main factors; the dependence on local markets and the increase in local demand for woodchips. The process of heating Colgate’s upper campus by burning woodchips requires a very large quantity of woodchips; so much that Colgate receives multiple deliveries of woodchips everyday. Since regular deliveries are required, fuel costs and time become a factor in supplying Colgate with woodchips. This limits Colgate to suppliers within a close proximity to campus. Colgate can order woodchips from suppliers within about 75 miles of campus. Suppliers any further than 75 miles cannot provide Colgate with woodchips as fuel costs and the time required to deliver become too high to be economically efficient. Because Colgate is dependent on a local market for its supply of woodchips, changes in supply or demand in the local area can affect the prices and supply Colgate is offered. The current situation is that demand for woodchips is increasing in the local market and this is driving the price of woodchips up. In 2002, Colgate was paying $20 per ton of woodchips. Currently, Colgate is paying $33 per ton. In just under six years, the price of woodchips has increased by 65 percent (Figure 1). The local price of woodchips can be expected to increase more in the future as demand increases and this makes it very important for Colgate to explore alternatives to buying woodchips. Growing our own biomass, in the form of willow, is one option that Colgate can consider.

![Figure 13. Increasing cost of woodchips over the past six years](image-url)
7.2 Willow Economics

Willow is very much a long-term investment. When growing willow, most of the costs are paid up front, as the site must be prepared and the willow must be purchased and planted. The benefits are, however, collected for over twenty years with lower costs during this period that include the cost of harvests and upkeep of the plants. In order to get the full economic benefit, seven or more rotations must be completed; this takes about 22 years (Abrahamson et al., 2002). Because of the nature of the costs and benefits associated with willow, discounting the future costs and benefits can play a significant role in deciding whether or not to grow willow. If high discount rates are applied, the present value of investing in willow decreases. However, if lower discount rates are used, the present value of investing in willow increases.

Annual yields of willow can be expected to increase over each rotation as is illustrated in Figure 2. First rotation yields are expected to fall in the range of 3.7 to 5.1 oven dried tons per acre per year (odt/A/yr). Second rotation yields increase by 35 to 100 percent, and, after two rotations, yields can be expected to be around 12 odt/A/yr (Abrahamson et al., 2002). It is important to note that yields have been as high as 24 to 30 odt/A/yr in Sweden (Keoleian & Volk, 2005). However, yields this high have not been reached in central New York.

As was mentioned before, a good portion of the costs of growing willow are experienced up front and the benefits are accrued over the 22 year cycle (Abrahamson et al., 2002). The upfront costs of growing willow include buying the actual plants. Costs vary depending on how much willow is purchased and how big the plants are. When dealing on a large scale, a local dealer located in Fredonia, NY, Double A Willow, currently sells 10 inch cuttings for $0.20 per cutting and 20 inch cuttings for $0.30 per cutting. Typical planting density is 6,000 cuttings per acre and using this information, the cost of purchasing willow in Central New York can be expected to be around $1200 or $1800 per acre, depending on what size cuttings are purchased.

7.3 Colgate’s Potential to Grow its Own Willow

Using Colgate’s average annual consumption of woodchips from 2004-2007, which is 17,965 tons, and an average yield of 12 odt/A/yr, Colgate would need to devote 1,497 acres to growing willow in order to produce enough woodchips to meet its demand each year. This is obviously not an option at this point in time as the Colgate Forest and Open Lands Stewardship Plan states that Colgate only owns...
1,137 acres of land (p. 2). However, by growing willow, Colgate can still currently produce a significant amount of the biomass it burns. As technology improves and average yields increase, less land will be necessary to produce a significant amount the woodchips Colgate burns. Of the 1,137 acres of land identified by the Stewardship Plan, 262 acres are open, non-forested lands. Of the open and non-forested land that Colgate owns, we have identified the Parker Farm Tract and the Hamilton Street Tract as two potential sites where willow can be grown in the near future.

The Parker Farm Tract consists of 354 acres, 57.5 of which is forested. The farmable portion of this land is currently leased out to a local farmer for $15,000 per year. We believe it is a good idea for Colgate to contact this local farmer and inquire about the possibility of him growing willow on this land to sell, in the form of woodchips, to Colgate. This would benefit Colgate as it would help stabilize the price of woodchips in the area by increasing supply, and Colgate would not be responsible for the costs of purchasing and maintaining the necessary equipment or for storing the woodchips.

The other potential site where willow can be grown in the near future is the Hamilton Street Tract, Management Unit N. This unit is 11.9 acres and is an abandoned hay field (Stewardship Plan, 2007). This tract of land is attractive because it is mainly clear, with the exception of some scrub brush, and it is adjacent to a main road. Its proximity to the road makes it easily accessible for equipment and trucks.

7.4 Concerns

There are some concerns regarding Colgate growing its own willow. These include the lack of long-term storage facilities for woodchips and the potentially high equipment costs relative to the small scale willow production that Colgate would be doing. Willow is less dense than other hardwoods and would require even more storage space for the same amount of weight compared to other hardwoods. In order to store willow supplies for longer than a few days, Colgate would have to build a large storage unit. As far as offsetting the equipment costs, it would be possible to hire out the harvesting work and any other machinery intensive tasks. The price of these services was unable to be determined, however, the process requires similar equipment to that of harvesting corn and could be hired out to a local farmer.

Review of Economics

- Growing willow may not be cost-effective for Colgate at this point in time
- As woodchip prices rise, growing willow becomes more and more cost-effective
- At today’s woodchip prices, the present value of Colgate farming 200 acres of willow over the next 22 years is $638,686
- For this project to be cost-effective, Colgate would have to hire out the farming work for no more than $48,000 per year, or woodchip prices would have to increase further
7.5 Recommendations

To get things started we believe Colgate should do a small scale test run of willow production. We have identified Management Unit N of the Hamilton Street Tract (p. 38 of the Stewardship Plan) as a good location for this. As was mentioned before, this 11.9 acre parcel is attractive because of its adjacency to a road, its proximity to Colgate, and the fact that it is mostly clear.

The assumptions made for the analysis of this plan are as follows: the growing cycle will be a seven rotation cycle spanning 22 years. First rotation yields will be 5 odt/A/yr and the remaining six rotations will yield 12 odt/A/yr. The value of the woodchips will be today’s current value of $33 per ton and the discount rate will be five percent. The size of the willow farm for this plan will be ten acres and Double A Willow will supply 10 inch cuttings for $0.20 per cutting. The entire 22 year cycle would yield a total of 2360 tons of willow

\[
[(5 \text{ tons} \times 10 \text{ acres} \times 4 \text{ years}) + (12 \text{ tons} \times 10 \text{ acres} \times 18 \text{ years})]
\]

which, after discounting at a rate of five percent, would be valued at $43,934. The estimated cost to purchase the ten inch willow cuttings for ten acres is $12,000. This cost is not discounted because it is realized upfront. Due to the small scale of this operation, it is recommended that Colgate hire out the planting and harvesting of the willow. We were unable to determine the cost of this service, but for this project to be cost effective, the cost would have to be $2400 or less each year. This plan is probably not cost effective, however, it would still be important to implement in order to see if this is something Colgate can do on a bigger, more cost-effective scale.

7.6 Future Potential

The plan described above is one way Colgate can test the feasibility of growing its own willow. Should that plan be successful, Colgate could consider planting willow on a larger scale on other university owned land. Applying the above plan to a larger scale should make it much more cost effective. Using the same assumptions as the above plan but increasing the willow farm size to 200 acres would yield a total present value of $638,686 without accounting for the unknown cost of hiring out the planting and harvesting [$878686 (PV of willow yields) - $240,000 (cost to purchase willow cuttings)]. At the current price of woodchips, this plan would be cost effective if the cost of hiring out the farming work is less than $48,521 per year. This may not be realistic at this point in time, but if the price of woodchips continue to rise as they have over the past six years, and this plan was reevaluated in six years, this figure would be increased to $91,911 per year. This figure seems much more realistic and even if the cost of hiring out the farm work is
higher than $91,911 per year, the plan could be reevaluated further into the future to analyze whether or not it is cost effective then. It all depends on how the price of woodchips changes in the future. If prices continue to rise, this plan will become more and more cost effective. If prices stop rising, or even decline, Colgate will continue to buy woodchips as that will be the most economical solution.

8. Conclusions

In this project we strove to address the feasibility for Colgate to grow its own willow biomass using all three components of sustainability: environmental, economic, and social. As such, we used an interdisciplinary approach to integrate the diversity of our academic backgrounds.

First of all, a literature review indicates that the production of willow is similar to traditional perennial cropping systems currently employed by New York farmers. This review highlights important factors to consider concerning the soil type and nutrient cycling associated with short rotation woody crops. Moreover, this review indicates that a willow plantation can be prepared, maintained and harvested with only slight modifications to standard farming equipment. The planter is the most specialized piece of equipment, but could be borrowed through a relationship with the SUNY College of Environmental Science and Forestry.

A geographic perspective is used to discuss the many factors influencing soil characteristics, and ultimately the social implications of willow farming—that is, the promising economic possibilities it represents to local farmers. A biological perspective is used to analyze the impacts this form of forestry would have on local biota, namely birds. We intended to determine if willow plantations would serve as ecological traps, areas that attract many species but result in low reproductive success rates. Despite these concerns, we find that breeding success within willow monocultures is comparable to natural habitats.

Furthermore, Geographic Information Systems is employed to discern the suitability of Colgate’s landholdings for growing willow biomass. Using the criteria of road-access, land cover, favorable soil, stream buffer, and low slope, we preformed a GIS suitability analysis in order to determine how much of Colgate’s property is capable of successfully supporting a willow plantation. Of the initial of 485 acres of Colgate land meet these criteria, we have highlighted three prime candidates for initial testing: the Parker Farm tract, the Bewkes Center, and the Hamilton Street tract.

The growing uncertainty of the local woodchip market initially prompted our investigation into the environmental and economic feasibility of growing willow biomass on Colgate-owned property for use in our steam-generating wood-burning facility. A cost-benefit analysis of the growing willow on Colgate-owned property revealed that current market conditions prevent Colgate-grown willow from becoming an economically feasible alternative to buying woodchips from outside venders. Nevertheless, current trends indicate that the market could allow for the production of willow on Colgate-owned land in the near future. As such, Colgate should begin experimentation on a small-scale and await shortages in the market before undertaking large-scale growing operations. Ultimately, we recommend the 10-acre Hamilton Street tract as an ideal location for an initial willow test plot.
References


