An Investigation Into Growing Biomass Using UBC Farm's Marginal Land

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APSC 261

November 28, 2013

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Date Submitted: November 28, 2013
APSC 261: Technology and Society I
Tutorial Instructor: Dr. Paul Winkelman

Abstract:

As part of its continuing mission to educate and operate sustainably, the UBC Farm wanted to see whether planting a fuel stock crop would be a beneficial investment towards the farm. The farm enlisted the help of various engineering undergraduates to investigate the requirements and to determine whether pursuing this venture would prove to be a worthwhile investment.The team assessed the initial process and investment and submitted a triple bottom line assessment. The land of the farm was surveyed and ue to the vigorous growth rate and lack of maintenance, red alder was chosen by the team as the crop of choice.

Table of Contents

List of Figures

1.0 Introduction

The dependence of natural gas and fossil fuel as our primary source of energy has spurred the research and development for alternatives. One of which is the processing of woody biomass at facilities like the Bioenergy Research and Demonstration Facility (BRDF) at UBC

The goal of this project is to determine the economic, social and environmental impacts of growing and supplying the BRDF with biomass grown from UBC Farm's marginal lands. The marginal lands are land that are not currently under use by the UBC Farm due to conditions or physical constraints. However, due to the low maintenance required and high survivability of some fuel stock plants, the previously unused land can be utilized for the production of these hearty fuel stock plants.

This report will outline and discuss the economic, social, and environmental aspects of the growth of biomass using the marginal land at UBC Farm. The possible benefits and disadvantages of the overall life cycle and process will also be touched upon in this assessment. From the possible yield of different crops, to the harvesting, processing, and transporting of the fuel stock plants to the BRDF. Possible environmental impacts such as the carbon neutrality of the process will be discussed. Lastly, the social influence of this project will be discussed.

Moreover, the environmental impacts of the project. The social impacts analysed overall show that the project will be give a positive impact to the University, neighboring communities and visitors to the farm. As part of the Farm's mission to educate on sustainable farming and practices, the Farm will use this crop to garner further awareness on alternative fuels while also making a contribution to educate that energy can be a community based affair.

2.0 Social Impacts

The social benefits of this initiative are best felt within the local community of the University of British Columbia. Though the scope of this project may impact social groups and entities outside of the university, the impact for the purpose of the triple bottom line will focus on the immediate impact that such an initiative can have on the surrounding community. Within the community, we have identified specific stakeholders, The primary stakeholder being the UBC Farm itself, and the other significant stakeholders being the Bioenergy Research and Demonstration Facility and the university as a whole. The goals of the primary stakeholder are to strengthen the relationships between the University', its energy initiatives and the Public via the Farm.

2.1 The UBC Farm

The UBC Farm, located on the south side of campus, is primarily a volunteer based venture run by the Centre for Sustainable Food Systems and acts as a forum for various community-based educational awareness programs. Due the high demand on its volunteers, Kate Menzies, our primary contact, requested that the fuel stock abid to her recommendations. In order to become a functional part of the farm, the chosen crop is requested to not require a lot of maintenance on part of the volunteers. Another point that Kate brought up was to take into account the harvest schedule of the regular crops to ensure that maintenance wasn't required during peak labour periods throughout the year. To be expected significant effort will be required to prepare the land for plantation and it is understood that this not coincide with any other harvest or plantation schedule.

The crop will serve the farm with several secondary agricultural benefits. Most of which will ultimately improve the functionality and effectiveness of the farm. Some of the ones mentioned are the crops ability to protect against soil erosion and protect against invasive species of plants such as blackberry bushes. The crop also has the ability, due to its high density, to be used a a windshield to protect more fragile crops from the frequent wide storms that are experienced in and around Vancouver.

2.2 The University of British Columbia

Currently as part of the university's initiative to become completely carbon neutral by the year 2020, the university overhauled the previous steam heating system and replaced it with hot water system. Also Included in this initiative, was the construction of the Bioenergy Research and Demonstration Facility, a joint project sponsored by various governmental and industry sources. Currently, this facility combusts two semi-truck worth of wood chips and other biomass materials daily to produce heat and electricity for the campus . Using this biomass, the BRDF is able to run in thermal mode or thermal and electric mode. In thermal mode, the facility is able to provide up to 25% of the campus' needs. In thermal and electric mode, the facility is able to provide up to 10% of the campus' need in heat and supply the Marine Drive Student Residence Building with electricity. The purpose is to illustrate that energy solutions could be tailor to meet the needs of a single community. As part of the community, the UBC Farm, wishes to partake in this initiative and help raise awareness of alternative energy sources sources. Since a large majority of the fuel stock burn at the BRDF is mostly imported from outside, The University isn't considered self sustaining. By introducing locally grown fuel-stock a better understanding of a community wide energy solution can be realized.

2.3 Various Educational Resources

As bi-product of this plantation, it is hoped that the university and adjoining communities will focus on this alternative energy source for its practical applications. As requested by Kate, some research time was taken look into the development of wood biomass crops on the community level. Could neighbourhood change local habits to plant fuel-stock crops in public places or in place of hedgerows? Such an option would provide the same benefits as other hedges such as breaking sightlines, acting as barriers but with the added benefit of lower maintenance on the part of the owner or municipality. These plants could periodically be harvested or trimmed and the waste be used to return power to the community. Since such tasks and community maintenance is undertaken by most municipalities, the cost to develop such a project would only exist in the plantation and harvest of new plants.

3.0 The Land and Yield

This section will provide a general estimate of the amount and type of land available to the UBC Farm for growing woody biomass. Factors regarding land type and climate will be used to determine the optimal woody plant species for biomass production. Using land area, climate, and plant type, an estimate for biomass yield will be created

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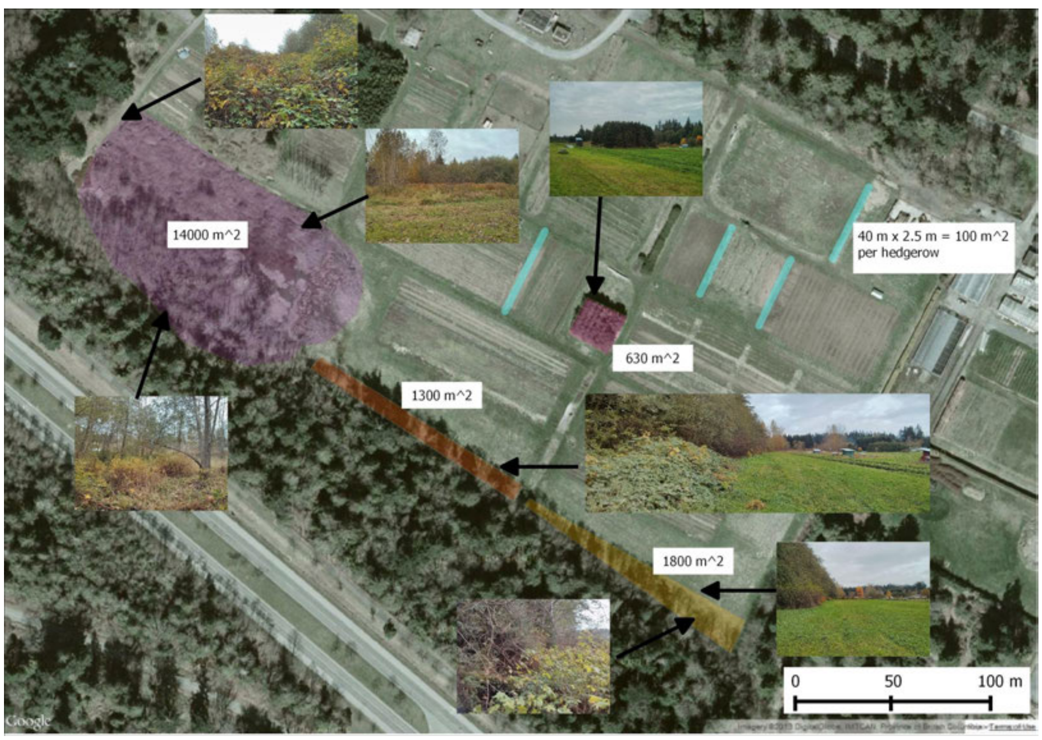
3.1 Land

The land on which the UBC Farm wants to grow woody biomass is deemed marginal land. This is land that the UBC farm has available, but does not use for crop production or any other operations. The primary farm areas, land that is optimal for other types of agricultural crops, will not be used for production of woody biomass. Multiple areas will be examined for growing conditions and determining the optimal crop.

Prospective locations for the growth of woody biomass were mapped out using a GPS device and GIS software. Figure-1 is a map of the UBC farm with prospective woody biomass growing locations highlighted.



Base map source: “UBC Farm.” 49°14 58.40” N and 123°14 15.91” W. Google Earth. April 3rd, 2009. October 15th, 2013.

Figure - 1: Aerial View of the UBC Farm.

Highlighted regions are areas being considered for the production woody biomass. These areas are labeled with their respective surface areas as well as photographs.

The forestry research plot (highlighted in pink on the map) is located at the center of the farm. The estimated area available in this region is approximated to be 630m^2. It is in direct sunlight and, since it is within the prime agricultural area, has good soil. On the land currently is a dense growth of coniferous trees. These trees must be removed prior to the growing of woody biomass. The removal of these trees can provide a large initial harvest of woody biomass. (What are those trees and are the suitable for the BRDF)

On the west side of the farm, (highlighted in purple,) there is a large section of land estimated at 14000m^2. This area contains wild grass, blackberry bushes, and tall deciduous trees. These pre-existing trees and shrubs can be harvested for biomass fuel. The existence of deciduous trees suggests favorable growing conditions for tree crops. The south side of this area borders the forest causing for a lack of southern exposure. This area is wet and receives poor drainage.

The south side of the farm houses two strips of land (one highlighted in orange and the other highlighted in yellow). The orange section is estimated at 1300 m^2 and the yellow section is estimated at 1800m^2. These sections lie on the southern edge of the UBC Farm, bordered by forest. These areas contain some maintained grass as well as blackberry bushes and other general brush. As the farm slopes southward, this area is wet. At the edge of the forest there is a drainage ditch. These sections, being on the north edge of the forest, do not get southern exposure.

Possible locations for hedgerows are highlighted in blue. Each hedgerow is estimated to have 100m^2 of area. The number of hedgerows may vary depending on farm space requirements and needs. Being in the prime agricultural space, the soil is expected to be good with significant exposure to sunlight.

3.2 Crop Selection

The two woody biomass crop being considered for plantation are: black cottonwood (a species of willow) and red alder. These two trees, when dried, fit the requirements of the BRDF facility. Crops that are less woody may not meet specifications, or, in the case of miscanthus, require extra treatment in order to be usable fuel. Both black alder and red alder occur naturally along the northern pacific coast (Niemiec & Laboratory, 1995). This means that they should grow well in the moist, temperate conditions of the UBC Farm. Both plants will regrow after harvest, not requiring replanting. Harvests of these plants can occur every 3 to 6 years. Growing periods of longer than 6 years can also be used depending on needs and requirements of these trees

Willow has an estimated yield of up to 10 dry tonnes per acre per year(Volk, Verwijst, Tharakan, Abrahamson, & White, 2004). This is in an agricultural setup with nitrogen fertilizers. Given the growing conditions and species of willow, black cottonwood, the yield would probably be between 5 and 7 dry tonnes per acre.

The majority of hardwood in the Pacific Northwest is red alder(Niemiec & Laboratory, 1995). In non-agricultural settings with good growing conditions, red alder has an estimated yield of 7 dry tonnes per acre per year(Niemiec & Laboratory, 1995). Red alder also fixes nitrogen (Niemiec & Laboratory, 1995). This means that it doesn't require nitrogen fertilizers and it may also benefit surrounding farm plants.

Being the dominant hardwood species in the Pacific Northwest, red alder is the recommended source of woody biomass given its success in this area and climate. The rapid growth rate of red alder combined with its ability to succeed in this region makes it the best option for ensuring a high yield.

2.3 Yield

The estimated yield is calculated by multiplying the estimated growth rate by the estimated available giving the number of dry tonnes of woody biomass produced per year. The estimated growth rate will be based on that of red alder, the recommended crop. Growing condition factors will be considered when rounding. This calculation will be made for each of the highlighted areas on Figure-1. Yields for each region are displayed on Figure-2.

Region	Estimated Yield (dry tonnes per year)
Pink (Forestry Plot)	1
Purple (West side)	24
Orange (South side)	2
Yellow (South side)	3
Blue (One hedgerow)	0.2

Figure-2: Yield for various regions based on estimated size and estimated growth rate of red alder.

The total yield depends on which combination of these lands the UBC Farm wishes to use and how many hedgerows it wishes to implement. The large purple area on the west side of the farm would provide the largest yield at 24 dry tonnes per year, a yield much greater than any of the other areas. If all of the land is used to grow Red Alder, the yield is estimated to be 30.2 tonnes per year. As the BRDF currently pays 60$ per tonne of dry, chipped wood fuel, the project could provide a gross income of $1812 per year.

4.0 Harvesting, Processing, and Transporting

The harvesting, processing, and transporting of the biomass will be discussed here. The applicability of these three processes play an important role in the possible success of this project. Since the stakeholder have requested that the project be done with as little financial requirements as possible. Possible solutions must use what is currently available to the UBC Farm and utilize them in the best way to streamline the processes of harvesting, processing, and transporting of the biomass.

4.1 Harvesting

Because of the nature of the operations of the UBC Farm, the lower the time and capital investment this project requires, the more likely the project will be adopted by the Farm. As a result of this constraint, no automated processes were considered; neither were the options of purchasing mobile harvesting equipment that would aid in the harvesting of the crops

The main concepts for the harvesting the biomass are the use of chainsaws and the brush cutter with saw blade attachments as shown in Figure- below. There are however further constraints on the use of equipment currently available .

Retrieved From on November 22, 2013: http://www.oassf.com/en/media/images/chainsaw-image.jpg

Figure-3: :Photograph of a typical chainsaw.

Retrieved from on November 22, 2013:
http://i00.i.aliimg.com/wsphoto/v1/460250974/-font-b-brush-b-font-font-b-cutter-b-font-font-b-Craftsman-b-font.jpg

Figure-4: Photograph of a typical brush cutter with saw blade attachment

The chainsaw would be a very quick way of cutting down the ready-for-harvest plants. However, due to safety and liability issues, the chainsaws can and will only be operated by paid UBC Farm workers. This is not an ideal solution because the UBC Farm works are understaffed and may not be able to spare the time to harvest the biomass. Costs would also increase to offset the income from the yield.

The brush cutter with the saw blade attachment would provide a less expensive solution since they could be operated by UBC Farm volunteers. These will not be able to cut down the biomass at the same speed as the chainsaw. Due to its ease of use and the possibility of training volunteers, the brush cutter shows to be the more promising alternative to the chainsaw.

In conclusion, the brush cutter should be used by the volunteers after adequate training to harvest the biomass. However, if an accelerated harvest schedule is desired, the UBC Farm workers always have the options to operate the chainsaw to cut down the biomass. Crops would have to be cut more frequently with the brush cutter as tree size must remain very small. Below is an estimate of the cost required to harvest the full crop yield:

Chainsaw	75 man hours (15sec/m^2)	2.5L/ man hr of gasoline
Brush Cutter w Saw Blade	150 man hours(30sec/m^2)	1.5L/man hr of gasoline

Figure-5: Tabulated Labour and fuel cost depending on harvesting option

With a wage of 25$/hr and a fuel cost of $1.50/L, harvesting the years yield with a chainsaw would cost $2156. With volunteer labour and weed eaters, the cost to harvest would be $338.

4.2 Processing

The processing of the biomass after would include the felling, collection and drying of the woody biomass. Due to Vancouver's climate with generally rainy winters, maintaining and drying the material will be an issue. Drying can be done in a covered and raised area located at the UBC Farm. With enough time, the woody biomass will be able to dry to the specifications necessary for the BRDF. Keeping the biomass in its post harvesting state should prove to have a benefit to the drying process as opposed to chipping the biomass and then storing it. By keeping the biomass in its intact state, air is allowed to circulate between the cracks, whereas when chipped, the air will have a significantly tougher time penetrating the pile. Furthermore, the exact duration of the drying process cannot be predicted, and must be experimented if the project was to proceed.

After the drying of the biomass, the wood chipper from UBC plant ops, similar to the one found in Figure - 4 below, can be borrowed and used to further process the dry biomass before being transported to the BRDF. Fuel cost to chip the entire years yield is estimated to be $120. This figure is based on the use of a 35HP wood chipper which can process 4 tonnes per hour.

Retrieved on November 22, 2013 from: http://images costco ca/image/media/500-263899-894__1.jpg

Figure-6: Photograph of a typical wood chipper.

4.3 Transporting

The transportation of the processed biomass must be done quickly after the original biomass has gone through the chipper due to the moisture content restrictions of the BRDF. By storing the biomass in wood chip from, unwanted moisture is allowed to penetrate the pile and add moisture back into the biomass.

The UBC Farm tractor, as shown below in Figure-7, and 12'X4.5' trailer can be utilized to transport the processed biomass to the BRDF. The options of obtaining another transportation device was out of the question because of the scope of this project due to the substantial cost of such a purchase. Furthermore, the UBC Farm van, as shown below in Figure - 8, can also be utilized for the transportation of the processed biomass. Fuel Cost to transport the full yield is estimated to be $30 if a Diesel powered tractor makes trips with a payload of one tonne. Diesel Tractors are fuel efficient and the distance is only about 3km. If the trailer cannot support this weight, more trips and fuel would be required. The van would likely require more trips and fuel.

Figure-7: An example of UBC farm's range of available tractors.

Figure-8 : Photograph of the UBC Farm van.

The method of transportation can be chosen by the workers as it makes little difference to the material. The tractor and trailer may prove to be less bothersome as it allows a larger load to be transported at once. The van's advantage would be its ease of use, a volunteer could potentially be able to drive the van full of biomass to the BRDF, whereas a UBC Farm worker would need to drive the tractor to the BRDF.

The BRDF pays a rate of $60/ton of dry, chipped wood fuel. Based on this rate the expected income is $1324 for the entire years yield if volunteer workers are used. If chainsaws and farm workers are used instead, the project would cost $494.

5.0 Environmental impacts

The primary advantage of burning woody biomass fuel over fossil fuels is the carbon neutrality of the process. Fossil fuels are created from biomass through chemical and geological processes acting over millions of years. Deposits act as massive carbon sinks, keeping carbon in solid, liquid, or gaseous form under the surface of the earth. Burning these deposits re-releases the carbon into the atmosphere at a rate far greater than it was stored. Thus, in the time scale of our species and the processes on the surface of the earth, fossil fuels are a non-renewable source which presents a clear danger to the prospect of maintaining a habitable planet. In contrast, biofuels grow by absorbing carbon from the atmosphere. When burned, this carbon is released, but unlike fossil fuels, this cycle can occur with a period of just a few years. For this reason the cycle can be considered to have a neutral impact on atmospheric CO_2 (Northrop, 2013). It should be noted that a cycle period of hundreds of years, though still carbon neutral, may still have a negative impact on the planet, as climate change is predicted to have serious negative effects within the century. An example of such a process is the destruction and burning of established forests.

For a simple carbon accounting of the process, one can approximate that the *dry* biomass is composed completely of hydrocarbons which are completely burned, releasing all of the carbon in the form of CO_2 and all the hydrogen in H_2O. Unlike a typical wood stove, the BRDF combusts the material at an extremely high temperature leading to inconsequential levels of CO or NO_x gasses. Heavy metals or radioisotopes present in the biofuel, absorbed from the ground, may be released to the atmosphere, but these effects are extremely small, far less than those involved in burning of coal, for example.

However, the carbon cost of land clearing, growth, harvesting, transport and storage of biofuel subtracts from this neutrality. For example, clearing a forest or marsh to grow a crop will destroy a form of carbon storage that is higher in density than the crop that is replacing it (Northrop, 2013). Furthermore, land clearing, tending of crops, harvesting, and transportation tends to use energy from fossil fuels as vehicles and equipment are typically powered by gasoline or diesel.

Our estimates of yield are 30.2 tonnes per year (maximum), resulting in an energy production of 161570 kWh per year.The carbon content of the land to be cleared is difficult to estimate as it is composed of a range of environment types, some of which are left untouched, whereas some are maintained through grass cutting or trimming. For this analysis the carbon impact of land clearing will be ignored. Irrigation and fertilization is deemed unnecessary for the immediate future as the crop (Red Alder) is similar in type to that which currently grows naturally in the area, and it is nitrogen fixing and thus does not require nitrogen replenishment. Using estimates of fuel consumption for harvesting, processing, and transporting, the project will offset 159000 kWh of energy from natural gas, which is UBC's primary source of heat energy. This is enough energy to supply approximately 10 residential homes with heat for the year. This amount of energy should completely offset the heating energy required by UBC Farm.

There are other local benefits to growing Red Alder at the UBC Farm. These trees, planted in marginal areas, provide a buffer to adverse weather. Red Alder is nitrogen fixing, which means that if the farm reclaims the land for growing food, the Red Alder will have increased the nitrogen content of the soil. The lack of fertilizer or pesticide requirements eliminates the associated problems of runoff into the environment.

The choice of crop, use of marginal lands, and combustion at the BRDF facility mitigates all of the major environmental concerns of the process. Any amount of Red Alder that can be grown and combusted at the BRDF to offset the use of fossil fuels will provide a net benefit to the environment.

6.0 Conclusion

Economically, this project has the potential to provide a small income to the UBC Farm of up to $1324 per year if the harvesting, processing, and transporting is accomplished by volunteers. If the fuel is harvested by paid farm workers, the project becomes unprofitable, at $-494 per year or more. This income or cost could be incurred yearly or after several years depending on the harvesting scheme used. To provide some feeling of scale to these numbers, the cost of the natural gas that could be replaced by the project is about $1903. This shows that even at the small scale, this fuel source is not extremely costly compared to natural gas. However, the real impact of the project will be small, as the yearly yield would only offset 0.27% of UBC's natural gas heating cost. It would however, easily offset the energy requirements of UBC Farm.

Environmentally, woody biomass harvested and burned in a clean burning power plant is a clear winner over natural gas due to its carbon neutrality. The cost of growing, harvesting, and transporting does offset the carbon neutrality, but the specifics of this project show those costs to be extremely small compared to the amount of carbon neutral energy being created. For example, the distance the fuel is transported is miniscule compared to the distance that most of the current fuel travels to reach the BRDF. Additionally, the use of marginal lands for growth does not compete with food production, and trees planted for biomass can provide an environmental buffer for nearby food crops. Red Alder is not an alien species to the area and is nitrogen fixing, meaning that it has the potential to improve the soil it is planted in rather than deplete it. In the future, methods could be devised to completely eliminate fossil fuels from the harvesting and transport activities.

Socially, this project would have many benefits. Many students are unaware of the BRDF and UBCs efforts to offset its natural gas carbon emissions. This project could be used to encourage more research and interest in the process. Even though the project is on a small scale, participants will learn about and be able improve upon the process of growing, harvesting, and combusting woody biomass.

The teams recommendation is to move ahead with a plan to grow Red Alder at UBC Farm. It may be wise to start with a smaller pilot project rather than beginning with the entire area available at the farm. This way risk is minimized while a specific procedure can be developed and harmonized with the other participants such as the BRDF or Faculty of Forestry.

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