An Investigation into Biofuel Fuelstock Production at the UBC Farm

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University of British Columbia

APSC 261

November 28, 2013

APSC 261

SUSTAINABILITY PROJECT REPORT

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November 28, 2013

Abstract

The UBC Farm is interested growing woody biomass within existing hedgerows and along farm margins, to supply biofuel fuelstock to the Bioenergy Research and Demonstration Facility (BRDF) on campus. This report investigates the available land area as well as the most suitable fuelstock crop for the UBC Farm. Furthermore, this report investigates the viability of the project using a triple bottom line analysis, taking into account the economic, environmental, and social factors involved.

Through the investigation, it was determined that approximately 0.75 hectares of land is available for this project, and that hybrid poplar would be the most suitable fuelstock crop. Economically, the proposed project was determined to create no significant profit, creating only $710 profit over the proposed 20 year life cycle. Environmentally, the project was determined to have no significant effect on greenhouse gas (GHG) reductions or clean energy produced, reducing GHG emissions by only 2650 kg/year and producing only 9000 kWh/year of clean energy (less than 0.01% of UBCs annual energy consumption). However, there are significant ecosystem and land use benefits to the project, such as decreasing soil erosion, flooding prevention, and creating habitat for local animals.

The project was determined to be most beneficial from a social aspect, by increasing awareness about biofuels, creating educational and research opportunities, and promoting UBCs reputation and involvement in sustainability. Based on our investigation, we recommend that the UBC Farm go ahead with this project, not for the financial or environmental benefits, but for the great social benefits, as a demonstration, learning, and outreach project.

Contents

1 Introduction 1

2 Land Availability 2

3 Crop Selection 4

4 Economic Assessment 6
4.1 Establishment, Production and Reclamation Costs . . . 6
4.2 Income . . . 7
4.3 Assessment . . . 7

5 Environmental Assessment 8
5.1 Impact on Land and Existing Ecosystem . . . 8
5.2 Greenhouse Gas Emission Reduction . . . 9
5.3 Assessment . . . 9

6 Social Assessment 10
6.1 Knowledge of Fuel Stock . . . 10
6.2 Benefits . . . 10
6.3 Educational Opportunities . . . 11
6.3.1 Case study for small-scale and Large Farms . . . 12
6.3.2 Educate the UBC community on Alternative sources of Energy . . . 12
6.3.3 Study subject for Poplar research at UBC . . . 12
6.3.4 Stakeholders within UBC community . . . 12
6.4 Assessment . . . 13

7 Conclusion 14
7.1 Economic Conclusions . . . 14
7.2 Environmental Conclusions . . . 14
7.3 Social Conclusions . . . 14

8 Recommendations 15
8.1 Land Recommendations . . . 15
8.2 Crop Recommendations . . . 15
8.3 Triple Bottom Line Recommendations . . . 15

List of Figures

1 UBC Farm Map with Available Land Area Highlighted. 2
2 Land available during site visit 3
3 Method of Determining Environmental Impact (Wisconsin 2013) . . 8
4 Survey Results depicting the existing knowledge about Fuel-Stock and its role in producing Bio-Fuel. 10
5 Survey results of the benefits expected from this project. 11

List of Tables

1 Hybrid Poplar Composition and BRDF Fuel Specifications (Sannigrahi 2009) (Nexterra 2007) 5
2 Economic Assessment Assuming a 20 Year Life Cycle and available Land Area of 0.75 Hectares 7
3 Summary of the faculties at UBC who could be a stake holder for the project 13

GLOSSARY

Greenhouse gas (GHG)
A gas in the atmosphere that absorbs and emits thermal radiation contributing to global warming, namely CO_2.
Oven dry tonne (ODT)
A metric tonne (1000kg) of biomass material with all moisture removed.
Fuel stock
The raw plant material used to produce biofuel
Biofuel
Fuel produced by thermal or bio-chemical conversion of organic fuel stock.
Genomics
Genomics is a discipline in genetics that applies DNA sequencing methods, to map, assemble, and analyze the function and structure of the set of DNA within a single cell of an organism)
Buffer Strip
An area of land maintained in permanent vegetation that helps to control air, soil, and water quality, along with other environmental problems, dealing primarily on land that is used in agriculture.
Coppicing
Cutting a tree trunk till ground level but not uprooting the tree. New growth happens from the left over tree stumps. endminipage

1 Introduction

The UBC Farm encompasses 24 hectares of integrated farm and forest land on UBCs South Campus. Managed by the Center for Sustainable Food Systems, the Farm explores and exemplifies new paradigms for the design and function of sustainable communities and their ecological support systems (Menzies 2013). Currently the UBC Farm is interested in growing woody biomass within existing hedgerows and along farm margins (areas that are not being used for food production), to supply Fuel stock for the Bioenergy Research and Demonstration Facility (BRDF). The BRDF, located on campus, produces second generation biofuel from woody biomass. By producing energy from this woody biomass, the BRDF decreases UBCs consumption of conventional fossil fuels, such as natural gas and coal, helping reduce greenhouse gas (GHG) emissions.

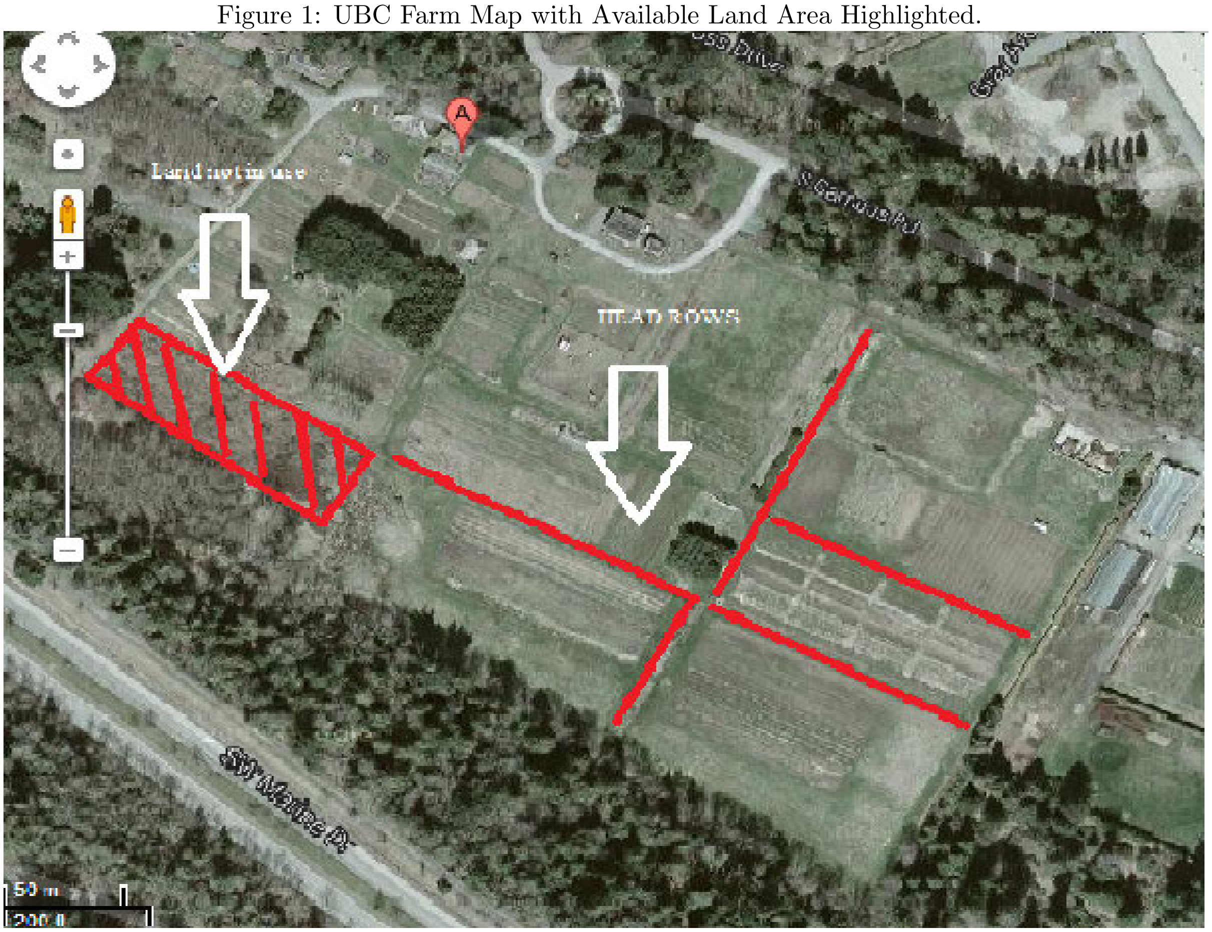
In recent years there has been a strong movement towards second generation Biofuels (Charles 2007). Unlike first generation Biofuels, which use food crops to produce Biofuels, second generation Biofuels come from cellulosic (woody) biomass. There are many reasons for this movement towards second generation Biofuels, including higher efficiencies and being more environmentally friendly. However, the major reason for this shift is that second generation Biofuel crops can be grown on lower quality land, whereas first generation Biofuels require prime agricultural land (Naik, 2010). Because of this, second generation Biofuels can be grown without decreasing food production. This is of particular importance to the UBC Farm, which has limited prime agricultural land.

Through this investigation will seek to determine if the UBC Farm should grow woody biomass on farm margins to supply fuelstock to the BRDF. This will be done using a triple bottom line analysis, taking into account the economic, social, and environmental factors of the proposed project. We will also determine what type of biofuel crop would be best suited for production at the UBC Farm.

2 Land Availability

To begin the investigation, the available land area at the UBC Farm was determined. The project was limited to marginal land and hedge rows, that are not used for agricultural purposes. The available land area was estimated to be 0.75 hectares of the total 20 hectares at the UBC Farm. The land was selected to so that planting and harvesting of the biofuel fuelstock will have a minimal impact on agricultural areas of the UBC Farm. Figure 1 displays the UBC Farm and highlights the land area available for fuelstock growth. The available marginal land was found to be on very wet soil (determined by site visit), and this turned out to be a limiting factor when determining the correct fuelstock crop. However, during our site visit, we realised that we could use this wetness to our advantage to suit our crop recommendation - Poplar.

Figure 1: UBC Farm Map with Available Land Area Highlighted.



Most of the shaded red area is not being utilized at the moment. The highlighted head rows are at the moment growing little trees to act as wind protectors. As seen in the pictures below, both of these lands can be utilized at the moment to grow fuel stock.

Figure 2: Land available during site visit

3 Crop Selection

There are many factors to consider when choosing a biofuel crop for the UBC Farm. The most important of these being the total crop yield, the suitability for the Vancouver climate, and the actual crop composition. Hybrid poplar and miscanthus have been found to be the best woody biofuel crop for the moderate Vancouver climate (Van Oosten 2008).

Miscanthus is a perennial grass crop that is often considered for biofuel fuelstock, and the UBC Farm currently has a demonstration crop of miscanthus growing in an existing hedgerow. However there are many concerns with growing miscanthus as fuelstock for the BRDF. Miscanthus crops have been shown to produce large yields of up to 20 oven dried tonnes per hectare per year (ODT/ha/yr) (Christian 2008). However, this is a misleading number. The fuelstock for BRDF must be wood fuel that is free of leafy greens or needles (Nexterra 2007). Applying this to miscanthus crops can reduce yields by up to 50% (Heaton 2010). The BRDF also requires that the fuelstock residues be 0.25-3 inches in all directions, with residues sized less than 0.25 inches being limited to 25% or less (Nexterra 2007). Because Miscanthus is a grass crop, there are concerns about the final chipped product being greater than 25% under the 0.25 inch limit. None of these problems are present when using hybrid poplar as biofuel crop.

Hybrid poplar is a very suitable short rotation coppice (SRC) crop for biofuel production. Once harvested, poplars sprout readily from the stump; this resprouting is known as coppicing. From each stump will sprout multiple stems and the coppice stand will be more productive than the old stand. Utilizing coppicing offers an inexpensive way to re-establish a stand without replanting. Coppice stands are usually more productive than the original stand in the first 5 years after harvest, due to the plant having an already established root system. Hybrid poplars should also be harvested in the dormant months from November to April, to minimize soil compaction and maximize resprouting. Another benefit to harvesting in the winter months is that this is outside of the agricultural growing season, and therefore there will be sufficient free labour to perform the harvest.

A major advantage to using hybrid poplar is that it has the correct composition as fuelstock for the BRDF as shown in Figure 1, and therefore will not require further processing before being sold to the BRDF.

On good sites, hybrid poplars grow faster than any other northern temperate tree. Because the soil on the UBC Farm margins are very wet and susceptible to flooding, the great flood resistance of hybrid poplar is a significant advantage (Liu 2006). In wet climates similar to Vancouver, yields of 7-20 ODT/ha/yr have been observed without the use of irrigation or fertilizers (Van Oosten 2008). Short rotation cycles

Table 1: Hybrid Poplar Composition and BRDF Fuel Specifications (Sannigrahi 2009) (Nexterra 2007)

Component	**Hybrid Poplar**	**BRDF Specifications**
Moisture Content	50%	10%-55%
Higher Heating Value(HHV)	8500btu/lb	>8500btu/lb
Carbon	48.45%	48%-52%
Hydrogen	5.85%	5%-6%
Oxygen	43.69%	36%-44%
Nitrogen	0.47%	<0.3%
Sulphur	0.01%	<0.025 %

of 1-5 years are optimal for hybrid poplar crops, with peak yields with 3 year rotation cycles. For this assessment, we use a conservative estimate of 10 ODT/ha/yr, with a harvesting cycle once every 3 years.

It is for these reasons that hybrid poplar is the best biofuel crop for the UBC Farm to grow as fuelstock for the BRDF.

4 Economic Assessment

A basic economic assessment was completed for this project to determine the economic viability of growing hybrid poplar fuel stock to sell to the BRDF. The economic assessment was completed assuming the UBC farm has access to the following equipment: Truck, trailer, wood chipper, cutting equipment (chainsaws). The economic assessment is also done assuming a 20 year lifespan for the project. Beyond this lifespan, a new economic assessment must be completed in order to take into account fertilizer requirements and new poplar cuttings cost. 20 years is the period in which coppicing hybrid poplar can be productive without fertilizers (Tubby and Armstrong, 2002). 20 years is also the time period in which coppiced hybrid poplars can survive before needing to be replaced (Tubby and Armstrong, 2002).

4.1 Establishment, Production and Reclamation Costs

Hybrid poplar has an optimal planting density of around 10,000 trees per hectare (Labrecque 2005). Because of this large density, the initial cost of the trees is the largest financial expenditure of this project. Hybrid poplar cuttings can be bought for an average price of $0.25 per cutting, bringing the total cost for the initial fuelstock crops to $1875 (Khanna 2011). This initial investment can be reduced by using cuttings from existing hybrid poplars on campus. The cost of establishing a hybrid poplar crop was found to be $360/hectare, putting the cost for this project at $270 (Khanna 2011). This establishment cost includes plowing, harrowing, plowing, and weed control.

The annual harvesting costs of this project take into account the fuel and machinery repair costs for the falling and chipping of the poplar biomass. These costs were found to be $125/year, for a total life cycle cost of $2500. Although the majority of the labour at the UBC Farm is by volunteers, there will be costs associated with accounting/management as well as supervisory field work. The time requirements of these staff are estimated to be 3 hours/year of management work, at $25/hour, and 6 hours per year of supervisory field work, at $18/hour (Menzies 2013). These labour costs add up to $183/year, for a total lifecycle cost of $3660.

The transportation costs are very low for the UBC Farm, due to its close proximity to the BRDF. An average financial cost for transporting freight in B.C. was found to be $0.20/tonne/km, which includes vehicle and vehicle operating costs (Transport Canada 2008). With a total round trip distance of 6km (Google Maps) and a yearly biomass yield of 15 tonnes (7.5 ODT, with a moisture content of 50%), the total cost for transporting biomass fuelstock to the BRDF was found to be $18/year. Over the total lifecycle of the project the transportation costs are $360.

At the end of the projects 20 year life cycle, there are costs associated with land reclamation, namely stump removal. The machinery operating costs for stump removal was found to be \$500/hectare (Khanna 2011). This leads to a land reclamation cost of \$375 for this project. However, if after the 20 year life cycle the land is to be turned into agricultural land, there will be considerable fertilizer costs to replenish the nutrients in the soils. In this assessment it is assumed that the area will remain marginal land and therefore not require the additional fertilizer costs.

4.2 Income

The BRDF pays a delivered price of \$65/ODT of Fuel-stock. With an expected yield of 7.5 ODT/year of hybrid poplar Fuel-stock, the expected income from this project is \$487.5/year. Over the lifecycle of this project the expected income is \$9750.

4.3 Assessment

The results from the economic analysis are displayed in Figure 2. As shown in Figure 2, the project is financially net positive over the entire 20 year lifecycle. However, the project does not lead to meaningful profits (\$710 over 20 years), due to its small scale. The project also requires a sizable initial investment of \$2145, but this can be significantly reduced by obtaining poplar cuttings from existing hybrid poplars at UBC, rather than purchasing them. Due to the small scale and meager potential profits, the project is not feasible if considering only the economic benefits, however, once initiated, the project does produce enough money to sustain itself. Also there is the possibility of obtaining government grants, which would help offset the financial burden making the project more economically viable.

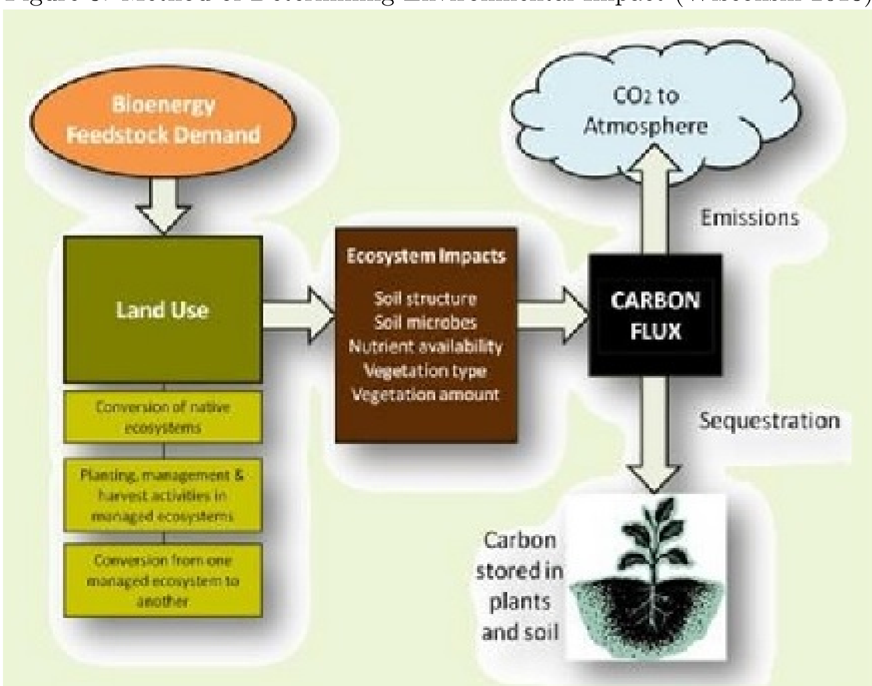
Table 2: Economic Assessment Assuming a 20 Year Life Cycle and available Land Area of 0.75 Hectares

	Annual(\$/year)	Life cycle (\$)
Expenses		
Poplar	–	1875
Establishment	-	270
Harvesting	125	2500
Labour	183	3660
Transportation	18	360
Land Reclamation	-	375
Total Expenses	-	9040
Revenue		
Fuel stock Sale to BRDF	487.5	**9750**
Lifecyle Profits	-	710

5 Environmental Assessment

A basic environmental assessment was completed to determine the environmental benefits and/or drawbacks of the proposed project. As shown in Figure 4, there are many factors to consider when determining the environmental effect of biofuels. The two main factors we explored in our investigation that were considered during the environmental assessment of this project. The factors considered were the impact on existing ecosystem and GHG emission reductions. These factors will be discussed in the environmental assessment and they will ultimately determine the environmental benefits and/or drawbacks of the project.

Figure 3: Method of Determining Environmental Impact (Wisconsin 2013)



5.1 Impact on Land and Existing Ecosystem

he impact that this project will have on the land will be very relatively small because only 0.75 hectares of the entire 20 hectare farm will be used. Because the land is not used for agriculture, there are no negative effects from the nutrient deterioration of the soil. Hybrid poplar crops have also been shown to decrease flooding and reduce soil erosion, which is beneficial for the UBC Farm (Labrecque 2005). By planting the fuelstock crops along the farm margins, a buffer strip is created, separating the agricultural land from the surrounding forest. A buffer strip is beneficial in decreasing wind erosion, improving water filtration, and stabilizing the land. The hybrid poplar crop will also provide habitat for the local ecosystem in terms of increasing bird life and creating a habitat for the natural living beings in that area.

5.2 Greenhouse Gas Emission Reduction

The calculated total CO_2 emission that this project will offset is 3000 kg/year which is equivalent to 0.6 cars per year. The CO_2 emission produced from the planting and harvesting hybrid poplar was found to be 350 kg/year (Alder 2007). There are also GHG emissions produced from the transportation of fuelstock to the BRDF, however because the distance is very small, the GHG emissions from transportation are negligible (i.e. less than 1 kg/year) (Transport Canada 2008). Taking these into account, the net CO_2 reduction of the project is predicted to be 2650 kg/year, which is equivalent to 0.5 cars/year. The total amount of clean energy produced from the fuelstock grown at the UBC Farm is 9,000kWh/year (Nextera 2007). These numbers are very small when compared to those of the overall BRDF, which produces 15,000,000kWh/year and reduces GHG emissions by 5,000,000kg/year (Nextera 2013). To further put this in perspective, the entire BRDF produces less than 5% of UBCs net power. From this we can see that the emission reductions and the power produced from this project are very minimal.

5.3 Assessment

From the above investigations, the emission reductions, and the power produced are very small, due to the small scale of this project. However, this project have a positive environmental effect on the land and existing ecosystem. It will create a habitat for the birds and insect life in that area, as well as protects the crops from wind erosion. Furthermore, the transition into forest land is better since it creates a buffer region between farm land and forest land. To summarize, the project is viable in the environmental aspect.

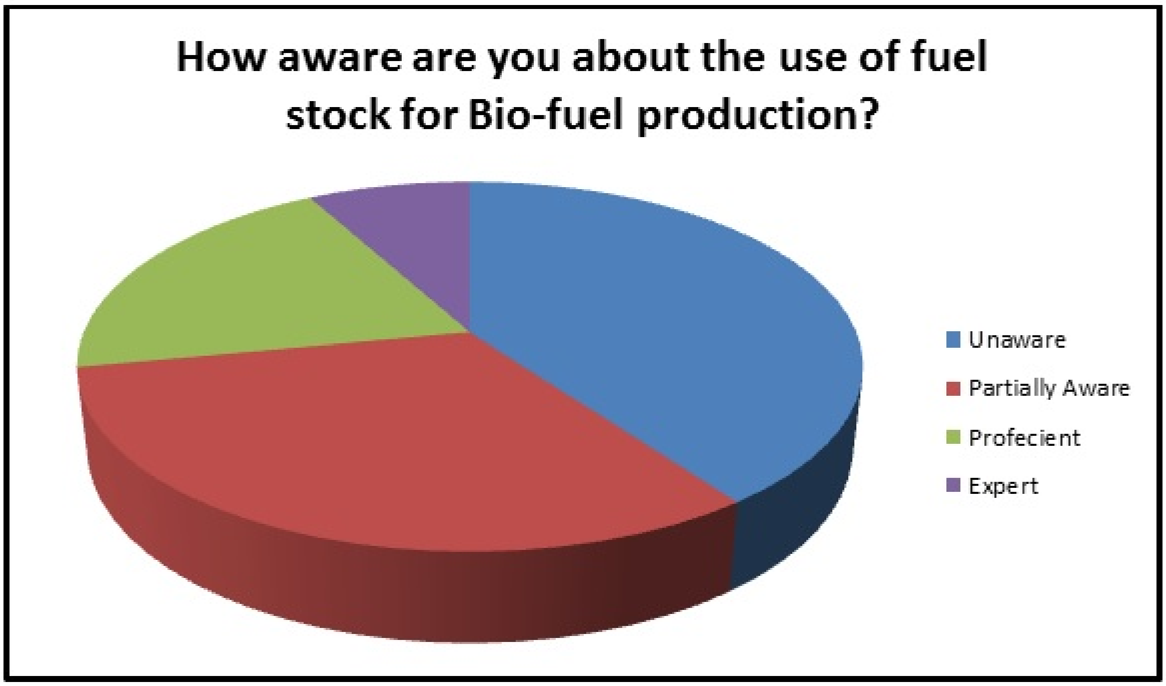
6 Social Assessment

The Social Assessment needs to be considerate of the UBC community and their voice in this subject. Thus, we created a focus group consisting of 25 students from various faculties across the community. This survey will be constantly referenced and its data used to make recommendations towards this project.

6.1 Knowledge of Fuel Stock

It was necessary to gage the knowledge that the UBC community has on the topic of Fuel stock and its use to create Bio-fuel. Here are the survey results when community members were asked this question.

Figure 4: Survey Results depicting the existing knowledge about Fuel-Stock and its role in producing Bio-Fuel.

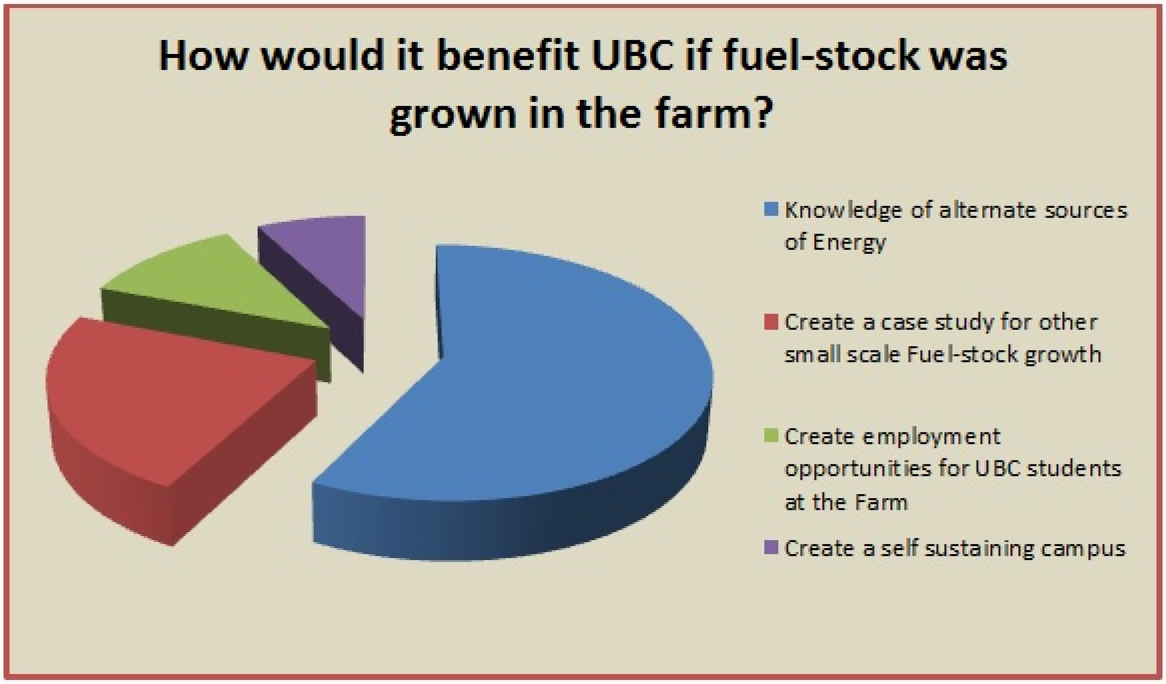


As seen in the graph, 72% of the focus group was not aware that Fuel-stock could be used to produce Bio-Fuel which is a source of Green Energy. This result shows that at the moment, our community members are not completely aware of the potential of Biofuel and/or that Biofuel is currently used on campus to produce electricity. This creates an opportunity to treat this project as an educational source for the UBC community.

6.2 Benefits

After the first question, the focus group was briefed about the role of Fuel Stock in the production of Bio-Fuel, the land available to be used and crop that we are proposing. Then, the group was asked the question of how it would benefit the UBC community socially with the introduction of this project at the UBC farm. The results are shown in a Pie chart below.

Figure 5: Survey results of the benefits expected from this project.



The survey results for this question does show the improvement in knowledge of the focus group on the topic of Fuel Stock and Biofuel. 78% of the focus group predicted similar benefits as our group did for this project. From our estimate of labour and energy production from this project, the last two options are not true. Since it is a small scale project, we are not expecting a great need of labour nor will the energy produced be sufficient to make the campus self sustainable. However, the first two options make a great point in terms of the social benefits we could expect from this project. They are discussed further in the rest of the social assessment.

6.3 Educational Opportunities

This project is a great source for educating not just our community about the growth of Fuel-stock for Biofuel production but is a gateway to creating a database for small scale and large farms around the world to access and learn from our experiences. Furthermore, it is great merger of the faculties around UBC who can be a stakeholder in this project and research various different parts of the project for further use.

6.3.1 Case study for small-scale and Large Farms

This project is small scale but this project could be used a case study for further large scale projects. At the moment fuel stock growth in farms is covered in a cloud of questions such as its effect on the growth of food crops, need of great financial investments and poor returns. By our estimates, this project does not require tremendous amount of investment if done on a large scale, has great potential for profit. In addition to that, this project all utilizes marginalized land at the UBC farm - Farm land that is not utilised by food crops or that is left uncultivated due to crop rotation, which means the project is contributing to the ecosystems and is also not disrupting the growth of food crops. This is a great incentive for small scale farms like ourselves to invest in fuel stock growth. By supporting this project, we are helping in creating a database of all these observations that can put an end to this confusion and contribute to educating people about the true potential of fuel stock.

6.3.2 Educate the UBC community on Alternative sources of Energy

As our planets natural resources are slowly being exhausted, our community should be familiar with the alternate sources for energy available for humankind to use. Since the future generations ability to meet their energy needs depends on our actions, it is very important that our community is aware that UBC is currently supporting and manufacturing alternate green sources of energy. This project can be used to spread the word to the community about the importance of researching and supporting green sources of energy.

6.3.3 Study subject for Poplar research at UBC

UBC has recently been involved with the Treenomix project which is Canadas first large scale Forestry Genome project. They have been researching greatly into mapping genes of Poplar and have had great breakthroughs. This project would help this team gain easy access to Poplar cultivation and help them further research Poplar to better its yield and make it the leading Fuel stock producing crop.

6.3.4 Stakeholders within UBC community

Since this project is so multidisciplinary, it invites stakeholders from a number of faculties at UBC to be a part of it. The table below lists a range of faculties and shows parts of the project that they could contribute to:

Table 3: Summary of the faculties at UBC who could be a stake holder for the project

Faculty	**Stake in the project**
Forestry	Research on Poplar and producing the high yielding variety suitable for fuel stock growth
Electrical Engineering	Research more efficient ways of producing Biofuels with the BRDF
Earth and Ocean Sciences	Show the positive effects of this project on the farm ecosystems for small scale farmers.
Business	Help increase the profit margin for the farmers as well as the BRDF.

6.4 Assessment

After analysing the Educational Opportunities that this project would create for UBC students and the community while guiding future small scale farm owners as well as large farm owners, it seems like a great project to pursue for the social benefits. We should note that since it is a very small scale project, no new labour will be created by this project nor will it make UBC self sustainable in terms of energy usage. However, the benefits outway the costs in this case and make this project very suitable for the UBC community and its sustainability promotions.

7 Conclusion

The observations and research conducted on this topic have directed the arguments to the following conclusions.

7.1 Economic Conclusions

The project does not seem viable from an economic point of view. It would require a mediocre startup cost but it would not be able to sustain itself since it generates low profits. Over the 20 year lifecycle, the project would generate about $710. If this project were to be implemented, government grants would have to be procured either through the university or through the state institutions. However, since it is a small scale project, economic viability is not the priority.

7.2 Environmental Conclusions

Since this is a small scale project, we do not expect a massive change in the GHG emissions or a dent in the use of conventional energy sources. However, it does contribute greatly to the farm ecosystems in terms of providing wind sheltering, increasing natural habitat and creating a buffer region between farmland and forest area. Furthermore, it provides a linear scale for bigger scale projects that could make a difference in the GHG emissions and promotion of green sources of energy. This project is Environmentally Viable.

7.3 Social Conclusions

This project creates a great social statement for UBC. It is a great educational opportunity for the students, research subject for faculties on campus, case study material for small scale and large scale projects around the world and a promotion for the use of alternate energy. This project would put UBC on the forum of university campuses pursuing sustainability and could be a study project for future generations. This small scale project could be the inspiration for farms around the world- both small and large to pursue fuel stock growth and clarify queries about disruption of food crops and high investment. On the whole, this project is definitely socially viable.

8 Recommendations

8.1 Land Recommendations

After visiting the farm and talking to the farm employees, the recommendations have been made towards using the head rows and the damp land available on the south boundary of the farm. These recommendations were made without disrupting field rotation cycles and food crops. These land parts are at the moment either uncultivated or cultivated with expendable small trees that could further help with producing some fuel stock when brought down. Thus this is the most efficient recommendation in terms of land availability for the project.

8.2 Crop Recommendations

The land availability and the research of different fuel stock crops point towards the use of Hybrid Poplar as a fit crop for the land. Our recommendations are using coppicing of emphHybrid Poplar as a cultivation method so as to get a long life cycle of 20 years without the use of fertilizers. They thrive in wet and damp conditions and provide the best results over a long period of time in terms of both profits and amount of fuel stock generated. Thus this seems as a perfect fit for the climate, land and eco-system.

8.3 Triple Bottom Line Recommendations

After reviewing the conclusions from Economic, Environmental and Social Assessments, we strongly urge UBC to pursue this project for its strong impact on the sustainability image on UBC and for its great benefits in creation of educational opportunities and impacting the eco-system of the UBC farm. We further recommend that if this project is approved, that the Farm apply for grants through the University or the provincial government institutions. Since we are an educational institution, it would only be apt to opt for a highly enriching educational project that benefits both its students and the community.

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