The role of Biofuels in the Environment, Economy and Society

A look at positive and potential negative impacts of biofuel production

Steffy Howard

April 10, 2012

THE UNIVERSITY OF BRITISH COLUMBIA

Forest Resources Management

Contents

Abstract

This paper examines the often under reported and overlooked downsides of biofuel production in the environmental, economic and social sectors. Environmentally speaking, biofuels utilize renewable resources, reduce carbon monoxide emissions from cars and provide alternate forms of energy. However, the positive environmental aspects of biofuels may not counteract the negative impacts. The potential environmental downsides of biofuel production include: loss of forests and biodiversity, food security issues and implications on climate change. Economic wise, biofuels increase exports for productive countries, increase demand for biofuel crops, and increase employment rates. Furthermore, utilizing biofuels provides more affordable vehicles, and contributes to technological growth and sustainability. However, the economic benefits provided by biofuel production may not outweigh the potential downfalls. Biofuels are expensive to produce and cause increased economic losses due to loss of timber and premature cutting. In addition, biofuel plants are often owned by foreign companies who take advantage of prime biofuel productive land in underdeveloped countries. As a result, wealth is rarely distributed fairly between the investor and the local economy. Foreign investment can often lead to clashing incentives for the country and the investor. Other economic issues include: increases in food prices, and food subsidies causing price inelasticity, market instability, and inflation. The social impacts of biofuel production can be beneficial and include: employment opportunities, increased worker skills and increased worker efficiency. However, these social benefits are only ascertained if foreign companies keep biofuel production plants small and within the country. In addition, there are a lack of regulatory guidelines and policies to enforce workers' rights. Social controversies exist where some reports have claimed that foreign companies treat biofuel workers unfairly. The absence of workers' unions, along with minimal workers' rights, harsh working conditions, lack of land rights and displaced farmers provide evidentiary credibility to this claim. Foreign companies tend to hire short-term, highly skilled laborers instead of providing training and opportunities to local workers. Finally, the controversial use of food crops for biofuel and the potential for rising food prices may provide a substantial reason to slow biofuel expansion. Solutions and recommendations are presented in which an alternative shrub (Jatropha) and evergreen tree (Pongamia) can be used as a non-edible alternative to biofuel food crops. Their abilities to withstand drought and marginal lands is also promising, although has limitations in crop production. In addition, burning wood residues like sawdust and wood pellets from deforestation can contribute substantially to heating and electricity. However, there are concerns regarding the carbon offset capabilities, technological capacity and fiscal feasibility of burning wood waste rather than manufacturing wood products. Cellulosic and lignocelluosic ethanol production along with algal oil is also discussed, and may be the future of biofuel production.

Keywords: Controversy, Rising Food Prices, Cellulosic Ethanol, Biodiesel, Jatropha, Pongamia, Lignocellulosic Ethanol, Algal Oil

Introduction

Biofuels are a topical subject in current affairs. Forms of renewable "bio" based products are, for the most part, considered positively in today's world. Words like biomass, biodiesel and bioethanol all paint a certain image in one's mind of environmental friendliness, climate awareness and renewable forms of energy. Indeed, biofuels do use renewable forms of energy and may be considered beneficial for the environment, the economy and society. The question is; to what extent do biofuels benefit the environment, the economy and society? This paper explores this question and critically examines the often overlooked and seemingly unreported potential downsides of biofuels.

The definition of biofuel is "fuel produced from renewable resources, especially plant biomass, vegetable oils, and treated municipal and industrial wastes*". Biodiesel uses vegetable oils and fats as an additive to diesel fuel, and bioethanol is produced by fermenting sugars in substances such as corn (Antanasov, et. al, 2007). Nothing seems harmful about these bioproducts and all seem favorable towards the environment, economic and social sectors. However, these definitions fail to demonstrate or explain the negative impacts associated with biofuels. The negative impacts of biofuels include deforestation and increases in agricultural prices, to name a few. Interestingly, the negative impacts are often overlooked and unnoticed because people assume that energy and fuel derived from plants and renewable resources is good for the environment. I am skeptical of this notion. Both positive and negative aspects of biofuels should be examined and presented to the public. Therefore, first, this paper will provide background information on the history of biofuels. Then, this paper will discuss both the positive and negative aspects of biofuels in relation to the environment, the economy and society. It is my ultimate intention to evoke significant critical thought towards massive biofuel production.

Background

Biofuels have been around since the early 1900's, at least as long as cars have (Purcell, 2011). In fact, the first car to run on only peanut oil was driven by Rudolph Diesel "at the Paris World's Fair in 1900" (Purcell, 2011). Biofuels simply have not been used much because the traditional use of fossil fuels to create diesel and gas are less expensive to extract and produce. However, with oil prices constantly on the rise, biofuels are beginning to play a more leading role in alternative forms of fuel energy. Biofuels are also attractive because they are produced from a renewable resource such as plant biomass and agricultural crops, and therefore pose no threat of running out. Growing concern of global warming has also sped up the popularity of biofuels (National Geographic, 2011) as people search for more environmentally friendly forms of energy. Many countries have been using biofuels for a long time (National Geographic, 2011). The U.S. uses gasoline mixed with ethanol which is a form of biofuel to power their cars (National Geogrpahic, 2011). Brazil is a mass producer of sugarcane which is made to produce ethanol (National Geographic, 2011). Indonesia produces palm oil which is used to produce ethanol, biodiesel and biofuels (National Geographic, 2011). Making biofuels often involves the heating and fermenting of starches and sugars from edible crops such as corn and sugarcane (National Geographic, 2011). The left over products are refined and used to produce fuel used in cars (National Geographic, 2011). A common mixture of biofuel in fuelling cars is known as B20 (Government of Alberta), where 20% of the fuel is biodiesel and 80% is petroleum based diesel. The first gas station offering B20 in Canada is in Unionville, Ontario and opened in 2004 (Government of Alberta). It should be noted however, that "currently, biofuels contribute close to 1% of the world's energy use in transport" (Keyzer et. al, 11, 2008). This proves that the use of fossil fuels to make oil and gasoline still far outweigh the biofuel sector. Nevertheless, rising oil prices and limited fossil fuels constantly put pressure on the biofuel sector to expand into new ways of using energy. The increasing pressure on the biofuel sector to expand may compromise its sustainability in the environmental, economic and social sectors. Thus, the following section describes current views on biofuels' role in the environment.

Biofuels and the Environment

First, biofuels are environmentally beneficial because they utilize renewable resources such as sugarcane and corn. In contrast, fossil fuels are a non-renewable resource and reserves are uncertain. However, the notion of using food crops like sugarcane and corn for biofuel production remains controversial. Some leaders in the European Union have raised concerns about using food crops to make biofuel products, which may lead to food security issues (Sachs, 2007). These issues are addressed under the European Union's climate change and energy package which requires the European Commission to "compile a report reviewing the impact of indirect land-use change on greenhouse gas emissions and to seek ways to minimise its impact"

(Sachs, 2007). According to a Food and Agriculture Organization report regarding food security, enough land could be available to accommodate both food crops and biofuel production (Sachs, 2007). The organization suggests five ways "to reduce the competition for scarce agricultural land between biofuels and food crops" (Sachs, 13, 2007). Some of these suggestions include:

- Concentrating biomass production used to make biofuels on wasted, degraded and deforested landscapes allowing the best productive land to be left for agricultural crops (Sachs, 13, 2007),
- Promoting a rapid shift to "cellulosic biofuels, produced from non-edible parts of food crops, forest residues, wild grasses, tree crops, animal fat and all types of green residues" (Sachs, 13, 2007), and
- Researching and improving oil plants and biofuel crops (Sachs, 13, 2007).

Wasted and deforested landscapes mean low site productivities, poor nutrient soils and regimes, and slow growing times (Rapier, 2011). As such, concentrating biomass production on these types of landscapes would result in poor, slow growth of biofuel crops, hindering their chance of successful production. Therefore, although using deforested and degraded landscapes for biofuel crops is a good idea, putting the notion to practice may not be feasible. Promoting cellulosic biofuels may be the key to more successful biofuel implementation; however it has production and affordability limits (Rapier, 2010). Cellulosic biofuel is discussed later in this paper.

The food controversy does not end there. Rossi and Yianna argue that "highly productive land is being used more and more for biofuel production leaving lower productivity land for subsistence farming" (15, 2008). In other words, food shortages are occurring where biofuel production is high due to the loss of farmland for agricultural crops. While the European Union "aims to get a tenth of its road fuels from renewable resources by the end of the decade", it has been met with significant criticism and opposition. Biofuels force food prices up and may do more harm to climate change than good (Keyzer et. al, 2008). For example, U.S. farmers have been offered incentives to shift from growing soy to growing corn for biofuels (Jha, 2008). This shift drives "up global soy prices, which in turn amplifies economic incentives to destroy Amazonian forests and Brazilian tropical savannas for soy production" (Jha, 2008). In Tanzania, more than 40 foreign companies have invested in large tracts of land for biofuel production, mainly along the coast (ActionAid, 2009). This coastal area known as Rufiji basin, "is one of the potential areas for the production of food crops in the country, with 60 percent of the land suitable for irrigation" (ActionAid, 14, 2009). Research has shown that Rufiji basin alone can provide enough food for Tanzania and the rest of Africa (ActionAid, 2009). Nevertheless, wealthy investors have purchased thousands of hectares of this prime land and have converted it to biofuel productive land (ActionAid, 2009). With a decreasing amount of productive land for farming, local people may become further deprived.

In addition, the production of biofuels may not only have implications on food shortages, but may also contribute to long-term water shortages. According to Rossi and Yianna, large quantities of water are needed to irrigate biofuel crops (2008), which may put additional pressure on human sustenance. For example, sugarcane is known for its "enormous water requirements" (Rossi & Yianna, 2008), yet deforestation has been occurring worldwide to make way for sugarcane growth for biofuel production (Keyzer et. al, 6, 2008). Massive sugarcane production may not need to occur when viable alternatives exist. For example, Jatropha is a drought resistant tropical shrub that grows in Africa and is suitable for biofuel production (Rossi & Yianna, 2008). The use of Jatropha is discussed later in this paper. In addition, land clearing and deforestation significantly contribute to erosion and water run-off, further contributing to water scarcity. Interestingly, the European Union's "target of 10% of transport fuel [to come] from biofuel would already take some 15% of its total arable land" (Keyzer et. al, 7, 2008). Thus, the implications biofuel production has on forests, biodiversity, food and water may already be seen to reduce the quality of life for local people and forests.

Second, biofuels are thought to emit fewer greenhouse gases than traditional fossil fuel. A study in Sweden on biofuel emissions performed by Börjesson reported that "biofuels produce up to 140 percent less greenhouse gas emissions than conventional fuels" (Jalbuena, 2010). Furthermore, "in a study of 26 biofuels, the Swiss method showed that 21 fuels reduced greenhouse-gas emissions by more than 30% compared with gasoline when burned" (Jha, 2008). However, "almost half of the biofuels, a total of 12, had greater total environmental impacts than fossil fuels" (Jha, 2008). Interestingly, the biofuels that had the greatest reductions in emissions were ones that were "produced from waste products such as recycled cooking oil, as well as ethanol from grass or wood" (Jha, 2008). Jha argues that reduced emissions do not outweigh the negative impacts biofuel production has on biodiversity loss (2008). Generating biofuels is an extremely demanding task regarding the need for biomass crops such as palm oil, sugar cane and corn (Jha, 2008). As a result, forests must undergo massive deforestation in order to make way for the crops to grow (Jha, 2008). In that sense, greenhouse gas reductions from biofuels may be negated by the carbon emissions of forest removal. Furthermore, biofuel crops also require nitrogen fertilizers which cause "increased emissions of $N0_2$; a greenhouse gas many times stronger in effect than $C0_2$" (Keyzer et. al, 2, 2008).

Biofuels however, should not be dismissed as an idea for alternative energy. As previously mentioned, the burning of biofuels reduces greenhouse gas emissions compared to fossil fuels. For example, using biofuels in cars reduces carbon monoxide emissions and is a better lubricant for car engines, allowing them to run longer (ClimateAvenue, 2011). Ethanol is an excellent substitute for gasoline, helping to reduce the amount of greenhouse gases emitted into the atmosphere by cars (ClimateAvenue, 2011). The issue however, lies in the amount of fossil fuel resources needed to produce biofuels, which may outweigh any greenhouse gas emission reductions (Laney, 14, 2006). For example, European Union leaders have recently made agreements and set targets for biofuel implementation ("Biofuels, trade and sustainability", 2008). In 2008, an agreement was made "on a new Renewable Energy Directive, which requires each member state to satisfy 10% of its transport fuel needs from renewable sources, including biofuels, hydrogen and green electricity, by 2020" ("Biofuels, trade and sustainability", 2008). Sustainability criteria was also established which "obliges the bloc to ensure that biofuels offer at least 35% carbon emission savings compared to fossil fuels" with that number climbing as high as 60% by 2018 ("Biofuels, trade and sustainability", 2008). Although these targets may be feasible, the European Union failed to mention the issues associated with biofuel production (deforestation, food and water shortages, and significant fossil fuel input), as outlined above. The key to successful biofuel implementation is to determine how to produce biofuels in a sustainable manner so that everyone wins.

In all, biofuels can be beneficial. Biofuels come from a renewable resource, use less greenhouse gases when burned (Jalbuena, 2010), improve vehicle longevity (ClimateAvenue, 2011), and provide an alternative energy source. However, it is important to consider the bigger picture. Producing biofuel crops requires a tremendous input of fossil fuels (Laney, 14, 2006). Furthermore, biofuel production contributes to large scale deforestation and is a controversial issue regarding food and water security (Rossi & Yianna, 2008). The use of biofuels could be extremely beneficial to the world, so long as production is sustainable. The following section will address the economic viability of biofuel production and the controversial issues surrounding it.

Biofuels and the Economy

The production of biofuels does create opportunities for countries to increase their exports which contribute to their economy in a positive manner (Rossi & Yianna, 2008). Since biofuels are increasing in demand worldwide, countries that mass produce biofuel crops such as Indonesia, Malaysia and Brazil may stand to benefit from large profits (Rossi & Yianna, 2008). Furthermore, people who sell their own crops for biofuel production may also benefit from the increased demand. However, as mentioned before, there are controversies over selling a food crop for biofuel production as opposed to selling it for food. Another factor that could be seen as a positive attribute for economies is affordability. The rising costs of fossil fuels and petroleum based products have begun to force poorer countries to consider more affordable alternatives (ActionAid, 2009). For example, in Tanzania the "country's spending on petroleum accounts for 25% of its foreign earnings" (ActionAid, 2009) with the transport sector consuming approximately 40% of the imported petroleum products (ActionAid, 2009). Biofuel promotion could reduce significant economic costs through the implementation of more fuel efficient vehicles. For example, a vehicle containing biodiesel still contains 80% petroleum fuel to 20% biodiesel (U.S. Department of Energy, 2012). If the cost of fossil fuels continues to increase, so will the cost of mixed gasoline with biodiesel. Needless to say, biodiesel mixed with petroleum is still less expensive than straight petroleum fuel.

Rising fossil fuel prices may also contribute to expensive biofuel production. Significant production of biofuels requires a significant input of fossil fuels (Keyzer et. al, 2008). Clearing land for biofuel production as well as the biofuel refining process requires significant fossil fuel input, making biofuel production plants less feasible (Keyzer et. al, 2008). In the short-term, rising fossil fuel costs may outweigh the benefits of biodiesel in cars. Furthermore, because biofuel production is not always profitable, it relies on subsidies and has minimum fuel blending requirements (Keyzer, et al, 2008). Keyzer argues that these subsidies and blending requirements “make biofuel demand highly price inelastic contributing to price instability on food markets, to increasing malnutrition, and to inflation” (2008).

On the other hand, promoting the use of biofuels may also create employment, diversify the rural economy, create markets for agricultural energy crops, and contribute to technological growth (ActionAid, 2009). As long as profit and wealth obtained from biofuel production is redistributed back into the country’s economy and people’s standard of living improves, then biofuel production is economically justifiable. However, there are often no incentives for foreign companies and investors to keep their money within the country (ActionAid, 2009). Consequently, at least in Tanzania’s case, biofuel plant investments and profits remain with wealthy foreign companies, while the actual country may see little to no economic improvement or wealth (ActionAid, 2009). If government policies were created to build incentives for foreign investors to redistribute wealth into the local economy, biofuel production could be sustainable.

Finally, some argue that biofuel production raises the price of food, and many people are uncomfortable with the concept of “using food like sugar cane and maize to fuel cars” (Brunner, 2011). Millions of people in the world are starving. Consequently, the allocation of food to biofuel production is extremely controversial, particularly in poorer countries. Rossi and Yianna claim there has been an “increase in the price of fodder (due to the growing use of agricultural commodities for biofuels production”) (15, 2008). As the price of food rises, the economy could become more unstable. In the United States, maize prices are rising as corn is being distributed to the biofuel sector instead of the agricultural sector (Sauser, 2007). The biggest influence on rising corn prices is actually seen in Mexico, where the price of tortillas doubled in a year (Sauser, 2007). Furthermore, “an estimate by Rosegrant (2008) from the International Food Policy Research Institute demonstrated that the increased biofuel demand during 2000-2007 has accounted for 39 percent of the increase in real prices in maize, 21 percent of the increase in rice prices and 22 percent of the rise in wheat prices” (Brunner, 2011). Unaffordable food prices may push struggling people further into poverty and increase levels of starvation.

However, the Food and Agricultural Organization argues that high food prices may also be “an opportunity in the long-run” (Hafez, 2008). The Organization argues that high food prices may present agricultural opportunities for smallholder farmers (Hafez, 2008). These opportunities could “fuel broader economic and rural development” where farming households may see “immediate gains” (Hafez, 2008). Furthermore, Hafez says that “other rural households may benefit in the longer run if higher prices turn opportunities for increasing output and creating employment” (2008).

In all, biofuel production could have a positive impact on countries’ economies. These impacts include: a fair domestic distribution of wealth, affordable alternatives to fossil fuels, job and market creation, and rural economic and technological growth (ActionAid, 2009). Although there are potentially positive long term impacts, the short-term trends are volatile. Rising fossil fuel prices along with rising food prices may cause market instability, malnutrition and inflation (Keyzer, et al, 2008). Furthermore, a lack of structural frameworks and policies for proper wealth distribution keeps money in the hands of the rich at the expense of the poor. The concept of poor wealth distribution touches on the social aspects biofuel implementation and is expanded on in the following section.

Biofuels and Society

As the biofuel industry expands with increasing demand there will be a greater need for people to work crops and plantations. Therefore, one positive social implication of increasing biofuel production is the creation of jobs and opportunities in poorer countries (Rossi & Yianna, 13, 2008). For example, currently “63,000 families of small farmers are involved in the production of vegetable oils for biodiesel: this number is expected to increase to 210,000 in the next year” (Sachs, 5, 2007). Furthermore, if biofuel production plantations remain in the hands of small stakeholder farmers, rather than larger investment firms, employment opportunities and creation are enhanced. For example, the palm oil industry in Indonesia and Malaysia “employs anywhere from 0.08 to 0.5 people per hectare, with higher employment rates associated with smallholder-based production” (German et. al, 2011). Smaller companies create more employment opportunities because they still require workers to perform manual labor, whereas larger companies can afford heavy machinery (German et. al, 2011). Machinery is more efficient and productive than human workers. As a result, workers often lose their jobs to mechanization (ActionAid, 2009). For example, “a sugarcane harvester (machine) can replace up to eighty cutters [workers] in [the] sugarcane industry” (ActionAid, 2009). In Brazil, although “sugarcane and ethanol production have generated significant direct employment, the number of workers employed in sugarcane production has decreased by 62% as a result of mechanization” (German et. al, 2011). In the soy sector, mechanized cultivation has reduced the number of workers to an average of only 0.05 to 0.06 jobs per hectare (German et.al, 2011). As an investors' biofuel production plant grows, a shift towards mechanized technology is predictable. The shift towards mechanization could also be viewed as a positive. The equipment used to cut sugarcane manually is a massive machete, and losing a limb is not unheard of. By shifting towards mechanized equipment, the job may become less dangerous for laborers.

As mentioned earlier, there is a lack of government policies providing incentives for foreign companies to redistribute wealth domestically. Corporate power regarding land development is raising some moral issues. In one study "palm oil companies in Indonesia seize land that many people rely on for development. Because the people don't have any formal rights to the land, palm oil companies can get away with it. That being said, it has created serious conflict among communities and companies" (Brunner, 2011). In addition, "labor rights are basically ignored by big companies. Death of people working in sugar cane plantations has been reported due to simple exhaustion. People cannot make a living and are often exposed to serious health hazards. Unions are so weak there that the government rarely listens" (Brunner, 2011). In conjunction with a lack of labor rights and poor health and safety standards, many small farmers growing food for agricultural purposes are being displaced by large companies for biofuel production (ActionAid, 2009). The displacement causes a significant amount of social upheaval and distress, which is perpetuated by biodiversity loss, "landlessness and deprivation" (ActionAid, 2009). For example, in the Kilwa Districts of Tanzania, tens of thousands of hectares "are being given to foreign investors or are in the process of being given to foreign investors" (ActionAid, 2009) for biofuel production. In the process, hundreds of local people and villagers are displaced "with minimum compensation for the loss of land and other properties" (ActionAid, 40, 2009). If small scale farmers do become employed by biofuel investors, they are certainly not producing crops for food. Not producing food crops may further exacerbate food security problems and contribute to rising food prices. Ironically, the sale of biofuel products "and/or salary earned from working in the biofuel companies is not adequate to cover the cost of buying food" (AcitonAid, 75, 2009). Moreover, short-term employment creation may have its downsides. In a report by the World Bank, "companies exhibit a bias toward workers with backgrounds in sedentary agriculture in their hiring practices, and in the process deprive indigenous communities of potential benefits" (German et. al, 2011). Although this may be true, it should be noted that unskilled workers are less productive. While companies may exhibit a bias towards a certain worker skill set, they are still creating jobs. Unfortunately, unskilled workers may only be hired as temporary employees (German et. al, 2011). If incentives existed for smaller companies to provide permanent jobs to indigenous people, a stronger and more skilled labor force would eventually emerge and exhibit long-term employee and production benefits. Training programs could be initiated to improve the production of unskilled workers and contribute to their long-term employment. A larger sector of skilled workers may also complement the increased use of heavy machinery. The newly skilled workforce could operate, maintain and control machine logistics, preserving employment following mechanization. A win-win situation for both the company and the employees could be created. For example, the companies' costs stay lower and their reputation better while local people become more skilled and employed over the long-term, helping to alleviate poverty issues.

A final social issue related to biofuels is land rights. It is argued that many small scale farmers are being displaced for biofuel production. In Indonesia, "630 land disputes [occurred] between palm oil companies and local communities" (German et. al, 2011), on top of which 3,500 disputes identified by the national land bureau existed within the country (German et. al, 2011). The main issues derived from these disputes were land compensation, lack of clear land rights, lack of transparency, lack of consent and unequal profit sharing agreements (German et. al, 2011). It has been reported that some people are even removed from their land violently; "involving acts such as murder or massacres, threats, kidnapping and torture. Their lands are seized and some of those are now planted with oil palm" (Brunner, 2011). If proper policies and regulatory frameworks existed whereupon fair agreements could be made between companies and local workers, the biofuel industry would become a more attractive initiative. Instead, the biofuel industry may be currently only attractive to self-interested foreign companies because of its increased demand worldwide and potential profitable outcomes. Governments need to establish criteria for workers and companies to ensure long-term employment while simultaneously ensuring the sustainability of land and food. To achieve such criteria, the government should establish guidelines and policies prohibiting the expansion of foreign biofuel production within a country unless the established criteria are met.

In all, biofuels could be beneficial toward society through job creation, worker skill set improvement (Rossi & Yianna, 2008) and the use of mechanized equipment. However, policies may need to be established to improve working conditions (Brunner, 2011), workers rights, and land rights (German et. al, 2011). Furthermore, companies should consider wealth redistribution and investing in employees for the long-term, potentially benefiting both the workers and the company.

Now that potential issues in the environmental, economic and social sectors have been addressed, the following section will provide prospective solutions and recommendations for implementing the use of biofuels in a sustainable manner.

Solutions and Recommendations

There are other types of plants that can be used for biofuel production including Jatropha and Pongamia. These plants are non-edible and also use less water (Rossi and Yianna, 2008). Along with being drought resistant, Jatropha also “produces seeds with an oil content of 37%” ("About jatropha plant," 2011) which is extracted for biodiesel. It is thought that the seeds from Jatropha shrubs after oil extraction can also contribute to energy production ("What is jatropha?," 2008). Unfortunately, Jatropha does have a few downsides. Since Jatropha is able to grow on marginal, dry lands, if planted there, it may only produce marginal crops (Endelevu Energy, 2009). As a result, some people argue that Jatropha should therefore be grown on more fertile lands, which simply returns to the issue of using up valuable agricultural crop space for biofuel crops. Contrarily, Rossi and Yianna argue that since Jatropha is a non-edible crop, then using Jatropha would alleviate the controversy over using food sources for biofuel production. However, they also note that Jatropha and Pongamia “take a long time to mature and their marketing and cultivation remain uncertain” (27, 2008).

Pongamia is an evergreen tree and belongs to the Papilionaceace family (Wani & Sreedevi). It can also tolerate drought conditions, marginal lands and is abundantly grown in India (Wani & Sreedevi). It is very similar to Jatropha with seed oil production and energy uses almost identical.

Another possibility to improving biofuel production and reducing the use of agricultural crops is to break down lignin and cellulose into useable biofuel (“Cellulosic ethanol”, 2009). Currently, only cellulose is broken down. Making cellulosic ethanol is one current trend that is in use today. Rather than being produced from edible starches such as sugarcane and corn, cellulosic ethanol is produced from agricultural residues like straw and corn stover, lignocellulosic materials like woodchips, and energy crops like switchgrass (“Celluosic ethanol”, 2009). Therefore, creating cellulosic ethanol is more sustainable, reduces greenhouse gas emissions and uses non-edible renewable crops. Furthermore, Bullis argues that “an acre of grasses or other crops grown specifically to make [cellulosic] ethanol could produce more than two times the number of gallons of ethanol as an acre of corn, in part because the whole plant can be used instead of just the grain” (2007). Even some grasses used in cellulosic ethanol production only require marginal lands to grow, “which means land that isn’t in competition with food crops” (“The Promise and the Problems of Ethanol”, 2012). Thus, implementing the use of cellulosic ethanol is beneficial because of its sustainability of renewable non-edible crops, its greenhouse gas reduction abilities, its efficiency to use whole parts of plants, and its usage of marginal lands. The downside however, is that cellulosic ethanol production has many more refining and processing steps, adding to time, cost and feasibility (Rapier, 2010). More complex refining processes is one of the main reasons cellulosic ethanol is not more widely used today (Rapier, 2010). Furthermore, cellulosic ethanol is not yet commercially available due to a lack of manufacturing facilities, “although some manufacturing facilities are being built” (“The Promise and the Problems of Ethanol”, 2012). Promoting the use of cellulosic biofuels is one of the best suggestions to solving food security issues; however, the shift is extremely slow due to a lack of funding, research and knowledge (Rapier, 2010). Rapier also argues that the technology of cellulosic ethanol cannot be mandated (2010). In other words, he argues that it is unrealistic to set a target for cellulosic ethanol implementation as so many variables and complexities exist for its feasibility. Using cellulose to create biofuels is a difficult process that is not fully understood.

Lignin makes up a large proportion of plants and studies are being done on lignocellulosic ethanol, but it remains difficult and expensive. BC Hydro, however, has made recent claims towards promoting and using wood mill residues as “clean, carbon-neutral electricity” (Parfitt, 2010). In fact, wood residues like wood pellets are a form of renewable, non-edible resource that can be used to generate heat and electricity when burned (Parfitt, 2010). With proper wood burning facilities, the amount of homes that can be heated is substantial. For example, in Williams Lake, B.C., roughly 2,000 tons of sawdust and woodchips are produced at the local mill (Parfitt, 2010). When these residues are burned, the intense heat spins electrical turbines "producing enough electricity to power about 52,800 households" (Parfitt, 2010). When deforestation occurs, due to the creation of biofuel production plants in other parts of the world, considering alternative uses for the wood residue on and off the deforested landscape would be beneficial. There are still criticisms today claiming that more feasible, lower cost and "clean burning technologies" exist for heating and electricity (Parfitt, 2010). Burning wood residues has high carbon offsets as opposed to manufacturing wood products. However, if implemented in a sustainable manner, burning residues is still a viable option for producing energy.

Finally, one prospective idea for biofuel production has to do with algae. Interestingly, algal oil can be extracted for biodiesel (Wagner, 2007). The extraction of oil from algae is not difficult. The challenge is "finding an algal strain with a high lipid content and fast growth rate that isn't too difficult to harvest" (Wagner, 2007). Producing algal crops has many advantages including: rapid growth-rates, high yields, bio-degradability, and its ability to consume $C0_2$ (Wagner, 2007). For example, the yield of algal oil per unit area "is estimated to be between 18,927 [and] 75,708 litres per acre, per year" (Wagner, 2007). This turns out to be "7 to 31 times greater than the next best crop: palm oil (2,404 litres)" (Wagner, 2007). Algae are also advantageous because they are non-edible and "require neither farmland nor fresh water" to grow (Wagner, 2007). Unfortunately, algae also have several disadvantages. These include: regulated sunlight and temperature requirements, wasted oxygen that "must be continually removed from the water", and difficulties growing the desired strain (Wagner, 2007). Creating the optimal environment for algae is costly and is one of the reasons algae use is not implemented more widely ("Better than corn?", 2011). A lack of "large scale commercial production of algae fuel" ("Better than corn?", 2011) exists today; however, expectations remain high for the future.

Overall, there are several alternatives to using renewable food crops for biofuel production. These include: the use of Jatropha and Pongamia shrubs which are non edible and can withstand dry, marginal lands (Rossi and Yianna, 2008), implementing the use of cellulosic ethanol ("Celluosic ethanol", 2009), implementing the use of lignocellulosic ethanol by considering wood residue alternatives for heating and electricity (Parfitt, 2010), and using algal oil for biodiesel (Wagner, 2007).

Concluding Remarks

Biofuels produced from food crops have significant environmental, economic and social consequences. Before wide scale implementation of biofuels occurs, serious consideration must be given to these consequences. There are a number of potential alternatives which may have more desirable outcomes, and exploring these alternatives could offer a more promising future for biofuels.

References

“About jatropha plant”. (2011). Retrieved from <http://www.jatrophabiodiesel.org/aboutJatrophaPlant.php>.

ActionAid. (2009). *Implication of biofuels on food security in tanzania*. Dar es Salaam: ActionAid Tanzania. Retrieved from <http://www.actionaid.org/sites/files/actionaid/implications_of_biofuels_in_tanzania.pdf>.

Atanasov, Roman, Eric Vyskocil, and Matthew Williams. (2007). "Ethanol Fuels." *Alternative Fuel Technologies*. N.p. <http://web2.uwindsor.ca/courses/physics/high_schools/2007/AlternateFuels/ethanolprod.html>.

“Better than corn?”*Algae set to beat out other biofuel feedstocks*. Worldwatch Institute. (2011). Retrieved from <http://www.worldwatch.org/node/5391>.

“Biofuels, trade and sustainability.” (2008, April 28). Retrieved from <http://www.euractiv.com/trade/biofuels-trade-sustainability/article-171834>.

“Biofuel Feed Stocks and Environmental Impacts."*ClimateAvenue*. (26 03 2011). N.p., <http://climateavenue.com/en.biofuel.index.htm>.

“Biodiesel: Background and Information.” Government of Alberta. *Transportation*. Alberta, Web. <http://www.transportation.alberta.ca/Content/docType57/Production/Biodiesel-Background.pdf>.

"Biofuels."*National Geographic*. National Geographic Society, (2011). <http://environment.nationalgeographic.com/environment/global-warming/biofuel-profile/>.

Brunner, Ariel. (2011). "Social Impacts of Current Biofuels." *BirdLife International*. Quinn Interactive. <http://www.birdlife.org/eu/EU_policy/Biofuels/eu_biofuels2b.html>.

Bullis, K. (2007, February 26). “Will cellulosic ethanol take off?” Retrieved from <http://www.technologyreview.com/energy/18227/>.

“Celluosic ethanol, trade and sustainability.” (2009, Updated March 5, 2012). Retrieved from <http://www.biofuelstp.eu/cell_ethanol.html>.

Endelevu Energy. (2009 December). “Jatropha Reality Check”. <http://www.worldagroforestry.org/downloads/publications/PDFs/B16599.PDF>.

German, L., Schoneveld, G. C., & Pacheco, P. (2011). The social and environmental impacts of biofuel feedstock cultivation: evidence from multi-site research in the forest frontier. *Ecology and society*, *16*(3), 24. Retrieved from <www.ecologyandsociety.org/vol16/iss3/art24/ES-2011-4309.pdf>.

Hafez, G. (2008). *The state of food insecurity in the world*. Rome: Food and Agriculture Organization of the United Nations. DOI: <ftp://ftp.fao.org/docrep/fao/011/i0291e/i0291e00.pdf>.

Jalbuena, K. R. (2010). Swedish biofuels emit less greenhouse gases than fossil fuels . *EcoSeed*, Retrieved from <http://www.ecoseed.org/bioenergy-blog/article/9-bioenergy/8126-swedish-biofuels-emit-less-greenhouse-gases-than-fossil-fuels>.

Jha, A. (2008, January 04). *Burning biofuels may be worse than coal and oil, say experts*. Retrieved from <http://www.guardian.co.uk/science/2008/jan/04/sciencenews.biofuels>.

Keyzer, M. A., Merbis, M. D., & Voortman, R. L. (2008). *The biofuel controversy*. Centre for Wood Studies, Stichting Onderzoek Wereldvoedselvoorziening van de Vrije Universiteit, Netherlands. Retrieved from <http://www.sow.vu.nl/WP's/wp08.01.pdf>.

Laney, K. (2006). *Biofuels: promises and constraints*. Washington: International Food & Agricultural Trade Policy Council. Retrieved from <http://www.agritrade.org/Publications/DiscussionPapers/IPC_Biofuels_Promises and Constraints.pdf >.

Parfitt, B. (2010). *Managing b.c.'s forests for a cooler planet: carbon storage, sustainable jobs and conservation*. (University of British Columbia) Retrieved from <http://www.policyalternatives.ca/sites/default/files/uploads/publications/reports/docs/ccpa_bc_ managingforests.pdf>.

Purcell, A. (2011, June 06). “Biofuels-climate hit or climate hype?” *ClimateAction*. Retrieved from<http://www.climateactionprogramme.org/carbon_reduction/biofuels_climate_hit_or_climate_hype/>.

Rapier, R. (2011, January 20). *Marginal land produces marginal biomass*. Retrieved from <http://www.consumerenergyreport.com/2011/01/20/marginal-land-produces-marginal-biomass/>.

Rapier, R. (2010, December 08). *Cellulosic ethanol reality begins to set in*. Retrieved from <http://www.energybulletin.net/stories/2010-12-08/cellulosic-ethanol-reality-begins-set>.

Rossi, A., & Yianna, L. (2008). Gender and equity issues in liquid biofuels production- minimizing the risks to maximize the opportunities. *Food and Agriculture Organization of the United Nations* , 13,15,27. Retrieved from <ftp://ftp.fao.org/docrep/fao/010/ai503e/ai503e00.pdf>.

Sachs, I. (2007). *United nations conference on trade and development: the biofuels controversy*. Retrieved from <http://www.unctad.org/en/docs/ditcted200712_en.pdf>.

Sauser, B. (2007). *Ethanol demand threatens food prices*. Massachusetts Institute of Technology. Retrieved from < http://www.technologyreview.com/energy/18173/>.

"The promise and the problems of ethanol." (2012). Retrieved from <http://www.dummies.com/how-to/content/the-promise-and-the-problems-of-ethanol.html>.

U.S. Department of Energy. (2012, March 29). *Alternative & advanced fuels*. Retrieved from <http://www.afdc.energy.gov/afdc/fuels/biodiesel_blends.html>.

Wagner, L. (2007). *Biodiesel from algae oil*. Mora Associates Ltd. Retrieved from <http://www.fao.org/uploads/media/0707_Wagner_-_Biodiesel_from_algae_oil.pdf>.

Wani, S. P., & Sreedevi, T. K. (n.d.). *Pongamia's journey from forest to micro-enterprise for improving livelihoods*. International Crops Research Institute for the Semi-Arid Tropics. Retrieved from <http://www.icrisat.org/Biopower/Wani_Sreedevi_Pongamiajourney.pdf>.

"What is jatropha?" (2008). <Retrieved from <http://www.jatropha-seeds.biz/>.

*Definition from <http://dictionary.reference.com/browse/biofuel>.