Jatropha as Biofuel: An Analysis of the Possible Implications for Food Security in Mali

Honours Thesis
Lara Green

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Abstract

Biofuels feature prominently in global climate change and energy security strategies. However, while concerns about climate change and energy security persist, the positive perception of biofuels has weakened in recent years, largely in response to their effects on food security. It is in the midst of such criticisms that jatropha is rapidly gaining momentum as a biofuel feedstock. Jatropha biofuel is said to avoid negative repercussions on food security because: 1) it will not compete with food crops and 2) it will contribute to rural development. These two claims imply that jatropha will not only avoid negative effects on food security, it will also enhance food security through rural development. This relationship between jatropha biofuel and food security has not been sufficiently explored. This study sought to address this critical gap by conducting a study on the possible food security implications of jatropha biofuel in Mali.

The two aforementioned claims were critically analyzed and evaluated in this paper to determine their legitimacy in the context of Mali. This helped to identify the possible effects of jatropha biofuel production on food security in Mali. The study found that jatropha has a strong potential to weaken food security, especially in a country as vulnerable as Mali. However, the current jatropha biofuel project, headed by a company called Malibiocarburant, has been structured in such a way that avoids this potential, and instead provides opportunities to enhance food security. Policy, practice and research recommendations are provided in light of the results from this study.

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Introduction

Biofuels and Food Security

Biofuels feature prominently in global climate change and energy security strategies[1] (IEA, 2008). This has spurred a recent surge in biofuel production worldwide, accompanied by the addition of biofuels to numerous government policies and agendas (FAO, 2008). Since biofuels currently rely predominantly on agricultural commodities they are closely interlinked with the global agricultural markets. The growing demand for biofuel feedstocks has therefore been recognized as contributing to the recent rise in global food prices, sparking widespread criticisms of biofuels for weakening food security (FAO, 2008; Naylor et al., 2007; Runge and Senauer, 2007). Thus, while concerns about climate change and energy security persist, the positive perception of biofuels has weakened in recent years[2]. This response has largely turned the debate about biofuels into one of food-versus-fuel, bringing food security to the forefront of this important dialogue.

The Food and Agricultural Organization (FAO) defines food security as existing when "all people, at all times, have access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996). Within this definition, the FAO recognizes four embedded dimensions of food security that are affected by a number of variables:

- **Availability of food** is determined by domestic production, import capacity, existence of food stocks and food aid.

[1] Biofuel is any fuel derived from biomass resources (Pahl, 2008). Biofuels usually refer to liquid fuels that can be used for transportation (Kleiner, 2007).
[2] It is important to note that concerns about food security are not the only reason biofuels have been experiencing a weakening of public support. Biofuels have also been criticized for negatively impacting the environment and for failing to reduce greenhouse gas emissions (Kleiner, 2007).

- **Access to food** depends on levels of poverty, purchasing power of households, prices and the existence of transport and market infrastructure and food distribution systems.
- **Stability** of supply and access may be affected by weather, price fluctuations, human-induced disasters and a variety of political and economic factors.
- Safe and healthy **food utilization** depends on care and feeding, food safety and quality, access to clean water, health and sanitation. (FAO, 2008, p.72)

In light of the diversion of food crops for fuel production and the recent rise in food prices, biofuels are predominantly impacting the first two dimensions: availability of food and access to food. For this reason, biofuels are increasingly seen as having negative effects on food security. It is in this context that *Jatropha curcas* L. has emerged as the "rising star on the biofuel scene" (Patton, 2007).

Jatropha

Jatropha curcas L. (herein referred to as jatropha) is a large shrub that belongs to the Euphorbiaceae family. It is native to tropical America but now thrives in most tropical and sub-tropical regions of the world (Jongschaap, Corre, Bindraban, Brandenburg, 2007). Jatropha is a hardy plant that can withstand long-periods of drought and can survive on marginal soils (Kumar and Sharma, 2008). This makes jatropha a useful plant in helping to prevent soil erosion. Furthermore, since the plant is toxic they have long been used a living fence around food crops, offering protection from livestock (Openshaw, 2000). The plant also has a long history of being used for medicinal purposes in many parts of the world (Kumar and Sharma, 2008). While the jatropha plant has served a variety of functions over the years, it is the potential for jatropha to be used as a biofuel feedstock that has attracted global attention in recent years.

Jatropha plants produce a fruit with oil-bearing seeds that contain 30-40% of their mass in oil (Sarin, Sharma, Sinharay, Malhotra, 2007). Through a process called transesterification, jatropha oil can be turned into a viable bio-diesel that can be used in conventional diesel engines[3,4] (Achten et al., 2008). This use of jatropha to produce biofuel has recently gained rapid momentum because it is claimed to avoid threats to food security, contribute to rural development and enhance energy security. Jatropha biofuel projects are planned or underway in various countries throughout Africa, Asia, Central America and South America equating to over 11 million hectares of land for jatropha cultivation worldwide (Pahl, 2008; Srinivasan, 2009). Jatropha biofuel is also attracting the attention of large corporations such as British Petroleum[5] and Air New Zealand[6] (Air NZ, 2008; BP, 2007). The wide range of countries pursuing jatropha biofuel and the involvement of large industry demonstrates the rapid pace at which jatropha biofuel is gaining momentum on a global scale. Mali is one country that has jumped on the jatropha bandwagon.

Mali

Mali was chosen for this case study for two main reasons: 1) it has a fragile state of food security and 2) it is in the early stages of pursuing jatropha biofuel. As such, it is vitally important to consider what implications jatropha biofuel production might have on food security in Mali.

Mali is a large country in the Sahel belt of Africa; except Mali's northern region, which is part of the Sahara desert[7]. Due to the country's geographic location, Mali has a very hot and dry climate, constraining agricultural production to only 14% of the land (Aune, n.d.). The country

[3] Pure jatropha oil can also be used as a diesel substitute; however, doing so requires modifications to the engine (Achten et al., 2008).
[4] Bio-diesel is a type of biofuel that is made from vegetable oil or animal fats. While jatropha oil is used to produce bio-diesel throughout this paper it will be referred to in more general terms as 'jatropha biofuel'.
[5] In 2007, BP signed a joint venture agreement with D1 Oils, called D1-BP Fuel Crops Limited, aimed at accelerating the planting of jatropha for large-scale biodiesel production (BP, 2007).
[6] In December 2008, Air NZ launched a successful first test flight powered by biofuel using a 50:50 blend of standard Jet A1 fuel and biofuel derived from jatropha oil (Air NA, 2008).
[7] The Sahel belt is a semi-arid region in Africa that spans the breadth of the continent and marks the transition between the Saharan desert to the North and the continents more fertile region to the South. The other countries within the Sahel belt are: Senegal, Mauritania, Burkino Faso, Niger, Nigeria, Chad, Sudan, and Eritrea.

therefore has a very limited food production capacity and relies heavily on imported food (Askoy, 2008). Furthermore, more than 50% of the population lives below the poverty line, hampering the ability of many Malians to access sufficient food (Aune, n.d.). These factors weaken food security in Mali, which is evident by the fact that more than 3 million people in Mali (or approximately 30% of the country's population) are undernourished (FAO, 2006). This situation will likely be exacerbated by the impending effects of climate change, which threaten to push Mali from a category four country into a category five country, the highest rank on the FAO's risk of hunger ranking (Butt, McCarl, Angere, Kyke and Stuth, 2005). It is evident that Mali's current state of food security is weak and vulnerable.

Mali is also a country with a weak state of energy security. Approximately 99% of the rural population lacks energy services (FACT, n.d.) and the country is heavily reliant on imported fossil fuels (MFCa, n.d.). Locally produced biofuel could make "energy services more widely and cheaply available in remote rural areas, supporting productive growth in agriculture or other sectors with positive implications for availability and access" (UN-Energy, 2007, p.31). Having a local energy source in Mali would make farmers less vulnerable to fluctuations in world oil prices, which in turn could help to stabilize food prices. Energy security is thus closely linked with food security. Therefore, improved energy security in Mali could profoundly impact food security.

Jatropha has the potential to address both the energy and food security fragility in Mali. Jatropha has been growing in Mali for decades, with an estimated 22,000 linear kilometers of this shrub throughout the country, and has been used in a variety of ways (Polgreen, 2007). Since the late 1980's, non-profit organizations have utilized pure jatropha oil as a fuel-source for rural

Malian communities[8]. However, it is only in very recent years that Mali has begun to pursue jatropha biofuel, making it one of many African countries engaging in the new jatropha biofuel market. Mali Biocarburant, a company established by the Royal Tropical Institute (KIT) and financed through public (the Dutch government) and private investments, is heading the first jatropha biofuel project in Mali[9]. Mali Biocarburant opened Mali's first bio-diesel production plant on February 11th, 2008. The jatropha biofuel project will be run as a for-profit organization, in an effort to provide an economically self-sufficient company and jatropha industry in Mali. Since Mali Biocarburant is the sole company currently producing jatropha biofuel in Mali, it will be the basis for this analysis.

Literature Review

It has been widely recognized that an expanding biofuel market contributed to the recent rise in food prices (World Bank, 2008; FAO, 2008; Doornbosch and Steenblik, 2007). This recognition has sparked a surge of research aimed at delineating the nature of the relationship between biofuels and food security. This gap in the literature suggests that the same rigorous assessment is not being applied to jatropha biofuel.

In the wake of record high food prices, Jean Ziegler, who at the time was the UN special rapporteur on the right to food, proclaimed biofuels as a 'crime against humanity' because of their negative effect on global food security and solicited a five year moratorium on the practice of using food crops for fuels (Ferrett, 2007). While the conclusions reached by other researchers

[8] From 1987-1990 the German Technical Cooperation (GTZ), in cooperation with the CNESOLER (Malian National Centre for Solar & Renewable Energy), developed an energy platform that could run on jatropha oil, making it the first experimentation of jatropha oil as a fuel in Mali. Mali Folkecenter, a Malian NGO that represents the Danish Folkecenter for Renewable Energy, and Eco-Carbone, a French based company, are the two main organizations currently operating in Mali on jatropha energy projects with pure jatropha oil (MFCb, n.d.; Eco-Carbone, n.d.).

[9] KIT is a non-profit organization based in the Netherlands that works with the public and private sector to achieve sustainable development, poverty alleviation and cultural preservation and exchange (KIT, n.d.).

have not been as strong, many have echoed similar concern that biofuels have the potential to shatter food security for the worlds poor, who spend the majority of their income on food (Runge and Senauer, 2008; Naylor et al., 2007). However, while Runge and Seanuer (2008), and Naylor et al. (2007) highlight the havoc that continued biofuel production could cause for food security by rising food prices, both recognize that the right policies could curb this potential.

A United Nations (UN) publication on sustainable bioenergy emphasized the need for a more comprehensive analysis, arguing that the current debate around food security and biofuels is "too simplistic and fails to reflect the full complexity of factors that determine food security at any given place and time" (UN-Energy, 2007). This argument has since been repeated and some attempts to further investigate and understand the overall effects on food security are underway (FAO, 2008; Pingali, Raney and Wiebe, 2008; Holtz, 2009; World Bank, 2008). However, the net effect of continued, or expanded, biofuel production on food security remains unknown (UN-Energy, 2007; FAO, 2008). The debate recognizes a link between biofuels and food security; it is the nature of this link that remains unclear and continues to be explored. The literature also continuously stresses the role of policy in shaping this link, highlighting the need for carefully designed policies that maximize the positive effects on food security and prevent or counteract the negative effects (Peskett, Slater, Stevens, Dufey, 2007; Pingali et al., 2008; UN-Energy, 2007).

While there is no clear decision about the effects of biofuels on food security, the act of engaging in a critical dialogue has motivated governments to re-consider biofuel strategies (Harrabin, 2008; Traynor, 2008). Although this is important, the aforementioned research and subsequent policy assessments are reactionary to the aftermath of a biofuel craze that left food prices at record highs. Due diligence surrounding food security has not been taken prior to previous biofuel commercialization strategies and scaled up deployment. The pursuit of new biofuels is an opportunity to apply a proactive assessment on food security implications prior to large-scale deployment, avoiding the need for mitigative measures. However, this opportunity is not being realized with one of the most recent biofuels on the agenda: jatropha.

Jatropha has primarily gained so much attention because it is claimed to avoid the food-versus-fuel debate and thus negative food security implications (BP, 2007; Tattersall, 2007; Malibiocarburant, n.d.; Centre for Jatropha Promotion, n.d.). After reviewing the jatropha literature, it was found that there are two primary reasons that are used to support this claim: 1) jatropha will not compete with food and 2) jatropha will contribute to rural development[10]. Both of these possibilities have tremendous potential to impact food security, positively or negatively. Competition with food could greatly hinder the availability of food, raising food prices and therefore affecting access to food (the currently criticized trend with most biofuels). On the other hand, rural development could help to improve access by increasing purchasing power. Positive benefits for rural communities could also improve availability of food since it could lead to overall agricultural growth (UN-Energy, 2007).

While it is evident that there is a link between jatropha biofuel and food security, specifically through competition with food and rural development, this link has not been sufficiently explored. Within the body of academic literature on jatropha, these claims are increasingly being investigated and critically analyzed (Benge, 2006; Jongschaap, et al., 2007; KnowGenix, 2008; Meena and Sharma, 2006; Achten et al., 2008; Openshaw, 2000; Kumar and Sharma, 2008; Hunsberger, 2009). This is occurring even more so in online media, such as websites and blogs, where concerns over food security are increasingly being expressed as the

[10] Rural development can be defined as "development that benefits rural populations; where development is understood as the *sustained* improvement of the population's standards of living or welfare" (Andriquez and Stamoulis, 2007).

jatropha industry gains momentum (Ghana Business News, 2009; Time, 2009; Amankwah, 2009; Earth Times, 2009). Despite the importance of addressing these two claims, there has only been one effort to thoroughly consider jatropha's effect on food security (Asselbergs et al., 2006). Asselbergs et al. (2006) attempted to determine how jatropha biofuel could be pursued in Cambodia in such a way that it would improve the situation of the poor without putting food security at risk. While this is a valuable step in the right direction, this study is specific to Cambodia and may therefore not apply elsewhere. Further research and analysis is needed to better understand the net effect of jatropha biofuel production on food security prior to continued large-scale deployment in a regional and global context.

Alarmingly, the pursuit of jatropha biofuel is following the same criticized trend of other common biofuels: launching into full gear without diligent consideration of food security implications. To correct this trajectory, it is strongly recommended that the two aforementioned claims be critically examined to understand the complete linkages between jatropha and food security before continued expansion. It must be remembered that the biofuel versus food debate is highly complex and that it is widely understood that biofuels are an integral component of a global energy strategy, given the right policy framework. Lessons learned from past biofuel experiences have taught us that a thorough level of research must be dedicated to biofuel and food security. This is a critical gap within the jatropha literature. It is this gap that this thesis serves to address for jatropha biofuel production in Mali.

Research Objectives

The literature review revealed that aspects of jatropha have the potential to significantly impact food security, as seen in recent events with corn ethanol. It was further revealed that this potential has not been sufficiently examined, exposing a critical gap in the jatropha literature.

This study seeks to address this oversight by evaluating the two claims about jatropha: 1) it will not compete with food and 2) it will contribute to rural development, to provide an analysis of potential impacts of jatropha biofuel production on food security in Mali.

It is hoped that this study will contribute to a better understanding of the link between jatropha and food security in Mali. It is further hoped that a similar framework will be applied to assess food security in other jatropha biofuel projects happening around the world. This paper will begin the much-needed discussion on food security within the jatropha sphere, in attempt to avoid unforeseen consequences and to proactively address food security in light of previous failure to do so with other biofuels with the overall intent of staving off unforeseen consequences. This research will also contribute to the growing body of literature that is trying to better understand the nature of the relationship between food security and biofuels, more generally.

Methodology

For this study, three main research tools were used to achieve the research objectives: *a posteriori* coding, critical analysis and a case study. *A posteriori* coding was used to identify the two most common claims about jatropha biofuel within existing literature. The two claims that emerged as most prevalent and are thus analyzed in this study are: 1) jatropha will not compete with food and 2) jatropha will contribute to rural development. A critical analysis of these two claims was then conducted by evaluating their legitimacy in consultation with relevant bodies of literature to reveal possible implications for food security in Mali. A broad array of literature was consulted during this process including: rural development, biofuels, jatropha and food security. The effects on food security were evaluated in consultation with the UN Sustainable Bioenergy Framework (2007), using the four dimensions of food security as a starting point for analysis.

The UN Sustainable Bioenergy Framework (2007) recognizes that the effects of biofuels will be highly context specific. It therefore recommends, "an analytical framework based on country typologies should be developed to facilitate the understanding of country specific effects" (UN-Energy, 2007, p.34). A case study was therefore chosen for this project, focusing on the nexus of jatropha biofuel and food security in Mali.

Delimitations

There are more aspects of jatropha beyond competition with food and rural development that interact with food security, including environmental effects of jatropha biofuel. However, due to time constraints and the length of this thesis, only the two most common claims about jatropha biofuel were analyzed in this study. This is, therefore, not a comprehensive analysis of the complex relationship between food security and jatropha biofuel in Mali. However, considering the importance of these two claims to food security, this study offers a valuable starting point for gaining a better understanding of this relationship.

Limitations

Due to time and resource constraints, this study was limited to a literature review and analysis. As a result, no primary research was conducted, which may limit the accuracy of the conclusions drawn in this study. While this is of concern, this study will still serve to highlight potential impacts on food security and can therefore provide a starting point for future research carried out in Mali.

Analysis

This section will seek to provide an in depth analysis of the two main claims about jatropha biofuel: 1) jatropha will not compete with food and 2) jatropha will contribute to rural development. The analysis will be undertaken as a case study, examining the possible effects of jatropha biofuel production on food security in Mali. It will further highlight the current knowledge gaps about jatropha biofuel that should be addressed with further research and studies to avoid any risks and maximize any benefits for food security.

Competition with Food

Many common biofuels have contributed to record high food prices in recent years because they divert food for fuel production and/or come into competition with food crops for similar resources (Runge and Senauer, 2007; Naylor et al., 2007; Peskett et al., 2007). Jatropha biofuel is widely acclaimed for avoiding such competition with food and the subsequent effects o food security (BP, 2007; Tattersall, 200; Malibiocarburant, n.d.; Centre for Jatropha Promotion, n.d.). This is largely because it is an inedible plant and can be grown on marginal lands that would not otherwise support food crops. These two supporting claims will be elaborated upon below.

Inedibility

Jatropha seeds contain a high concentration of phorbol esters making them toxic, and therefore inedible, to both humans and animals (Adolf, Opferkuch, Hecker, 1984). Since jatropha is not a food crop, it does not divert food for fuel production. This is a significant element of jatropha that makes it unique to other currently popular biofuel feedstocks, such as corn ethanol. “Filling the 25-gallon tank of an SUV with pure ethanol requires over 450 pounds of corn –

which contains enough calories to feed one person for a year" (Runge and Senauer, 2007, p.1). This statistic powerfully highlights the potential for food crops that are used as biofuel feedstock to weaken food security by lowering the availability of food, and thereby access to food. Jatropha's inedibility thus helps to lessen potential competition with food crops and lower the risk for food security.

Furthermore, jatropha's toxicity makes it a useful living fence around food crops by offering protection from animal incursions (Achten et al., 2008). Planting jatropha around food crops can therefore serve to protect food production. This benefit has long been taken advantage of in Mali, which now has an estimated 22,000 kilometers of jatropha hedges (Polgreen, 2007). The fact that jatropha is not a food crop thus not only helps to prevent competition with food, if correctly planted, as it has been in Mali for decades, it can help to increase the availability of food.

Marginal Lands

Jatropha is also gaining attention as a biofuel feedstock that avoids competition with food because it can be grown on marginal lands that would otherwise not support food crops. This would have tremendous potential in Mali since approximately 85% of the land is currently unarable (Aune, n.d.). However, evidence suggests that jatropha will not be viable as a biofuel feedstock if grown on marginal lands without irrigation and fertilizer inputs.

Jatropha plants can survive in areas with as little as 250 mm of rainfall per year (Katwal and Soni, 2003) and can withstand long periods of drought by shedding most of its leaves to reduce transpiration loss (Kuman and Sharma, 2008). However, it is becoming increasingly accepted that irrigation would be required in such conditions to produce economically viable yields for biofuel production. While research on seed yield is patchy, the data that exists reveals a strong correlation between seed yield and water input. Achten et al. (2008) found that a minimum annual average rainfall of 500-600mm per year is required to yield a harvestable amount of seeds. Studies from India found that jatropha grown on marginal lands without irrigation had an average yield of 1.1-2.75 tonnes per hectare after five years of growth (Jatropha World(a), n.d.). This is significantly lower than jatropha yields grown on marginal lands with irrigation, which produced 5.25-12.5 tonnes per hectare after five years (Jatropha World(a), n.d.).. It is thus well supported that jatropha grown for biofuel production would require additional water inputs if grown on marginal lands.

This is of significant concern to an immensely water-scarce country like Mali. Mali is divided into three climatic zones: the Saharo-Sahalian, the Sahelo-Sudanian, and Sudano-Guinean zones (Butt et al., 2005). The Saharo-Sahelian zone is extremely dry with an annual rainfall of 100-200mm (Butt et al., 2005). The Sahelo-Sudanian zone has an annual rainfall of 200-400mm and the Sudano-Guinean zone has an annual rainfall of 400-800mm (Butt et al, 2005). Since jatropha as a biofuel feedstock is said to require an average of 500-600 mm of rainfall per year (Achten et al., 2008), irrigation will be required in most parts of Mali to produce a harvestable yield. Agriculture in Mali is already highly constrained by limited water resources; with only 14% of the country suitable for agriculture because the rest is too dry (Aune, n.d.). It can, therefore, be concluded that jatropha cultivation for biofuel will also be severely constrained by water in Mali and could put immense stress on water resources. Furthermore, climate change will likely exacerbate these agricultural constraints since various models and climate projections have revealed a hotter and drier future for Mali (Butt et al., 2005).

Additional stress on Mali's limited water resources could have severe implications for food security. It has been found that climate change will significantly reduce precipitation in

Mali, resulting in a 15-19% decrease in cereal production and a doubling of food prices (Butt, T., McCarl, B.A., Angerer, J., Dyke, P., Stuth, J., 2003). Planting jatropha on marginal lands with irrigation would indirectly compete with other agricultural crops by increasing the demand for such a scarce resource. "If the same land and other resources are needed for both food and biofuel feedstock crops, their prices move together even if the feedstock crop cannot be used for food" (FAO, 2008). Coming into competition with food for water would put pressure on food crops during an already volatile time for food production in Mali. Furthermore, this competition could contribute to an even greater rise in food prices – with potentially catastrophic implications for food security, since food prices are one of the most important determinants of food security (UN-Energy, 2007). This demonstrates that even if jatropha is planted on marginal lands in Mali, there is a strong potential for it to compete with food crops for water resources, yielding significant consequences for food security.

Jatropha is also said to be suitable for marginal lands because it is well adapted to poor soils with low nutrient content (Heller, 1996; Ogunwole et al., 2008)[11]. It has been demonstrated that jatropha is not only able to grow on poor soils; it also helps to remediate these soils, offering long-term ecological benefits. In a study conducted by Ogunwole et al. (2008), jatropha grown on marginal soils improved soil aggregation, helping to decrease soil erosion. The study also found that jatropha has the potential to increase carbon sequestration in soils, increasing the soils nutrient content (Ogunwole et al., 2008). The use of jatropha to reclaim marginal lands could help to improve future availability of food. However, it is likely that this benefit could not be realized if the jatropha was being grown for biofuel production. Similarly to the issue with water, jatropha can grow on marginal lands; however, it will require fertilizer to produce an

[11] Due to limited studies, the minimum level of nutrients required for jatropha to grow is not yet known. However, it is strongly documented that jatropha is well adapted to marginal soils (Openshaw, 2000; Heller, 1996).

economically viable yield for biofuel production (Achten et al., 2008; Foidl, Foidl, Sanchez, Mittelbach, Hackel, 1996). This could further increase the risk of jatropha coming into competition with food and threatening food availability and food prices. This occurred in Vietnam where increases in food production led to increased competition for fertilizer. As a result fertilizer prices rose, becoming a contributing factor to mounting food prices (Bradsher and Martin, 2008).

It is thus evident, that while jatropha is able to grow on poor soils in dry climates, irrigation and fertilizer would be required to produce sufficient seed yields for biofuel production, as was found from trials with jatropha in Tanzania (Messemaker, 2008). This also proved true for many farmers in Kenya, who after being promised a cash crop on their marginal lands were disappointed with pitiful seed yields (Hunsberger, 2009). Requiring such inputs could bring jatropha into competition with food, rendering the claim that this was inherently avoided as false.

In addition to having the potential to indirectly compete with food crops for resources, there is economic incentive to plant jatropha on arable land since it would reduce production costs while maintaining high oil yields. This would mean jatropha is planted on land that could otherwise be used for food production, bringing jatropha into direct competition with food. "Reality shows that, if unchecked, jatropha is mainly NOT planted on marginal lands, and NOT in arid areas, but in tropical areas, where the climate – warm winters and heavy rainfall – is largely conducive to food crops, which will inevitably be displaced by biofuels crops" (Clements, 2009). Currently 27% of the land under cultivation for jatropha biofuel projects around the world is agricultural land that could otherwise be used for food production (Jatrophabook, n.d.). Of this 27%, 13% is on land that used to be under food production

(Jatrophabook, n.d.). This highlights a further threat to food crops – the potential for crop switching.

In this case, crop switching refers to replacing food crops with jatropha plants. "An individual farmer will produce feedstock for biofuels if the net revenue he or she earns is greater than for alternative crops of uses" (FAO, 2008). This trend occurred in the United States with corn ethanol. When an increased demand for corn ethanol pushed maize prices up from $2.60/bushel to $4.25/bushel in March 2007, the amount of land dedicated to maize production increased by 19% at the expense of other food crops such as soybean plantings, which declined by 15% (Naylor et al., 2007). Therefore, if jatropha offers a farmer a higher income than their current food crops, it is likely that farmers will switch their land over to jatropha cultivation. A higher income for farmers may help to improve access to food; however, crop switching may significantly weaken availability of food.

It is evident that there is a multitude of ways in which jatropha biofuel could come into competition with food crops, despite the claims that state otherwise. Such competition has the potential to decrease availability of food and drive up food prices, weakening access to food. Jatropha would then be following the highly criticized trend displayed by other common biofuels. The rapid expansion of biofuels at the expense of food crops has been recognized by the FAO (2008) as one of the factors that contributed to a significant rise in food prices in 2007-2008. By the end of 2007, the price of wheat, corn and soybeans had doubled in less than two years. Wheat reached $10/bushel, corn reached $5/bushel and soybeans reached $13.42/bushel, breaking or approaching record highs (Brown, 2008). "Some countries will benefit from higher prices, but the least-developed countries, which have been experiencing a widening agricultural trade deficit over the last two decades, are expected to be considerably worse off" (FAO, 2008, p.72). These drastic price increases had enormous implications for global food security. Food became increasingly unaffordable for the poor, sparking food riots in a number of countries around the world (Adams, 2008). Jatropha poses similar risks to food security if it comes into competition with food for land or other resources.

Mali is particularly vulnerable to such risks. Since agricultural land is already a rare commodity, there is no arable land available for jatropha cultivation without displacing other crops. Furthermore, 50% of the population in Mali lives below the poverty line (Aune, n.d.) and are thus especially vulnerable to an increase in food prices. There is justifiable concern that jatropha biofuel in Mali could greatly threaten food security by coming into competition with food crops for land or other resources. However, Mali Biocarburant has designed a jatropha program that will help to mitigate such risks. The use of the presscake and the practice of intercropping are two strategies employed by Mali Biocarburant that will help to reduce the risk of competition with food.

Pressing the seed to get the jatropha oil produces a presscake that can be used as a fertilizer. The application of this presscake back onto the jatropha field can increase the seed yield by up to 120% (Ghosh et al., n.d.), decreasing the need for external fertilizers required by other agricultural crops. In Mali, the presscake is sold back to the jatropha farmers to use on their crops. By keeping the presscake in the jatropha production system they are ensuring that jatropha does not come into competition with other agricultural crops for available fertilizer.

Mali Biocarburant also integrates its activities with existing agricultural systems by requiring farmers to practice intercropping, the integration of jatropha with food production by growing it with one or more crops simultaneously in the same field (Mali Biocarburant, n.d.; Jatropha World, n.d.). Mali Biocarburant ensures intercropping by requiring their farmers to plant jatropha in rows that are 5 meters apart with food planted in between (Vogl, 2009). The current jatropha biofuel operation in Mali is small enough that this could be easily monitored. As a result, each field will only be about 10% jatropha, avoiding any intensive farming (Vogl, 2009). There are a number of reasons intercropping helps to avoid competition with food.

Intercropping allows jatropha to be grown on arable land where greater yields can be realized without displacing or competing with food crops. Furthermore, intercropping on arable land will help to increase seed yield with minimal or no water and nutrient inputs (Singh, Swaminathan, Ponraj, 2006), thus avoiding competition with food for production inputs. “Where successful intercropping can be developed, jatropha production will be able to go hand in hand with food production” (UNEP, n.d).

Intercropping could also help prevent crop switching. Since more than half of the population in Mali lives below the poverty line and over 80% of the population depends on agriculture for their livelihood (Aune, n.d.), if there was economic incentive to grow jatropha instead of food there would be a high risk of crop switching in Mali. Since Mali is already a net importer of food and agricultural goods (Aksoy, 2008), crop switching would make Mali more dependent on other countries for a consistent and sufficient supply of food. However, intercropping with food crops allows farmers to access the emerging jatropha industry, without doing so at the expense of food production. Mr. Banani, a Malian farmer, is one example of how beneficial intercropping can be. By planting one row of jatropha for every seven rows of regular food crops, Mr. Banani was able to “double his income on the field in the first year and lose none of his usual yield from his field” (Polgreen, 2007). Further benefiting the farmers, intercropping allows for a diversification of income, providing more protection from the volatility of the market by spreading risks over different crops (UN-Energy, 2007, Messemaker, 2008). This is critical since already farmers in India, Burma and Kenya are experiencing unfulfilled promises on their newly planted jatropha crops (Hunsberger, 2009; Meena and Sharma, 2006; Time, 2009).

Intercropping jatropha can also benefit the food production system, beyond their potential as a living fence. Jatropha "has a phytoprotective action against pests and pathogens, providing additional protection to intercropped plants" (Greco and Rademakers, n.d.). Intercropping jatropha is further said to complement farming systems because they can help to improve the microclimate, decrease soil erosion and provide humus, helping to revitalize the soil (Openshaw, 2000). Furthermore, intercropping instead of monoculture plantations can help to maintain biodiversity, reduce soil degradation and decrease vulnerability to pests (Richards, 1983). Each of these offers protection to food production in the long-term. There have been problems with intercropping in Tanzania, where the canopy got to be too large and blocked the sunlight from the other crops (Messemaker, 2008). However, this occurred with 2-3 meter spacing between the crops (Messemaker, 2008). Mali Biocarburant requires there to be 5 meters of spacing, which should help to overcome this obstacle. The other barrier to intercropping is the desire to achieve economies of scale (Messemaker, 2008). This will be further discussed in the next section when looking at rural development.

There are numerous benefits to an intercropping system with jatropha. As has been described above, it can help to prevent competition with food while also protecting and potentially augmenting food production. Intercropping jatropha therefore appears to be a sound strategy for protecting and improving food security in Mali.

Rural Development

"Because hunger in developing countries tends to be concentrated in rural areas, little sustained progress in food security is possible without paying particular attention to agriculture and rural development" (UN-Energy, 2007, p.33). This is especially true in Mali where 70% of the population lives in rural villages and 76% of this rural population is considered poor (compared to 30% in urban areas) (FAO, 2006; PRSP, 2002). The potential for jatropha to contribute to rural development could therefore have profound effects on food security in Mali.

Agriculture has long been recognized as playing a critical role in rural development; a role that was recently reasserted in the 2008 World Development Report (World Bank, 2008). There are numerous success stories that speak to the importance of agriculture in poverty reduction and rural development strategies (World Bank, 2008). One example of such a success story is China, who experienced a 45% decrease in rural poverty in only 20 years largely because of growth in the agricultural sector (FAO, 2008, p.26). Biofuels have the potential to stimulate such a growth in the agricultural sector by increasing income-generating activities, and enhancing energy security and services in rural communities. Jatropha is widely acclaimed as a biofuel crop that can live up to these heightened expectations and significantly contribute to rural development (Henning, 1996; Jatropha World, n.d.; Openshaw, 2000; Kumar and Sharma, 2008). There are, however, significant barriers and challenges to realizing rural development through agricultural initiatives. This section will explore the potential for jatropha biofuel to contribute to rural development by analyzing jatropha's contribution to income-generating opportunities and energy security in Malian communities.

Employment

The World Bank (2008) stated that the priority of rural development policy should be to create more jobs in agriculture and the rural nonfarm economy. However, “creating jobs in rural areas is a huge and insufficiently recognized challenge” (World Bank. 2008, p.17). It is argued that jatropha biofuel production could help overcome this challenge by opening up a new agricultural market, creating various new opportunities for rural employment (Jatrophabook, n.d.). However, this has not always proven to be the case with new agricultural markets. There are inherent barriers preventing rural populations from benefiting from large-scale agricultural production initiatives (Pingali et al., 2008).

Weak infrastructure in developing countries may favour large-scale commercial farms over small-scale agriculture (Dorward, Kydd, Morrison, Urey, 2004). An increasingly globalized economy and our current drive to achieve economies of scale also tend to favor large-scale producers, often at the expense of small-scale producers (EPA, 2007). This can result in a concentration of wealth and land, with negative implications for rural development (US-Energy, 2007; Peskett et al., 2007). An accumulation of land may end up pushing poor farmers off of their land and into deeper poverty. This is already happening in Ghana, where small-scale farmers, especially women, are being displaced from their land so that foreign companies can start up large-scale jatropha biofuel projects (Amankwah, 2009). This type of agricultural system means that most countries see only a small portion of the population profiting from agriculture (UN-Energy, 2007). This significantly limits the potential for agriculture to contribute to poverty alleviation in rural communities.

“A key question often overlooked in the biofuels debate is whether there is anything new or different about biofuels that could allow developing countries to overcome these constraints in ways that support agricultural growth, poverty reduction, and food security" (Pingali et al., 2008). It is argued that large-scale biofuel production, including that of jatropha, could present similar impediments to rural development as described above (Peskett et al., 2007). Jatropha will, therefore, not inherently contribute to rural development. However, the jatropha project in Mali is largely avoiding such impediments.

Mali Biocarburant's business model is designed in such a way that will likely maximize benefits for rural communities and avoid the aforementioned criticisms of agriculture and development. The UN Sustainable Bioenergy Framework (2007) recommends business strategies that maximize the people involved in the value added chain, arguing that this will dramatically enhance the development benefits of biofuels. Mali Biocarburant has kept every stage of the biofuel production process local and capitalized on employment opportunities[12]. In Malibiocarburant's system, there are farmers who grow the jatropha that then sell the jatropha seeds to the local farmers union cooperative. The farmers union then presses the seeds and sells the presscake back to the farmers and sells the glycerol to a local women's cooperative for soap production (to be discussed further below). The farmers union sells the jatropha oil to Mali Biocarburant to make the biodiesel and distribute it throughout Mali. Openshaw (2000) criticizes the jatropha biofuel craze for putting too much emphasis on jatropha's use as oil, while neglecting the other beneficial uses of the plant. Mali Biocarburant is an example of a company that is trying to take full advantage of the various spin-off industries jatropha offers, including fertilizer and soap production.

Glycerin is a by-product of the transesterfication process that turns the jatropha oil into bio-diesel. This glycerin can be used to make high quality soap that can be locally sold, increasing the possibility to earn income off of local resources (Henning, 1996). Mali

[12] There is no information on how many jobs will be created from Malibiocarburant's project.

Biocarburant has taken advantage of this opportunity by forming a relationship with a local women's cooperative that buys the glycerin from the production plant and uses it to make soap. This helps to ensure that women are gaining access to the benefits of the jatropha biofuel production industry in Mali. This is an important aspect of Mali Biocarburant's business strategy since it is widely acknowledged that increasing the social and economic participation of women has profound benefits for rural development, sometimes more so than increasing income for males since "women are more likely than men to use their earnings to improve their living situations and to educate their children" (Grameen Bank, 2009).

Beyond maximizing income-generating opportunities, Malibiocarburant is also designed in such a way that supports and provides income to small-scale producers. The UN Sustainable Bioenergy Framework (2007) recognizes that having lots of small-scale producers working together to supply larger facilities, as opposed to having one large-scale producer, increases the value added chain and has a greater contribution to rural development. The framework further emphasizes, "ownership of value-added parts of the production chain is critical for realizing rural development benefits and full economic multiplier effects associated with bioenergy" (UN-Energy, 2007, p.7). Mali Biocarburant satisfies both of these recommendations, signifying positive repercussions for Mali's rural communities.

The farmers union cooperative allows small-scale farmers to jointly meet the needs of Malibiocarburant's bio-diesel production plant. "Cooperatives can provide the scale effects, security and infrastructure needed to balance large-scale producers and processes" (Asselbergs et al., 2006, p.30). This is a similar business model to the wildly successful milk cooperatives in India. Cooperatives of small-scale farmers organizing together to protect and control the production and sale of their milk sprung up around India starting in 1946 (The Indian Dairy

Industry, n.d.). These cooperatives have substantially enhanced incomes for millions of India's poorest small-scale farmers (Kurien, 1996). For this reason, this business structure has been hailed as a model for rural development, a model that puts development in the hands of the farmers that serve to benefit (Kurien, 1996). This demonstrates the potential for Mali's farmer cooperative to improve livelihoods of rural jatropha growers.

Asselbergs et al. (2006) argue that cooperatives will only "work in situations where sufficient commitment from and cooperation by the participants are guaranteed" (Asselbergs et al., 2006, p.30). Mali Biocarburant has incorporated a strategy to help insure this level of commitment. The farmers union owns 20% of Mali Biocarburants company shares (Mali Biocarburant, n.d.). "Thus farmers have direct benefits through the sales of products and they also share in the increased value of the shares as well as dividends that are foreseen" (Mali Biocarburant, n.d.). This makes the farmers personally invested in the success of the project. It also offers opportunities for increased incomes in rural communities and further spreads the profits throughout the community.

Despite Mali Biocarburants strong business model, there remain concerns about the infancy of jatropha biofuel and the possibility for unfulfilled promises. It is argued that we do not yet know enough about jatropha biofuel production to fully understand the associated benefits and risks (Achten et al., 2008; Messemaker, 2008). It is, therefore, too early to understand if jatropha will in fact contribute to rural development. Despite such knowledge gaps (Olden, 2007; KnowGenix, 2008; Achten et al., 2008; Messemaker, 2008), many are being promised that jatropha will stimulate economic development in rural economies. For farmers in India, Kenya and Burma this promise remains unfulfilled primarily due to failing yields, unexpected production costs and a lack of demand for their seeds (Acharya, 2009; Time, 2009; Hunsberger, 2009). An Indian study undertaken by Meena and Sharma (2006) revealed that 99.5% of tribal farmers and 98.8% of non-tribal farmers felt that a lack of marketing facilities to sell jatropha was the biggest constraint for jatropha growers in India. These examples illustrate the risks of engaging in jatropha biofuel when it is still in its nascent stages of development.

This risk could negatively affect stability of supply and access to food since farmers are being encouraged to engage in a new and volatile market without a complete understanding of the risks or challenges involved before becoming reliant on the jatropha biofuel market. This supports the need for further research on jatropha biofuel crops to better understand the link between jatropha biofuel and rural development. In the mean time, Mali Biocarburants' dedication to intercropping jatropha with food may help to curb this risk. Intercropping jatropha with other crops diversifies income, preventing farmers from becoming dependent solely on jatropha crops (Jatropha World, n.d.).

Energy Security

Jatropha could also contribute to rural development by increasing energy security and services in rural communities, with profound improvements to the local economy and lifestyle. Jatropha biofuel can be used to run generators, vehicles, grain mills and other technologies. Each of these would offer new opportunities to rural communities and can help to stimulate development through agricultural and economic growth. Having improved access to energy services can also help to support existing agricultural systems, with positive ramifications for food security. This link between the introduction of energy and rural development is powerfully demonstrated in the case of Bhoksing Village, Nepal. Once the village was able to generate electricity various new income-generating activities became available and the residences of the village experienced a significant improvement in their quality of life (UNDP, 2005). Jatropha also has the potential to enhance energy security by providing a local energy source, thereby reducing dependence on imported fossil fuels (Jatropha World, n.d.). "Energy today is at the heart of every economic, environmental and developmental issue…developing countries need to expand access to reliable and modern energy services to alleviate poverty and increase productivity, to enhance competitiveness and economic growth" (UNIDO, 2008, p.6). Energy security plays a pivotal role in rural development and must therefore be considered in the context of jatropha.

The potential for jatropha to enhance energy security will largely depend on the local context and the type of industry being developed. If jatropha biofuel is produced solely for export to supply the growing global energy demand, rural communities in the producing country will continue to face energy insecurity (Pressend, 2008). This is happening in Malawi where jatropha oil is exported to Europe for conversion into biodiesel rather than used to meet the local energy demands (PANOS, 2006)[13]. This is the opposite of the jatropha project in Mali. The Malian government has refused any jatropha biofuel initiatives that are designed to produce biofuel for export. The National Centre for Solar and Renewable Energy in Mali has had numerous businesses from around the world interested in developing a large jatropha biofuel industry in Mali, however, they have all been turned down. This is because Mali is committed to solving their local energy needs before even considering export-oriented biofuel opportunities (Tattersall, 2007). Mali Biocarburant's program is designed to help solve the energy needs of Mali's 700 rural communities and to reduce poverty across the country. This ensures jatropha biofuel will contribute to energy security, upon success and since Mali is not harvesting jatropha for export, the concerns about constraints and access to trade are avoided (FAO, 2008).

[13] The proportion of jatropha that was exported versus used for local energy needs was not available. However, the article implied that jatropha was primarily being pursued as a strategy to engage in a growing global market as opposed to a strategy to improve local energy security in Malawi (PANOS, 2006).

Conclusions

This study critically evaluated the complex relationship between jatropha biofuel and food security in Mali in advance of large-scale deployment. Two common claims are used to defend and promote jatropha biofuel programs amidst growing criticisms of the effects the biofuel industry on food security These two prevalent food security related claims are: 1) jatropha plantations will not substitute food crops and 2) jatropha will contribute to rural development. Both of these claims interact with one or more of the four dimensions of food security, making them essential to explore in this study. These claims were analyzed and evaluated to determine their legitimacy in the context of Mali and their subsequent impacts on food security. A national case study was selected as the most appropriate means of evaluating the suitability of Jatropha biofuels considering its geographical specificity; a point lost with present day biofuel deployment schemes. Mali is particularly relevant since it is just embarking on an ambitious Jatropha biofuel program (Mali Biocarburant) that may act as a template for other national programs. It was found that the Malian jatropha biofuel program exhibits a strong potential to both improve and weaken food security. Its success is strongly dependant on the local context and its design of the technical, commercial, public outreach and regulatory program components. Under the current structure in Mali, it was found that jatropha biofuel is likely to strengthen food security under the pretense of rural development and food substitution. Elements of the programs design may be carefully transplanted to other regions to bear similar results.

Due to the current environmental and socio-economic conditions, there is a high risk of jatropha biofuel coming into competition with food production in Mali. This could occur if jatropha required fertilizer or water inputs, thus competing with food for the same resources. Jatropha would also compete with food if it were planted on Mali’s limited arable land.

However, despite such a high degree of risk, an analysis of Mali Biocarburant's operations demonstrated a commitment to protecting food production. Mandatory intercropping of jatropha with existing agricultural crops is the main reason Mali Biocarburant will be able to avoid competition with food while still maintaining economically viable yields for biofuel production. Intercropping only accounts for 15% of current jatropha biofuel plantations (Jatrophabook, n.d.). Thus, while intercropping can help avoid competition with food it is receiving minimal attention. This highlights the role of project design in determining the effect on food security. While Mali Biocarburant is minimizing the risk of competition through their business practices, in other contexts jatropha may significantly compete with food.

The potential for jatropha to contribute to rural development is a very important claim for a predominantly rural country like Mali. While there are often significant barriers to effective poverty-oriented agriculture, Mali Biocarburant has maximized the potential for rural development from jatropha biofuel. They achieved this goal by creating new income generating opportunities dealing with jatropha seeds, press cake fertilizers and soap. Their operations strongly align with the recommendations given in the UN Sustainable Bioenergy Framework for poverty-oriented biofuel projects. Importantly, Mali Biocarburant maximized income-generating opportunities from its operations, retained income in rural communities and ensured the participation of small-scale farmers and women by setting up a local farmers cooperative. Giving this cooperative part ownership of the company will further help to ensure a successfully run cooperative with widespread and local benefits. Mali Biocarburant also recognized the invaluable role of women in the rural development process and has ensured their participation in the jatropha biofuel project through a partnership with a local women's cooperative for soap production. Mali Biocarburant uses more than just the oil from the jatropha plant to drive economic growth by taking advantage of the entire jatropha system. In addition to soap production, the residual seed cakes are resold to the farmers as locally sourced fertilizer. The commercial cooperative structure of Mali Biocarburant will ensure that the benefits to rural development are not lost in the pursuit of large-scale agricultural production and that maximum benefits to the community are realized.

The Malian policy to ensure all local energy needs are met prior to considering export-oriented production also complements the objective of maximizing rural development potential of jatropha. This ensures the fuel will be used to increase and improve energy services and to enhance the country's energy security, while limiting the activity of large multinational corporations and capital flight. This is not guaranteed if jatropha biofuel is produced for export. This unique government policy ensures that the local population will benefit from a jatropha biofuel industry in Mali. Mali Biocarburant's business strategy, accompanied by the Malian governments vision, is very promising from a rural development perspective. This bodes well for food security in Mali.

This study revealed the discrepancies in the knowledge that supports the two claims and also highlighted the challenges in realizing the potential to improve food security. However, despite such barriers, both claims regarding jatropha biofuel are likely to be realized in Mali with the current jatropha biofuel program. This means that overall, jatropha biofuel in Mali is expected to improve food security. This will not be the case for all jatropha biofuel programs, as the design of the project will significantly shape the outcome, as was stressed in this study.

Limitations of the study were the complex and regionally specific elements to food security and lack of primary research. Since food security is highly complex and shaped by a number of different, interacting and often unpredictable variables, determining the exact effect jatropha biofuel will have on food security in Mali is extremely challenging. This study was also limited to secondary research, which may mean that local characteristics that would shape the outcome of this study were overlooked or misinterpreted. While these may alter the conclusions reached in this study, the framework for the study is invaluable.

The analysis revealed that there is potential for jatropha to negatively affect food security, something that has been overlooked in much of the current debate on jatropha biofuel. This should caution the pursuit of jatropha biofuel as a silver bullet for climate change and energy security, since this approach is driven by a narrow understanding of the jatropha biofuel and could lead to catastrophic implications for food security. The most important conclusion drawn from this study is that plans to engage in jatropha biofuel production should be carefully thought out and should not proceed without fully considering the implications for food security. This due diligence should also be applied to the design of the jatropha program to ensure it will capitalize on the opportunities to improve food security and will avoid or mitigate the potential to weaken food security. The evidence suggests that Malibiocarburant is one company that has found a way to do just this.

Recommendations

Given the conclusions from this study, the following recommendations can be given for a responsible jatropha biofuel industry. These recommendations emerged in the context of Mali but can be applied to other case studies.

Policy

- To prevent competition with food, policies should be in place that limits the location and type of jatropha plantations. Such a policy should encourage or mandate intercropping of jatropha to ensure the most protection of food security and that agricultural land is not used for biofuel production.

- All jatropha projects should be aimed at supporting and utilizing small-scale producers and creating spin off goods and services. This will offer the greatest potential for poverty reduction and rural development. A policy that limits the tract of land that can be under jatropha cultivation may help to prevent a large-scale agricultural approach and reduce the potential for a centralization of wealth and land. A policy that supports or requires small-scale driven cooperatives may be the most effective way to ensure industrial agricultural schemes do not trump small-scale producers, while at the same time providing sufficient oil for biofuel production.
- To maximize benefits for food security, a policy similar to that of the Malian government that requires all energy needs to be met prior to export-driven biofuel markets should be put in place.

Future Projects

This study has highlighted the importance of careful project design to ensure protection of food security. Future projects should adhere to the above policy recommendations. It is also advised that future projects consult the UN Sustainable Bioenergy Framework (2007) to identify best practices for jatropha biofuel production with regards to food security. The project should be designed in such a way that maximizes the value added chain of the jatropha system, taking advantage of the full range of benefits offered by the plant, without becoming fixated on its oil-properties only. The type of project being implemented by Malibiocarburant should act as a model for future projects in Mali. Projects, both in Mali and elsewhere, should be aimed at small-scale biofuel production to meet local energy needs, at least until these needs have been sufficiently met. Meticulous project design is essential for protecting food security and projects should therefore not move forward until there is sufficient research and evidence to guide careful project planning.

Further Research

Due to the nascent stages of jatropha biofuel production, there is an enormous need for further research on jatropha as a biofuel feedstock. Once there is less uncertainty and fewer knowledge gaps within the jatropha biofuel literature, a more comprehensive analysis of food security implications can, and should be, undertaken. Future research and studies should focus on the following:

- Research should examine effective policy mechanisms to address the aforementioned policy recommendations.
- Much more research is needed on best agricultural practices for jatropha. This will help to avoid unfulfilled promises and failed crops. It will further help to maximize seed yield production on existing lands, helping farmers achieve the most benefit from their jatropha plants as possible. A better understanding of how jatropha should be cultivated so as to work with the ecosystem functions and existing agricultural practices could greatly enhance seed yield while offering further benefits to food production.
- Lastly, further research is needed that examines this relationship between food security and jatropha biofuel. This nexus has largely been overlooked in the current jatropha biofuel discussion, which is highly problematic considering jatropha's potential to negatively impact food security. Further understanding of this relationship will help protect food security and will also help to take advantages of benefits for food security. Since the nature of this relationship will greatly vary depending on local context, it is

recommended that further case studies be conducted to take a close look at this link. It is also recommended that further research be done on Mali, including a more comprehensive study and primary research.

Project Stewardship

Meetings with Dr. Matthew Schnurr were held regularly throughout this semester. Over this time, various stages of the writing process were submitted for review and were discussed at meetings with Dr. Schnurr. Appendices A-C are the drafts that have been edited by Dr. Schnurr and since been revised. Further help was sought from the Dalhousie Writing Centre.

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Appendices

Appendix A: Analysis and Conclusions Outline

Note: Sections 1-5 are not necessarily part of the analysis. These sections will likely appear earlier in the paper (probably before the literature review). However, I included them in this outline because it helps me to organize the structure/order of the main points/topics that I will use to direct my analysis. The analysis will be based on sections 6-8.

1.0 What is Jatropha
- Describe the plant
- Define biofuels
- Describe jatropha's potential as a biofuel source

2.0 Jatropha and Food Security
- Define food security (UN definition).
- Four dimensions of food security: availability, access, stability and utilization
- Three claims about jatropha that relate to food security: contributes to rural development, has positive effects on the environment and avoids the food versus fuel debate (doesn't compete with food crops).
- Justify and explain why these three claims were chosen and how they relate to one or more of the dimensions of food security
- This thesis will analyze and weigh these claims about jatropha in the Malian context against the dimensions of food security to determine what effect jatropha biofuel production may have on food security in Mali.

3.0 Why Mali?
- Large-scale jatropha biofuel initiatives
- Fragile state of food security
- Climate change threatens to increase food insecurity
- So, jatropha biofuel production in mali needs to be assessed in terms of possible impacts on food security.

4.0 About Mali
- Brief background about Mali: political, economic and geographic

5.0 Jatropha in Mali
- Historical uses of jatropha plants in Mali
- Current actors in jatropha biofuel initiatives in Mali: GTZ, MFC and AREED, Malibiocarburant and KIT, Centre for Solar and Renewable Energy in Mali
- Describe the nature of the different initiatives: not for export, goal is to provide sustainable energy to Mali's 12,000 rural communities, focused on the jatropha system

(using all of the components of jatropha biofuel production, including soap production, improvement of food crops and fertilizer seed cakes).

- Locally focused and small scale initiatives (decentralized approach)
- Malibiocarburant is slightly more centralized since there is only one biofuel production facility and the biofuel is distributed from there. All stages of the process still remain in Mali. Describe the Malibiocarburant jatropha project. This project model is what the assessment will primarily be based on.
- The initiatives are partnerships between the government, European businesses and international organizations (such as KIT and UNEP (AREED)

6.0 Competition with Food Crops

6.1 Claims

- Doesn't compete with food crops because: can be grown on wasteland where food crops can't be grown

6.2 Challenges (is challenges the right word? Would 'opposing claims' or something be better?)

- However, there are concerns that jatropha might be grown on arable land to enhance crop yield for biofuel production.
- Also concerns, considering experiences with other biofuels (such as corn ethanol), that farmers may switch food crops to biofuel crops if there is a monetary incentive to do so.

6.3 Mali

- Describe how the claims and/or challenges are reflected in the jatropha biofuel programmes in Mali.

6.4 Conclusions for food security

- Considering the above, how will this aspect of jatropha biofuel likely impact food security.
- Describe what dimensions of food security will be impacted.

7.0 Rural Development

7.1 Claim

- Contributes to rural development because: provides income off of unarable land, increased job opportunities (at all stages of the process), increased energy security (and decreased energy costs), increased opportunities in rural communities with introduction of electricity, provides income for women (soap production)

7.2 Challenges

- There are barriers and obstacles to agriculture/biofuel programmes benefiting rural communities.

7.3 Mali

- Describe how the claims and/or challenges are reflected in the jatropha biofuel programmes in Mali.
- The structure of the programmes in Mali seems to avoid the challenges above and demonstrate the above claims.

7.4 Conclusions for Food Security

- Considering the above, jatropha biofuel production in Mali is likely to enhance rural development and thus positively impact food security
- Dimensions of food security impacted are: availability, access and stability

8.0 Environmental Impacts

8.1 Claims

- Soil: increased water retention
- Decreased soil erosion
- Provides organic fertilizer (seed cake)
- Climate change mitigation strategy (Malibiocarburant is part of carbon credit program)
- Climate change adaptation strategy (a way to use the increasing amount of unarable land in Mali (increasing due to climate change). Also improves the soil, potentially turning it into arable soil in the future
- Interplanting jatropha with other crops improves the other crop (living fence to keep animals out and because of the beneficial effects on the soil)

8.2 Challenges

- It is not yet known if irrigation would be necessary for economically viable yields.
- It is also not yet known how much fertilizer would be necessary for plant growth on wasteland (not known if the fertilizer seed cakes would be sufficient)
- Unknown what environmental effects would occur from large-scale jatropha plantations (concerns about effects on soil – would deplete soil of existing nutrients?)

8.3 Mali

- Describe how the claims and/or challenges are reflected in the jatropha biofuel programmes in Mali

8.4 Conclusions for Food Security

- Considering the above, explain how jatropha biofuel programmes in Mali are likely to positively impact food security in Mali.

9.0 Conclusions

- NOT YET KNOWN.
- But, research up to date suggests that jatropha biofuel production in Mali, as currently practiced, would have very beneficial impacts on the state of food security in the country.
- Will comment on how other jatropha biofuel projects that are more industrially focused, such as those in India, yield more concerns about the overall impacts on food security and thus would require further research.
- Make general recommendations for the future of jatropha biofuel production in Mali.

Appendix B: Analysis Draft #1

Analysis draft submitted on March 2nd, 2009. Edited by Dr. Matthew Schnurr.

Competition with Food

Claim:

Many common biofuels, such as corn ethanol and palm oil, have been widely criticized for threatening global food security (Naylor et al., 2007). It is argued that such biofuels decrease the supply, and thereby increase the price, of foods because they divert land away from food crops and use food for fuel production (Naylor et al., 2007). Jatropha biofuel is widely acclaimed for evading this fuel-versus-food criticism because it is argued that jatropha plants do not compete with food. The fact that jatropha is an inedible plant and can be grown on marginal lands support this claim.

Jatropha plants are toxic, and therefore inedible, to both humans and animals. Since it is an inedible crop, jatropha cultivation for biofuel production does not divert food for fuel production. Furthermore, since jatropha plants are toxic to animals they have long been used as fencing to protect food crops. It can thus be argued that jatropha not only avoids competition with food by not using food crops for fuel, but also protects food crops. Jatropha is also gaining attention as a biofuel feedstock because it can be grown on marginal lands. Jatropha plants can withstand long periods of drought by shedding most of its leaves to reduce transpiration loss (JatrophaWorld, n.d.). It can also be grown on poor soils with limited nutrients (Jatropha World, n.d.). Jatropha biofuel is thus promoted as a biofuel crop that can be grown on unarable land and therefore does not compete with food crops for land.

Challenges

There remain, however, uncertainties and criticisms to the claim that jatropha does not compete with food. The claim that jatropha can be grown on marginal lands for biofuel production remains highly contested. “JCL is capable to reclaim wasteland. But is it able to produce ecologically and socio-economically viable amounts of energy in these barren situations?” (Achten et al., 2008). This question is critical to explore to evaluate the potential for jatropha to compete with food. While jatropha can be grown on marginal lands, and thus is able to avoid direct competition with food crops, it is argued that irrigation and fertilization is necessary on such lands to yield harvestable amounts of jatropha seeds for biofuel production (Achten et al., 2008). It would no longer be marginal land if water and fertilizer were necessary production inputs.

If jatropha was grown on marginal lands, but fertilizer and irrigation were used to gain sufficient yields, there would be an increased risk of jatropha crops competing with food by increasing pressure on resources needed for both crops. “If the same land and other resources are needed for both food and biofuel feedstock crops, their prices move together even if the feedstock crop cannot be used for food” (FAO, 2008). In other words, if jatropha biofuel production requires fertilizer and water inputs they will be competing with food crops for similar resources. Jatropha is less likely to increase the demand for fertilizer because pressing the seed to get the jatropha oil produces a seedcake that can be used as fertilizer. Demand for water will likely increase, however, if jatropha is grown on marginal land. Therefore, growing jatropha for biofuel production on marginal lands does not necessarily evade the potential for competing with food.

Since “growing any crop on marginal land with low levels of water and nutrient inputs will result in lower yields” (FAO, 2008), there is incentive for jatropha to be planted on arable land. Jatropha would then come into direct competition with food over land, repeating the highly criticized trend seen in the expansion of other biofuel feedstocks, such as sugarcane in Brazil (Naylor et al, 2007). Further increasing the likelihood of jatropha being grown on arable land is the potential for crop switching. “An individual farmer will produce feedstock for biofuels if the net revenue he or she earns is greater than for alternative crops of uses” (FAO, 2008). “The impact of such a shift from food production to biofuel production is unpredictable, as it depends on the availability of natural resources and the competition emerging from the incorportation of this crop in the food production system” (Johnschaap, R., Corre, W., Bindraban, P., Bradenburg, W., 2007). However, this possibility of crop switching away from food production further increases the risk of jatropha cultivation coming into competition with food crops.

Food Security

The claim that jatropha will not compete with food supports the belief that jatropha will not adversely affect food security. However, it has been demonstrated above that there are discrepancies to the facts underlying this claim. It is, however, undisputed that jatropha offers a biofuel feedstock that is otherwise inedible. Jatropha thus avoids the ethical questions raised about using food crops for fuel production in a world where hunger is rampant (Runge and Senauer, 2007). This is a significant element of jatropha that makes it unique to other popular biofuel feedstocks, such as corn ethanol. “Filling the 25-gallon tank of an SUV with pure ethanol requires over 450 pounds of corn – which contains enough calories to feed one person for a year” (Runge and Senauer, 2007, p.1). This statistic powerfully highlights the negative ramifications for food security of using food for fuel production. It is important to recognize that jatropha’s inedibility does help to lessen the negative effects of jatropha cultivation on global food security.

The potential for jatropha to compete with food for resources, specifically land and water, is however a concern for food security. If jatropha is grown on marginal land and thus decreases the availability of water resources and/or fertilizer, both of which may also be required by food crops, the price of production for food may increase. This could raise the overall cost of the food produced. Since food prices are one of the most important determinants of access to food (UN-Energy, 2007), this rise in price could negatively impact household food security.

While it would avoid competition with production inputs, if jatropha were to be planted on arable land to increase seed yield, availability of food and access to food will likely be negatively impacted. This impact would be compounded if farmers were to switch their food crops to jatropha plants to increase their net revenue. Using arable land for biofuel feedstocks as opposed to food crops has the potential to decrease availability of food by diverting good land away from food production. This decrease in availability may then lead to an increase in price, further diminishing food security by decreasing access to food. This series of events is similar to what occurred in the production of other biofuels, most notably corn ethanol, (Naylor et al., 2007), thus giving valid reason for concern about the effects of jatropha cultivation on arable land for food security.

It is also important to consider the positive effects a rise in food prices may have on food security. "The demand for biofuels could reverse the declining trend in real commodity prices that has depressed agricultural growth in much of the developing world over recent decades" (FAO, 2008, p. 5). If jatropha were to compete with food and drive the prices of food up, there would be those who would benefit from the increased revenue. Since income impacts the purchasing power of households, access to food could be significantly improved. However, such benefits would not be equally spread. "Some countries will benefit from higher prices, but the least-developed countries, which have been experiencing a widening agricultural trade deficit over the last two decades, are expected to be considerably worse off" (FAO, 2008, p.72). Therefore, large numbers are still likely to experience worsening food security from rising food prices.

Mali

There is reason to be concerned that jatropha plantations in Mali will indirectly compete with food by increasing pressure on water resources. "The minimum annual average rainfall at which JCL is known to yield a harvestable amount of seeds is 500-600mm yr-1" (Achten et al., 2008, p. 14). Mali is just south of the Sahara desert and thus does not have an abundance of rainfall. The country is divided into three climatic zones: the Saharo-Sahalian, the Sahelo-Sudanian, and Sudano-Guinean zones (Butt, McCarl, Angerer, Dyke and Stuth, 2005). "The Saharo-Sahelian zone is extremely dry with an annual rainfall of 100-200mm (Butt et al., 2005). The Sahelo-Sudanian zone has an annual rainfall of 200-400mm and the Sudano-Guinean zone has an annual rainfall of 400-800mm (Butt et al, 2005). Whether the jatropha plants need irrigation will therefore depend on which zone the jatropha is grown in. Only if jatropha is planted in the Sudano-Guinean zone will irrigation not be required to produce a harvestable yield. Since the locations of jatropha plantations in Mali are not clear in available sources of information, it cannot be determined whether jatropha is competing or will compete with the limited water resources in Mali. However, it is clear that where the plants are grown will affect the impact of jatropha cultivation on food security and should thus be carefully chosen.

While the indirect competition with food cannot be determined, it appears safe to conclude that jatropha is not competing with food for arable land in Mali. Malibiocarburant made it clear that "this bio fuel is all about yields that are harvested from jatropha plants either integrated with food crops or on kilometres of land (stretching along the roadside)" (Malibiocarburant, n.d.). Since the jatropha plants are integrated or on otherwise unsuitable land for food production (roadside), jatropha cultivation in Mali is unlikely to compete with food for cropland. This will especially be true if Malibiocarburant is *requiring* that all jatropha seeds bought be grown from unsuitable cropland or from intercropping systems. This would help to ensure that farmers do not switch their food crops to jatropha plantations, but instead plant jatropha among their food crops (a practice with mutual benefits for both crops: see Environmental Impacts), as is seen in one of the photos on the Malibiocarburant website where jatropha is planted among rows of sesame seeds (Malibiocarburant, n.d.).

Evading competition for land is tremendously important in Mali, since only 14% of the land can be used for agricultural production, a number that is expected to decrease with the encroaching effects of climate change (Aune, n.d.). Increased pressure on water resources would also be less likely if intercropping and roadside plantations were being practiced. These practices would allow jatropha to be grown on arable land with sufficient rainfall or already established irrigation systems without putting food crops at risk. Enforcing intercropping is also very important in Mali to prevent crop switching. Since more than half of the population in Mali lives below the poverty line and over 80% of the population depends on agriculture for their livelihood (Aune, n.d.), if there was economic incentive to grow jatropha instead of food there would be a high risk of crop switching. Since Mali is already a net importer of food and agricultural goods (Aksoy, 2008), crop switching Mali more dependent on other countries for a consistent and sufficient supply of food. Mali is therefore more at risk of experiencing decreased food security if crop switching were to occur. Good point.

The current environmental and socio-economic conditions in Mali create a high-risk scenario for jatropha cultivation to come into competition with food. There exists a high risk for competition with food in Mali due to the current environmental and socio-economic conditions. Such competition could have negative implications for access to food and availability of food – with the potential to decrease food security in Mali (as discussed above). However, the jatropha project in Mali, being undertaken by Malibiocarburant, appears to be designed in such way that helps to avoid both direct and indirect competition with food, and thus avoid potential negative impacts on national food security. This discussion does highlight the importance of the project design when assessing the impact on food security and the existing risks to consider when undertaking future jatropha initiatives in Mali.

Rural Development

Claim

Jatropha is widely acclaimed as a crop with the potential to significantly contribute to rural development (Henning, 1996; Jatropha World, n.d.; Openshaw, 2000; Kumar and Sharma, 2008). Rural development can be generally understood as “development that benefits rural populations; where development is understood as the *sustained* improvement of the population’s standards of living or welfare” (Andriquez and Stamoulis, 2007). The critical role that agriculture plays in rural development was recently reasserted in the 2008 World Development Report (World Bank, 2008). The potential for jatropha cultivation to contribute to rural development is thus well supported. Good review here

A primary reason jatropha is seen as a driver for rural development is the potential for jatropha biofuel production to increase employment in rural areas. Workers would be needed to harvest the seeds, this is still done manually, to press the seeds and to run the biofuel production plant. Each of these offers new opportunities for employment in rural areas, which would increase household income and thereby contribute to poverty reduction. Has this happened in other areas of jatropha production?

Jatropha biofuel production will also increase opportunities for income generation through soap production. When jatropha oil is turned into bio-diesel through a process known as trans-esterfication, glycerin is produced as a by-product. The glycerin can then be used to make high quality soap. This provides new business opportunities in rural communities, especially for women. It is widely acknowledged that increasing the social and economic participation of women has profound benefits for rural development, sometimes more so than increasing income for males since “women are more likely than men to use their earnings to improve their living situations and to educate their children” (Grameen Bank, 2009).

Jatropha would also provide a source of energy to rural communities that have otherwise been cut off from this resource. This could have profound effects on the local economy and lifestyle. Jatropha biofuel could be used to run generators, vehicles, grain mills and other technologies. Each of these would offer new opportunities to rural communities and can help to stimulate development through agricultural and economic growth. It would also offer opportunities to improve the standard of living in rural communities by providing electricity to homes. For those communities that already have access to energy, jatropha would provide an alternative to fossil fuels. This would be significant for countries that are reliant on the import of fossil fuels, as it would help to increase energy security.

With climate change gaining increased attention in the international arena, global demand for biofuel is increasing (FAO, 2008). An expanding biofuel market may offer new markets for agricultural producers and thus new opportunities for rural communities (World Bank, 2008, p.70). “The emergence of biofuels as a major source of demand for agricultural commodities could help revitalize agriculture in developing countries, with potentially positive implications for economic growth, poverty reduction, and food security” (Pingali, Raney and Wiebe, 2008).

Challenges

There is, however, debate over the claim that jatropha biofuel production will inherently contribute to rural development. The lack of knowledge about jatropha biofuel feeds skepticism about the reliability and sustainability of such claims (Achten et al., 2008). It is argued that there are numerous knowledge gaps about jatropha biofuel production that need to be filled prior to singing praise for jatrophas role in rural development more specifics needed – what gaps??? (Achten et al., 2008). It is also important to note that the design of the jatropha biofuel program will impact the benefits to rural communities. For example, if soap production is left out of the jatropha biofuel production system, there may be less of a contribution to rural development.

It is further recognized that there are inherent barriers to rural populations benefiting from large-scale agricultural production initiatives (Benge, 2006; Pingali, Raney and Wiebe, 2008). Constraints to technological innovation and access to trade have been discussed in two FAO reports (FAO, 2004; FAO, 2005), highlighting the key constraints facing developing countries that are trying to benefit from agricultural growth. “A key question often overlooked in the biofuels debate is whether there is anything new or different about biofuels that could allow developing countries to overcome these constraints in ways that support agricultural growth, poverty reduction, and food security” (Pingali, Raney and Wiebe, 2008). This question is accompanied by the concern that the benefits from agricultural growth are not always equally spread (Pingali, Raney and Wiebe, 2008; Benge, 2006; Fabrizio and Valdes (Eds), 2007).

Food Security

The potential for jatropha biofuel production to contribute to rural development is critical to consider when assessing the implications of jatropha biofuel on food security. If the claim that jatropha will contribute to rural development turns out to be true, then the dimension of food security that will predominantly be affected is access to food. Since access to food largely depends on levels of poverty and the purchasing power of households (FAO, 2008), the potential for jatropha biofuel production to increase employment and household income in rural communities could significantly improve this dimension of food security. The other dimension of food security that could be affected is stability of supply and access. Since jatropha biofuel production is in its infancy, there are many knowledge gaps that have to be addressed. As was mentioned above, this could mean that jatropha biofuel is being promoted as a tool for rural development too soon, risking premature investments with income fluctuations or disappointments down the road. This could in turn affect stability of income and therefore stability of access to food.

Jatropha biofuel production has the potential to significantly improve food security if it does in fact contribute to rural development. Thoroughly considering the potential for rural development within the context of the country or region in which the biofuel program is being implemented is essential to gain a better understanding of the relationship between jatropha biofuel and food security. It is also important for designing a biofuel program that can best harness the potential for positive change in rural communities.

Mali

This claim is tremendously important to a country like Mali where 70% of the population lives in rural villages (FAO, 2006). More importantly, 75% of the population that is below the poverty line lives in these rural areas (FAO, 2006), highlighting the tendency for poverty to accumulate in rural as opposed to urban communities. If jatropha biofuel production is able to contribute to rural development in Mali, food security could be significantly strengthened.

Due to the nature of the biofuel program being implemented by Malibiocarburant, Mali will likely experience enhanced rural development because of the jatropha initiative. Malibiocarburant has formed a relationship with a local women's cooperative that will buy the glycerin to make soap. This helps to ensure that women are gaining direct access to the benefits of jatropha biofuel production and provides them with an income generating activity, increasing employment and reducing poverty in the community. Good Malibiocarburant is also keeping every stage of the biofuel production process local, including the biofuel plant, offering maximum opportunities for local employment.

Another promising feature of the Malibiocarburant project is the focus on meeting local needs first. The program is designed to help solve the energy needs of rural communities and to reduce poverty across the country. The National Centre for Solar and Renewable Energy in Mali has had numerous businesses from around the world interested in developing a jatropha biofuel industry in Mali, however, they have all been turned down because Mali is not interested in producing jatropha biofuel for export until the countries own needs have been met (Reuters, 2007). Since Mali is not harvesting jatropha for export, the concerns about constraints and access to trade are evaded. Therefore, such constraints to rural development will not apply to the situation in Mali.

Since Mali is dedicated to meeting local energy needs, energy security will increase, further contributing to rural development. This is an incredibly significant feature of jatropha for a country like Mali, who is currently heavily dependent on imported fossil fuels. Having a local energy source would make farmers less vulnerable to fluctuations in world oil prices, which in turn could help to stabilize food prices and therefore stabilize access to food. Introducing energy into rural communities could also stimulate economic growth and improve the standard of living.

In Mali, small-scale farmers supply the jatropha nuts to a farmers union who then extracts the oil. The union sells this oil to Malibiocarburant for producing biofuel. This business structure further adds to the potential for Malibiocarburant to effect development in rural communities. A recent UN report on sustainable bioenergy (UN-Energy, 2007) emphasizes the value in such a system; "there are numerous examples of successful cooperative structures where several independent SME (small and medium sized enterprises) biomass producers work together to supply larger facilities or markets. The development benefits of bioenergy are enhanced dramatically when more people own more of the value-added chain" (p.17).

It is evident that the jatropha biofuel program in Mali demonstrates tremendous promise for rural development in Mali. This would have numerous benefits for food security in the country since rural development is so tightly intertwined with access to food, a critical dimension of food security. If access to food were improved by jatropha biofuel production in Mali, this would make jatropha remarkably different than other biofuels in the past, which have been heavily criticized for decreasing access to food around the world (Naylor et al, 2007).

Appendix C: Analysis Draft #2

A revised analysis draft submitted on March 17th. Edited by Dr. Matthew Schnurr.

Competition with Food

Many biofuels, such as corn ethanol and palm oil, have come under criticism for threatening global food security (Naylor et al., 2007). It is argued that such biofuels decrease the supply, and thereby increase the price, of foods because they use food for fuel production and divert land away from food crops (Naylor et al., 2007). Jatropha biofuel is widely acclaimed for evading this fuel-versus-food debate because it is an inedible plant and can be grown on marginal lands that do not support food crops.

Jatropha plants are toxic, and therefore inedible, to both humans and animals. Since it is an inedible crop, jatropha cultivation for biofuel production does not divert food for fuel production. Jatropha's toxicity have made it useful as a fence to protect food crops against incursions from animals: there are an estimated 22,000 kilometers of jatropha hedges in Mali that have been used for decades as a living fence and to prevent soil erosion (Polgreen, 2007). Jatropha thus not only avoids direct competition with food crops but actually serves to protect existing stocks.

Jatropha is also gaining attention as a biofuel feedstock because it can be grown on marginal lands. Jatropha plants can withstand long periods of drought by shedding most of its leaves to reduce transpiration loss. It can also be grown on poor soils with limited nutrients details to support this? Minimum levels of potassium, nitrogen, phosphorous, etc.. Jatropha biofuel is thus promoted as a biofuel crop that can be grown on land that would otherwise be considered unarable. (Jatropha World, n.d).

The claim that jatropha can be grown on marginal lands for biofuel production remains highly contested. While jatropha can be grown on marginal lands, both irrigation and fertilization are necessary to yield economically viable amounts of jatropha seeds for biofuel production (Achten et al., 2008). To support a high biomass production on marginal lands, jatropha requires high amounts of nitrogen and phoshorus fertilization (Foidl N, Foidl G, Sanchez, Mittelbach, Hackel, 1996). Cut this and leave it until after you've made the point about water/irrigation

"The minimum annual average rainfall at which JCL is known to yield a harvestable amount of seeds is 500-600mm yr-1" (Achten et al., 2008, p. 14). Studies from India reveal that jatropha grown on marginal lands without irrigation had an average yield of 1.1-2.75 tonnes per hectare after five years of growth. This is in contrast to jatropha grown on marginal lands with irrigation, which produced 5.25-12.5 tonnes per hectare after five years (Jatropha World(a), n.d.). this is great stuff! While evidence on seed yield is patchy, the data that exist reveals a strong correlation to annual average rainfall, demonstrating the potential for a 500% increase in seed yield with a higher mean rainfall (Achten et al., 2008, p. 5). Exact water and nutrient needs for jatropha in varying environmental conditions is not yet known due to limited experience with its cultivation for biofuel, however, it is evident that irrigation and fertilization would be necessary on marginal lands.

If jatropha was grown on marginal lands, but fertilizer and irrigation were used to gain sufficient yields, there would be an increased risk of jatropha crops competing with food by increasing pressure on resources needed for both crops. "If the same land and other resources are needed for both food and biofuel feedstock crops, their prices move together even if the feedstock crop cannot be used for food" (FAO, 2008). Great quote selection In other words, if jatropha biofuel production requires fertilizer and water inputs they will be competing with food crops for similar resources, even if it does not compete for land. This trend is evident in Vietnam where increases in food production led to increased competition for fertilizer. As a result fertilizer prices rose, becoming a contributing factor to mounting food prices (Bradsher and Martin, 2008). Great!

Jatropha is less likely to increase the demand for fertilizer because pressing the seed to get the jatropha oil produces a seedcake that can be used as fertilizer. Demand for water will, however, likely increase if jatropha is grown on marginal land because of the required irrigation. Increased competition for water in regions where water resources are limited will likely display a similar trend to fertilizer shortages in Vietnam with regards to food prices. Brklacich and Leybourne (1999) emphasize this link between increased competition for water and rising food prices. Therefore, growing jatropha for biofuel production on marginal lands does not evade the potential for competing with food.

Due to the production inputs for growth on marginal land, it is apparent that there is incentive to instead plant jatropha on arable land. "Reality shows that, if unchecked, Jatropha is mainly NOT planted on marginal lands, and NOT in arid areas, but in tropical areas, where the climate – warm winters and heavy rainfall – is largely conducive to food crops, which will inevitably be displaced by biofuels crops" (Clements, 2009). Great quote Further increasing the likelihood of jatropha being grown on arable land is the potential for crop switching. "An individual farmer will produce feedstock for biofuels if the net revenue he or she earns is greater than for alternative crops of uses" (FAO, 2008). This trend occurred in the United States with corn ethanol. When maize prices rose from $2.60/bushel to $4.25/bushel in March 2007, the amount of land dedicated to maize production increased by 19% at the expense of other food crops such as soyabean plantings, which declined by 15% (Naylor et al., 2007). The possibility of crop switching away from food production increases the risk of jatropha competing with food crops for land.

The claim that jatropha will not compete with food supports the belief that jatropha will not adversely affect food security by not affecting the availability of food. However, it has been demonstrated above that there are discrepancies to the facts underlying this claim. It is, however, undisputed that jatropha offers a biofuel feedstock that is otherwise inedible. Jatropha thus avoids the ethical questions raised about using food crops for fuel production in a world where hunger is rampant (Runge and Senauer, 2007). This is a significant element of jatropha that makes it unique to other popular biofuel feedstocks, such as corn ethanol. “Filling the 25-gallon tank of an SUV with pure ethanol requires over 450 pounds of corn – which contains enough calories to feed one person for a year” (Runge and Senauer, 2007, p.1). This statistic powerfully highlights the negative ramifications for food security of using food for fuel production. It is important to recognize that jatropha’s inedibility does help to lessen the negative effects of jatropha cultivation on global food security.

If jatropha does increase the price of food the repercussion for food security will be severe. Food prices are one of the most important determinants of access to food (UN-Energy, 2007). Using arable land for biofuel feedstocks will decrease availability of food by diverting good land away from food production. This decrease in availability will increase the price of food, further weakening food security by diminishing access to food.

This chain of events has sparked widespread criticism of biofuels (FAO, 2008). By the end of 2007, the price of wheat, corn and soybeans had doubled in less than two years. Wheat reached $10/bushel, corn reached $5/bushel and soybeans reached $13.42/bushel, breaking or approaching record highs (Brown, 2008). “Some countries will benefit from higher prices, but the least-developed countries, which have been experiencing a widening agricultural trade deficit over the last two decades, are expected to be considerably worse off” (FAO, 2008, p.72). These drastic price increases therefore had enormous implications for global food security because food became largely unaffordable in the developing world, sparking food riots around the globe (Adam, 2008). It was this relationship between biofuels, food prices and food security that led Jean Ziegler, the United Nations’ Special Rapporteur on the Right to Food, to declare biofuels as ‘a crime against humanity’ (Monbiot, 2008). It is evident that jatropha would pose significant danger to food security if it were to compete with food and thus contribute to rising food prices.

The potential for jatropha biofuel to compete with food is vital to consider in the Malian context. Mali borders the Sahara desert and is thus an immensely water-scarce country. The country is divided into three climatic zones: the Saharo-Sahalian, the Sahelo-Sudanian, and Sudano-Guinean zones (Butt, McCarl, Angerer, Dyke and Stuth, 2005). “The Saharo-Sahelian zone is extremely dry with an annual rainfall of 100-200mm” (Butt et al., 2005). The Sahelo-Sudanian zone has an annual rainfall of 200-400mm and the Sudano-Guinean zone has an annual rainfall of 400-800mm (Butt et al, 2005). Since jatropha requires an average of 500-600 mm of rainfall per year, irrigation will be required in most parts of Mali to produce a harvestable yield.

Agriculture in Mali is already highly constrained by limited water resources. Only 14% of this large country is suitable for agriculture, while the rest is too dry (Aune, n.d.). This will further be exacerbated with the impending effects of climate change. Various models and climate projections have revealed a drier future for Mali because of global climate change (Butt et al., 2005). Butt et al. (2003) argue that such a reduction in precipitation would result in a 15-19% decrease in cereal production and a doubling of food prices in Mali. Since food prices are known to impact access to food (FAO, 2008), increased pressure on Mali's limited water resources will clearly have drastic impacts on food security. It can thus be concluded that jatropha production will also be limited by water in Mali and therefore come into competition with food crops for water resources if irrigation is required. This would put pressure on food crops during an already volatile time for food production in Mali with potentially severe consequences for food security.

Competition with food over land is also a concern in Mali. As was mentioned above, only 14% of land in Mali is suitable for agriculture (Aune, n.d.). Agricultural land is already a rare commodity; therefore, evading competition for land is essential to protect food security in Mali. Malibiocarburant made it clear that "this bio fuel is all about yields that are harvested from jatropha plants either integrated with food crops or on kilometres of land (stretching along the roadside)" (Malibiocarburant, n.d.). Integrating jatropha with food crops by growing it with one or more food crops simultaneously in the same field is known as intercropping (Jatropha World, n.d.). Intercropping is said to have several benefits over monoculture plantations with regards to food security. "Where successful intercropping can be developed, Jatropha production will be able to go hand in hand with food production" (UNEP, n.d.), as opposed to coming into competition with food for land use. Intercropping also allows jatropha to be grown on arable land where greater yields can be realized without displacing food crops. Furthermore, intercropping provides the necessary fertilizer and irrigation for jatropha crops without additional expenditure (Singh, Swaminathan, Ponraj, 2006), thus avoiding competition with food for production inputs, the implications of which is discussed above.

Intercropping jatropha can also benefit the food crops they are intercropped with. If jatropha is planted as a fence around food crops its toxicity will help to protect crops from grazing livestock. Jatropha also "has a phytoprotective action against pests and pathogens, providing additional protection to intercropped plants" (Greco, Rademakers, n.d.). Intercropping jatropha is further said to compliment farming systems because they can help to improve the microclimate and provide humus, helping to revitalize the soil (Openshaw, 2000). These aspects of intercropping systems allow jatropha cultivation that benefits food production as opposed to competes with food production. This in turn could positively affect food security in Mali by protecting and enhancing food crops.

Intercropping could also help prevent crop switching. Since more than half of the population in Mali lives below the poverty line and over 80% of the population depends on agriculture for their livelihood (Aune, n.d.), if there was economic incentive to grow jatropha instead of food there would be a high risk of crop switching. Since Mali is already a net importer of food and agricultural goods (Aksoy, 2008), crop switching would make Mali more dependent on other countries for a consistent and sufficient supply of food. Malibiocarburant ensures intercropping by requiring farmers that they buy from to plant jatropha in rows that are 5m apart with food in between, intensive farming of jatropha will not be supported by Malibiocarburant (Vogl, 2009). As a result, each field will only be about 10% jatropha (Vogl, 2009). By planting one row of jatropha for every seven rows of regular food crops, Mr. Banani, a Malian farmer, was able to "double his income on the field in the first year and lose none of his usual yield from his field" (Polgreen, 2007). Ensuring that jatropha is grown using intercropping systems allows farmers to access the emerging jatropha industry, while preventing them from abandoning food production.

There exists a high risk for competition with food in Mali due to the current environmental and socio-economic conditions. Such competition could have negative implications for access, availability and stability of food – with the potential to decrease food security in Mali. However, the jatropha project in Mali, being undertaken by Malibiocarburant, appears to be designed in such way that helps to avoid both direct and indirect competition with food, and thus decrease the likelihood of negative impacts on national food security. This discussion highlights the importance of the project design when assessing the impact on food security. A thorough analysis of the potential for jatropha biofuel production to compete with food crops must be undertaken prior to pursuing jatropha projects in Mali and elsewhere around the world to avoid negative implications for food security.

Rural Development

One of the groups that might have the most to gain from the recent 'biofuel boom' are rural producers. An expanding biofuel market may offer new markets for agricultural producers and thus new opportunities for rural communities (World Bank, 2008, p.70). "The emergence of biofuels as a major source of demand for agricultural commodities could help revitalize agriculture in developing countries, with potentially positive implications for economic growth, poverty reduction, and food security" (Pingali, Raney and Wiebe, 2008).

Jatropha is widely acclaimed as a biofuel crop that can live up to these heightened expectations and significantly contribute to rural development (Henning, 1996; Jatropha World, n.d.; Openshaw, 2000; Kumar and Sharma, 2008). Rural development can be generally understood as "development that benefits rural populations; where development is understood as the *sustained* improvement of the population's standards of living or welfare" (Andriquez and Stamoulis, 2007). The critical role that agriculture plays in rural development was recently reasserted in the 2008 World Development Report (World Bank, 2008). Agricultural growth in China was largely responsible for the decline in rural poverty from 53% in 1981 to 8% in 2001, a major improvement (FAO, 2008, p.26). The potential for jatropha cultivation to contribute to rural development is thus well supported.

Jatropha is expected to boost rural development by increasing employment in rural areas. The World Bank (2008) has recognized that the priority of rural development policy should be to create more jobs in agriculture and the rural nonfarm economy. However, "creating jobs in rural areas is a huge and insufficiently recognized challenge" (World Bank. 2008, p.17). Jatropha biofuel production could help overcome this challenge by creating employment for seed harvesters (this is still done manually), as well as opportunities in processing and running the biofuel production plant. Since jatropha biofuel production is in its nascent stages of development it is too soon to be able to assess the industries impact on poverty reduction in rural communities. However, similar trends have already been observed in Zimbabwe where jatropha crops have created many new jobs and is already claimed to be significantly contributing to poverty reduction (ANSI, n.d.). Job creation has been reported in other biofuel industries as well. In Brazil, for instance, the sugar cane ethanol industry has created approximately 300,000 jobs, many of which are in rural communities and 60,000 of which went to small farmers (Braun and Pachauri, 2006).

Jatropha biofuel production further increases income-generating activities through soap production. When jatropha oil is turned into bio-diesel through a process known as trans-esterfication, glycerin is produced as a by-product. The glycerin can then be used to make high quality soap that can be sold "in local markets and nearby towns, increasing the possibilities of earning income with local resources" (Henning, 1996). Traditionally it is women who make the soap (Henning, 1996). It is widely acknowledged that increasing the social and economic participation of women has profound benefits for rural development, sometimes more so than increasing income for males since “women are more likely than men to use their earnings to improve their living situations and to educate their children” (Grameen Bank, 2009). Soap production is therefore a very valuable by-product of jatropha biofuel production in terms of rural development.

Jatropha would also provide a source of affordable, usable energy to rural communities. This could lead to profound improvements to the local economy and lifestyle. Jatropha biofuel can be used to run generators, vehicles, grain mills and other technologies. Each of these would offer new opportunities to rural communities and can help to stimulate development through agricultural and economic growth. This link between the introduction of energy and rural development is powerfully demonstrated in the case of Bhoksing Village, Nepal. Once the village was able to generate electricity various new income-generating activities became available and the residences of the village experienced a significant improvement in their quality of life (UNDP, 2005).

Jatropha also has the potential to enhance energy security by providing a local energy source, thereby reducing dependence on imported fossil fuels (Jatropha World, n.d.). “Energy today is at the heart of every economic, environmental and developmental issue…developing countries need to expand access to reliable and modern energy services to alleviate poverty and increase productivity, to enhance competitiveness and economic growth” (UNIDO, 2008, p.6). This illustrates the link between energy security and rural development and thus the importance of this claim. Can you rewrite this final sentence to give it a little more oomph?

However significant debate and discrepancies also exist over the claim that jatropha biofuel production will inherently contribute to rural development. First, it is argued that we do not yet know enough about jatropha biofuel production to fully understand the associated benefits and risks (Achten et al., 2008). Therefore, it is too early to be confidently singing praises for jatropha's role in rural development. This is evident in India's rapid push for jatropha cultivation. Some farmers argue that the government's promise that jatropha would stimulate economic development in rural economies has yet to be realized due to failing yields and unexpected production costs (Acharya, 2009). This supports the need for further research on jatropha biofuel crops prior to reaching reliable conclusions on jatropha's role in rural development goals.

Furthermore, there are inherent challenges to rural populations benefiting from large-scale agricultural production initiatives (Pingali, Raney and Wiebe, 2008). Two FAO reports (FAO, 2004; FAO, 2005) have highlighted barriers to technological innovation and access to trade as the two key constraints facing developing countries that are trying to benefit from agricultural growth. Weak infrastructure in developing countries may favour large-scale commercial farms over small-scale agriculture (Dorward, Kydd, Morrison, Urey, 2004). An increasingly globalized economy also tends to put small-scale agricultural producers at a disadvantage to large transnational corporations (TNCs) (Dorward et al., 2004). This favouring of large agricultural industries increase land concentration and may reduce access by the poor to land (Peskett, Slater, Stevens, Dufey, 2007). Furthermore, this agriculture system means that most countries see only a small portion of the population profiting from agriculture (UN-Energy, 2007). Such tendencies in the current agricultural system limit the potential for agriculture to contribute to poverty alleviation in rural communities, thus weakening the link between agriculture and rural development.

"A key question often overlooked in the biofuels debate is whether there is anything new or different about biofuels that could allow developing countries to overcome these constraints in ways that support agricultural growth, poverty reduction, and food security" (Pingali, Raney and Wiebe, 2008). It is argued that large-scale biofuel production, including jatropha, will present similar impediments to rural development as have other agricultural crops (Peskett et al., 2007). The argument that jatropha biofuel production will inherently contribute to rural development is thus flawed since it does not take into account the varying factors that determine the effects of agriculture on rural economies, including the nature of the industry and the specific characteristics of each country.

The claim that jatropha will necessarily improve energy security is also disputed. If biofuels are grown solely for export to supply the growing global energy demand, rural communities will continue to face energy insecurity (Pressend, 2008). This has happened in Malawi where jatropha oil is exported to Europe for conversion into biodiesel rather than used to meet the local energy demands (PANOS, 2006). Good The discussion around jatropha and energy security highlights another way in which the design of the program will influence jatropha's contribution to rural development.

This debate around jatropha's contribution to rural development is critical to consider when assessing the implications of jatropha biofuel on food security. Since access to food largely depends on levels of poverty and the purchasing power of households (FAO, 2008), the potential for jatropha biofuel production to increase employment and household income in rural communities could significantly improve this dimension of food security. Therefore, if jatropha biofuel can raise the incomes of small farmers and rural laborers in developing countries, then it may play an important role in improving food security in developing countries.

The potential for rural development is enormously important in Mali where 70% of the population lives in rural villages (FAO, 2006). Even more importantly, 75% of the population that is below the poverty line lives in these rural areas (FAO, 2006), highlighting the tendency for poverty to be a predominantly rural phenomenon. If jatropha biofuel production is able to contribute to rural development in Mali, food security could be significantly strengthened.

Due to the nature of the biofuel program being implemented by Malibiocarburant, Mali will likely experience enhanced rural development from the jatropha initiative. Malibiocarburant has formed a relationship with a local women's cooperative that will buy the glycerin to make soap. This helps to ensure that women are gaining direct access to the benefits of jatropha biofuel production and provides them with an income generating activity, increasing employment and reducing poverty in the community. Malibiocarburant is also keeping every stage of the biofuel production process local, including the biofuel plant, offering maximum opportunities for local employment.

Another promising feature of the Malibiocarburant project is the focus on meeting local needs first. The program is designed to help solve the energy needs of rural communities and to reduce poverty across the country. The National Centre for Solar and Renewable Energy in Mali has had numerous businesses from around the world interested in developing a jatropha biofuel industry in Mali, however, they have all been turned down because Mali is not interested in producing jatropha biofuel for export until the countries own needs have been met (Reuters, 2007). Since Mali is not harvesting jatropha for export, the concerns about constraints and access to trade are avoided.

Because Mali is dedicated to meeting local energy needs first, jatropha can contribute to energy security, further contributing to rural development. This is an incredibly significant feature of jatropha for a country like Mali who is currently heavily dependent on imported fossil fuels. Furthermore, 99% of the rural population lacks energy services (FACT, n.d.). As discussed above, energy security can have profound benefits for rural communities. Having a local energy source would make farmers less vulnerable to fluctuations in world oil prices, which in turn could help to stabilize food prices and therefore stabilize access to food. Introducing energy into rural communities could also stimulate economic growth and improve the standard of living. Good stuff.

In Mali, small-scale farmers supply the jatropha nuts to a farmers union who then extracts the oil. The union sells this oil to Malibiocarburant for producing biofuel. This business structure further adds to the potential for Malibiocarburant to effect development in rural communities. A recent UN report on sustainable bioenergy (UN-Energy, 2007) emphasizes the value in such a system; “there are numerous examples of successful cooperative structures where several independent SME (small and medium sized enterprises) biomass producers work together to supply larger facilities or markets. The development benefits of bioenergy are enhanced dramatically when more people own more of the value-added chain” (p.17).

Malibiocarburant runs a similar business model to the wildly successful milk cooperatives in India since both involve farmer cooperatives. Cooperatives of small-scale farmers organizing together to protect and control the production and sale of their milk sprung up around India starting in 1946 (The Indian Dairy Industry, n.d.). These cooperatives have substantially enhanced incomes for millions of India’s poorest small-scale farmers (Kurien,). For this reason, this business structure has been hailed as a model for rural development, a model that puts development in the hands of the farmers that serve to benefit (Kurien, 1996). This demonstrates the potential for Mali’s farmer cooperative to improve livelihoods of rural jatropha growers. Furthermore, the farmer union owns 20% of Malibiocarburants shares (Malibiocarburant, n.d.). “Thus farmers have direct benefits through the sales of products and they also share in the increased value of the shares as well as dividends that are foreseen" (Malibiocarburant, n.d.). This further offers opportunities for increased incomes in rural communities and prevents profits from accumulating in the hands of only a few.

Malibiocarburants' dedication to intercropping jatropha should also enhance the contributions to rural development. Intercropping jatropha with other crops prevents dependence on only one crop, offering a diversification of income (Jatropha World, n.d.). This is important since jatropha is in its infancy as a domesticated biofuel feedstock. It is recognized that significantly more research must be undertaken prior to an expansion of jatropha biofuel production to avoid unfulfilled promises and negative social or environmental consequences (Olden, 2007; KnowGenix, 2008; Achten et al., 2008). This illustrates the risks of becoming reliant on jatropha for one's livelihood. An Indian study undertaken by Meena and Sharma (2006) revealed that 99.5% of tribal farmers and 98.8% of non-tribal farmers felt that a lack of marketing facilities to sell jatropha was the biggest constraint for jatropha growers in India. This is one example of a risk jatropha farmers may confront if they become reliant on a successful jatropha industry at this early stage of development. Intercropping therefore further protects food security by enhancing stability of income, one of the four dimensions of food security (FAO, 2008).

It is evident that the jatropha biofuel program in Mali demonstrates tremendous promise for rural development in Mali. This would have numerous benefits for food security in the country since rural development is so tightly intertwined with access to food, a critical dimension of food security. If access to food were improved by jatropha biofuel production in Mali, this would make jatropha remarkably different than other biofuels in the past, which have been heavily criticized for decreasing access to food around the world (Naylor et al, 2007).