

**AC 2008-1306: THE DEVELOPMENT OF AN ECONOMIC MODEL FOR
BIODIESEL PRODUCTION IN GHANA**

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The Development of an Economic Model for Biodiesel Production in Ghana

Abstract

In this paper, the results of a project in which an interdisciplinary team of honors students travelled to Ghana in West Africa for the purpose of developing an economic model of biodiesel production from energy crops in this region is described. The students included majors in engineering, business and finance, economics, and global studies. Student teams were divided into three broad categories: a science/engineering team, a business/economics team, and a cultural/infrastructure team. While each student had a primary team responsibility, they were also required to work across team boundaries to ensure integrated and realistic solutions emerged from their efforts. The ASU team initially met with students and faculty from the Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi, Ghana, a partner university with ASU in this study. They travelled to Biemso, a small rural village in which a project is underway to produce biodiesel fuel from the oil seed bearing plant known as *Jatropha Curcas*. In addition, they travelled both to major cities and to other rural villages to study the economic environment of Ghana.

The result of the project is a comprehensive model of the feasibility and the best management practices for the production of biodiesel from crops as a tool for economic development, and has resulted in the production of seven undergraduate honors theses at ASU

The project described in this paper is part of a larger interdisciplinary initiative at ASU known as GlobalResolve, in which entrepreneurial models for economic progress in developing countries are pursued. This leads to unique design constraints on projects that result in very rewarding experiences for the students that are involved.

Introduction

Biodiesel development is one component a sustainable energy solution, especially in developing countries where biomass is readily available. One source of biodiesel is *Jatropha*, a shrub that grows wild in many tropical global locations. It is susceptible to frost, but otherwise is very hardy and produces fruit that can be pressed for oil which can be further processed into diesel fuel. This paper describes a student project in the GlobalResolve program at Arizona State University (ASU) to investigate developing a biodiesel economy for African villages by cultivating *Jatropha curcas*. A team of multi-disciplinary students from the Honors College at ASU traveled to Biemso, Ghana, in which faculty and students from Kwame Nkrumah University of Science and Technology have undertaken a United Nations sponsored project to grow *Jatropha Curcas*. In addition, the students travelled to other rural villages in Ghana as well as the major cities of Kumasi and Accra to study the economic and business environment, as well as the technical infrastructure, in the area. This paper describes the GlobalResolve program and this biodiesel project that has the goals of providing students global experience in problem solving and plans to help the village develop a plan for a sustainable biofuels venture.

Global Resolve at ASU

The biodiesel project described in this paper grew out of an interdisciplinary intercultural initiative at ASU called GlobalResolve. GlobalResolve was established at ASU in 2006 as a social entrepreneurship program designed to enhance the educational experience for interested and qualified students by involving them in semester-long projects that directly improve the lives of underprivileged people, and/or those in under-developed nations throughout the world. Through GlobalResolve, ASU students and faculty collaborate with international universities, residents of rural villages, local governments, financial institutions, and non-governmental organizations (NGOs) to develop and disseminate “no-tech”, “low-tech”, and “high-tech” solutions that address pressing public health or environmental needs of a developing-world population. Because solutions developed by GlobalResolve are designed to be replicable locally, regionally, and internationally, the solutions also create the potential for profitable new business ventures that generate sustainable income streams for impacted populations.

The method of operation of GlobalResolve emphasizes global student teaming to solve local problems. Candidate villages are identified, local needs are surveyed, and technological solutions are developed that can form the basis of new entrepreneurial ventures within the village. This requires a collaborative effort on the part of ASU, the rural village, local universities, local government and financial institutions, and NGOs. In addition to the evaluation of biodiesel crops described in this paper, GlobalResolve initiatives have included the development of a water purification system for the impoverished village of Famanye, Ghana, production of gelled ethanol fuel for cooking in the Ghanaian village of Domeabra, the development of a neurosurgical medical device for healthcare in South Africa, and the assessment of wind energy on the Hopi Reservation in northern Arizona.

The Biofuels Project

The motivation for this biofuels project is that the development of liquid transportation fuels from biomass, such as ethanol or biodiesel, holds promise as a possible solution to both economic and environmental problems caused by the accelerating use of petroleum throughout the world. Since both biodiesel and ethanol are derived from solar energy captured through the photosynthetic process, they are considered to be renewable fuels. Ethanol is a fuel suitable for Spark Ignition (SI) engines that is obtained through fermentation of biomass, followed by distillation to purify the product. Biodiesel is a fuel consisting of processed vegetable oils or animal fats that can be utilized as a primary fuel in Compression Ignition (CI) engines, either directly or blended with petroleum derived diesel fuels. Biodiesel fuel may be obtained from waste, such as used cooking oil or as a byproduct of animal slaughter, or it may be grown directly as an energy crop. Dozens of potential energy crops for biodiesel have been proposed, including soybean, castor beans, palm oil, rapeseed (canola), jatropha, sunflower, and even algae.¹

There are several advantages to biodiesel that have resulted in intense research and development efforts worldwide. First, it is a direct substitute for fossil fuels. While some fossil fuels are consumed in the production of biodiesel, in the United States it has been estimated that the return on the energy investment is 3.2 times the input energy required². Second, the direct carbon signature of biodiesel usage is zero since the carbon contained in biodiesel has been fixed

through the photosynthetic process that removes CO₂ from the air. (Assuming the energy required to produce biodiesel is obtained from fossil fuels, this number increases but remains well below the carbon signature of direct utilization of an equivalent amount of petroleum based diesel fuel.) Third, at the tailpipe diesel engines operating on biodiesel produce lower direct emissions of Carbon Monoxide (CO), particulates (PM), hydrocarbons (HC) and sulfur compounds. Fourth, in comparison to petroleum based diesel fuel, biodiesel reduces the emission of specific hazardous chemical compounds, including some that are suspected of causing cancer, by as much as 90%. Fifth, biodiesel has been shown to increase the lubricity of Ultra-low Sulfur Diesel fuel (ULSD). Finally, biodiesel fuel is relatively easy to manufacture and use so that almost immediate and significant market penetration presents minimal technical problems, as long as it is economically feasible.

The question of economic feasibility of crop-based biodiesel is a very important problem, but answers are elusive for several reasons. First, biodiesel competes directly with petroleum based diesel fuel and it is not enough to simply demonstrate technical feasibility. In addition, it must be shown that production costs can be close enough to petroleum diesel that *reasonable* government based incentive programs and tax structures can make the product competitive. Second, it is difficult to draw general conclusions concerning the performance of biodiesel crops because agriculture is highly dependent on local conditions and because determining the energy required to produce and process the crop is difficult. For example, the crop that produces the best yield in a tropical rain forest is unlikely to be the same as the best crop in a desert environment. A crop grown in close proximity to a processing facility with a customer nearby in need of the product is more likely to be economically feasible than one which incurs large transportation costs. Third, many of the regions in the world that are most suitable to the growing of energy crops are in developing nations with struggling economies, which can benefit a great deal should these resources prove economically viable. However, the economics of biodiesel in developing countries is very different than that in developed regions with well-established modern economies and infrastructures. Consequently, what is needed is a general model for biodiesel crop evaluation that accounts for all these variables and can be easily modified to predict economic feasibility of potential biodiesel crops once the base inputs have been determined, and the development of such a model by the students was the goal of this project.

In this paper students evaluated the potential for biodiesel production of the plant known as *Jatropha curcas*. *Jatropha curcas* is an indigenous plant that grows wild in tropical climates throughout the world, including West Africa, and produces an abundance of oil-bearing seeds³. The plant is toxic, and is widely used in hedges around fields to keep domestic animals out of crops. The plant thrives in poor soil and is drought tolerant. Due to these attributes it has been identified as a promising plant for the production of crop-based biodiesel fuel, and pilot projects to grow *Jatropha* are underway in several places, including Ghana⁴. Consequently, because of these ongoing projects and the availability of at least some data on this plant, it was decided to use *Jatropha* as the base for this study.

The problems of the developing world are not simple to solve, and effective solutions require the contributions of experts from many diverse fields all working toward a common goal. To properly engineer a viable system in this environment requires an interdisciplinary team consisting of experts in agriculture, health and medicine, local cultures, economics and supply

chains, product design, micro-financing, and other disciplines. The team that has been assembled for this project consists not only of experts in these areas, but these experts have been assembled from all over the world. Consequently, this initiative is involving students and faculty in a project that is truly “three dimensional.”

The genesis for the biodiesel project in Ghana occurred in May of 2007 when a team of students and faculty from ASU and KNUST in Kumasi, Ghana met in Kumasi to explore joint research projects. In that meeting the challenges that face the development of renewable energy technologies throughout the world, and the need for a comprehensive model for evaluation of biodiesel crop potential, was discussed. It was pointed out that the United Nations project that had just been initiated at Biemso provided a testbed for the development of such a model. The ASU team and KNUST faculty and students involved in the project visited the village of Biemso, met with the Chief who had donated the necessary land, and visited the *Jatropha* fields, which were just being readied for planting. The seedlings are shown below in figure 1.



Figure 1. *Jatropha* Acreage near Biemso

Upon returning to the United States, the team contacted the ASU Barrett Honors College to seek support for the project, and the student team was assembled. Honors College students are required to produce an undergraduate thesis that demonstrates a meaningful advancement of knowledge in the students chosen field. In this case, the students will produce a team thesis during the spring semester of 2008 based on their work on this project

Project Description

The specific problem statement given to the students was to develop a comprehensive economic model of the feasibility of biodiesel production from the indigenous plant known as *Jatropha Curcas* in West Africa. Three students on the team (two chemical engineering and one design) are responsible for the technical and engineering requirements of the project, including evaluation of technology and processes suitable for use in West Africa, and to present these results as an input to a comprehensive economic model. Four students (economics, business and global studies) are responsible for understanding the economic system in Ghana, determining and evaluating the cultural and systemic constraints that are present, and quantifying these results in such a way that they can be fused into the general economic model. Finally, all students are responsible for the integration of information into the final economic evaluation.

To gather the information needed for the project, the students travelled to Ghana with faculty from ASU in January 2008. They initially met with faculty and students at KNUST. Following these meetings they, along with their Ghanaian partners, travelled to Biemso as well as other rural villages in Ghana, and to the major cities of Accra and Kumasi, to study the economic and technical infrastructure of the country. The specific project plan is described in the next section.

Project Plan

The schedule for the Ghana trip is shown below in figure 2.

Wed. Jan. 2	Leave Phoenix, Midnight Jan 1st
Thu. Jan. 3	Arrive Accra 8AM, drive to Kumasi, late afternoon arrival.
Fri. Jan. 4	Meetings at KNUST.
Sat. Jan. 5	Visit Biemso about <i>Jatropha</i> and biodiesel
Sun. Jan. 6	Return visit to Biemso
Mon. Jan. 7	Visit Domeabra
Tues. Jan. 8	Visit to Suame Magazine, return to KNUST for wrap up
Wed. Jan. 9	Return to Accra
Thur. Jan. 10	Business in Accra
Fri. Jan. 11	Leave Accra 8:30AM, return to Phoenix at 11:00PM

Figure 2. Ghana Trip Schedule

To maximize the value of the trip, each of the sub-teams developed a detailed project plan detailing specific information they needed to obtain to complete their portion of the project. They evaluated the most likely source for this information, and assigned specific data gathering responsibilities to individual team members, including specific questions to be asked during meetings with Ghanaian partners. Each evening, the team met to discuss progress in obtaining the needed information, new problems and questions that have arisen, and modified subsequent schedules and responsibilities accordingly. As an example of this planning, the Engineering team developed the following plan for the meetings with KNUST faculty on January 4th and students and the subsequent trip to Biemso on the 5th.

Answers we are seeking:

1. Is jatropha oil (or any oil based on a similar plant with similar extraction procedures) currently extracted with proficiency in area of interest?
2. Assuming 1 is true, what mechanism is being used to extract the oil?
 - a. What processes for extraction
 - b. Growth of the plant – (Economic problem)
 - c. Is there a better way of doing things?
3. What is the standard composition of jatropha plant and constituents?
 - a. What is the plant/fruit like?
 - b. Where is the highest concentration of oil?
 - c. What is the most economical way to get oil out of the plant? (Engineering problem – maximize price and oil content extraction)
 - d. Are there any contaminants located in oil?
4. What machinery is necessary to bring about production of useful Jatropha byproducts, and is the manufacture of these byproducts cost-effective based on current substitutes?
 - a. Can current machinery be used with Jatropha?
5. How are products like soap and fertilizer currently made?
 - a. How much do soap and fertilizer currently cost in the market? Are they imported? Would local production be cheaper?
 - b. If commercial use is not profitable, what is the method for disposal of these byproducts?
 - c. Is it safe and environmentally friendly?
6. What biodiesel production facilities currently exist in Ghana, and is it possible to get a tour?
7. How easy is it to get land dedicated to things like this? What kind of local and national government procedures would be required to install a new processing plant, and on what land could it be done?
8. What are the environmental regulations, and how are hazardous or potentially hazardous chemicals transported in Ghana?
 - a. What are the transportation costs?
9. What are the hazards associated with Jatropha production?
 - a. Flammability
 - b. Toxicity (Jatropha is quite toxic.)
 - c. Have there been any injuries or deaths related to Jatropha in Ghana?
10. Is anyone investigating alternative uses of Jatropha such as:
 - a. Soap from glycerin
 - b. Fertilizer from the seed cake
 - c. Leaves to feed silkworms
 - d. Blue dye from bark
11. Is anyone considering Jatropha as a comprehensive energy resource?
 - a. Combustion of seedcake briquettes
 - b. Jatropha oil for lamps
 - c. Jatropha boilers
 - d. Jatropha oil for cooking
12. Discern from chief what he expects of us, and his “master plan” for the village
 - a. Determine the availability of non-tilled land for Jatropha
 - b. Determine farmers willingness to convert to Jatropha

- c. Inspect *Jatropha* plants, especially the seeds
- 13. Evaluate how villagers interact with their environment and with technology
 - a. See how they deal with toxic substances
 - b. Observe their cooking practices.

Both teams planned the entire trip in similar detail to that shown above. This trip occurred after the paper was submitted. Therefore, the answers to these questions and results of the trip will be presented at the ASEE conference for this paper was written and an addendum will be available by contacting the authors.

Conclusions

In this paper a unique capstone project has been described in students worked with outstanding academic records worked as part of an international, interdisciplinary, intercultural team to critically evaluate the economic potential of the bio-crop *Jatropha curcas*, a problem which is of critical importance to the rapidly evolving biofuel industry, much of which is located in the developing world. In addition, the students developed a general economic model of the problem with well defined inputs which can be extended to similar problems throughout the developing and developed world.

As the global economy develops, it is becoming increasingly clear that effective solutions require the contributions of experts from many diverse fields all working toward a common goal. The evaluation of the economic potential of an energy crop requires an interdisciplinary team consisting of experts in agriculture, health and medicine, local cultures, economics and supply chains, product design, micro-financing, and other disciplines. The project that was described in this paper involved such a diverse team, and has been an invaluable learning experience for all of the students involved in the project.

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