Future of Kaʻū Farm Land: Ecological & Economic Analysis for Land Use Decision Making

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Executive Summary

Hawaiʻi Island's southern region of Kaʻū contains a 12,000-acre site in the town of Pāhala, where the construction of a biofuels production facility has been proposed to provide electricity and transportation fuel to the Island. Local farmers and ranchers lease this land, owned and managed by the Olson Trust, for diversified agriculture – mainly cultivating coffee, macadamia, and cattle grazing. However, future uses for the land are in question due to a proposal to cultivate biofuel feedstock, which may cause the Olson Trust land to become unavailable to current lessors.

This report examines the biofuel proposal and diversified agriculture activities through the lens of environmental capacity – water as a limiting resource – and then moves on to making economic analysis based on the possible land-use decisions.

Five scenarios for land use allocation were developed, based on availability of tillable land and current and projected usage of land based on market demand for production. The requirements for each activity were then assessed and total water demands were calculated to determine feasibility. After the feasibility confirmation, the options were then processed to see which of scenarios based on water availability could yield highest revenue and benefit the local community directly.

Based on estimates, water need for biofuel feedstock does have an advantage over macadamia nuts and truck crops but not over cattle grazing and coffee production. Therefore, only two scenarios were within the range of water budget and were thus chosen to be assessed according to economic benefits. With the USDA National Agricultural Statistics Service's Hawaiʻi Annual Statistics Bulletin data, average revenues for each land use were used. Overall, the scenario that does not introduce biofuel feedstock to the region is most beneficial to the Kaʻū region in terms of revenue stream. Even when compared with the current production level which does not maximize the land use, the introduced biofuel feedstock scenario created less revenue for the local community.

There are other resource inputs and limitations that should be considered in future studies for agricultural growth and development in Kaʻū. However, this study, focused on water limitations, provides a starting point for more holistic economic input-output analysis of land use.

Introduction

Hawai‘i Island’s southern region of Ka‘ū contains a 12,000-acre site in the town of Pāhala, where the construction of a biofuels production facility has been proposed to provide electricity and transportation fuel to the Island. Local farmers and ranchers currently earn their livelihoods on this land, which will become unavailable for such activities should the biofuels proposal succeed. Using a comparison report by a team led by Lynette Leighton and three fellow graduate students as a basis, this report expands its attention to the economic comparison of proposed biofuel feedstock production with diversified agriculture and ranching.

History

Ka‘ū district is located at the southern part of Hawai‘i Island, about 20 miles away from active volcanoes (Figure 1). The agriculture district of Ka‘ū is concentrated in the area around Pāhala and Wood Valley (Melrose & Delparte, 2012, p. 77). The 12,000 acres of land proposed for biofuel feedstock cultivation is located in the small town of Pāhala, with about 1,300 residents as of 2011. Most of the town’s history of settlement and land use is dominated by the sugarcane industry, which came to an end in 1993. The major economy of Pāhala today consists of macadamia orchards, coffee farming, vegetable farming, and cattle ranching.

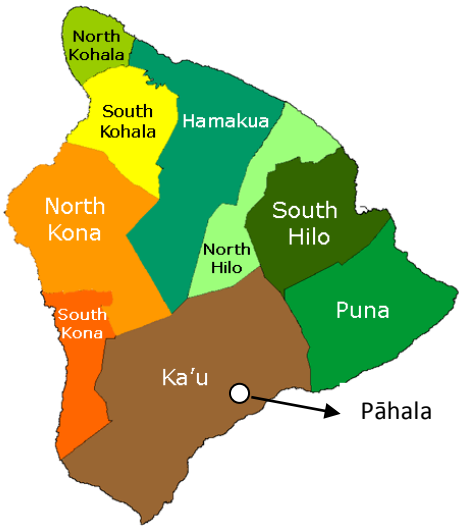

Figure 1. Districts of Hawai‘i Island[2].

[1] US Census 2010 Demographic Profile for Pāhala CDP, Hawai‘i [http://factfinder2.census.gov/faces/nav/jsf/pages/community_facts.xhtml]
[2] Big Island of Hawai‘i Districts [http://www.to-Hawai‘i.com/big-island/districts.php]

The sugar cane cultivation in Pāhala was controlled by C. Brewer & Co. for about 100 years, with many of the residents of Pāhala having historic ties as employees (or descendants of employees) of the sugar plantations. Large tracks of land were available for purchase once "Big Sugar" came to an end in the mid-1990's, which were divided and bought by several people – Mr. Edmund C. Olson owning 10,000 acres, which are managed through the Edmund C. Olson Trust II ("Olson Trust"), and Asha and Monika Mallick, who own 2,000 acres, managed by the Mallick Trust.

With the end of "Big Sugar," local ranchers and farmers have been able to lease parcels of land from the Olson Trust to for agricultural activities while retaining the character of the Kaʻū area, as per Mr. Olson's vision for the land (Burnett, 2011). Approximately 6,000 acres of the Olson Trust lands are used for cattle ranching, with about 10,000 head of cattle for grass-fed beef production. Approximately 1,300 acres are used for macadamia orchards, 500 acres for coffee, and 200 acres allocated to "other than pasture" uses (such as harvesting platforms, roads, the Kaʻū Coffee Mill). There are 425 acres of land leased for "truck crop and tropical fruits" cultivation, of which the vegetables are sold at local markets.

Land Analysis

Environmental Properties of the Land

1) Water

Even back in the "Big Sugar" days, this land was not irrigated despite being on the dry side of the island that receives only about 40 inches of rainfall per year. Much of the land remains not irrigated even with current development of ongoing agricultural activities, relying mostly on rainfall. The rapid runoff of rainwater due to the steep slope of the area, combined with the porous soil that does not retain much water, poses yet another challenge in growing crops on all of the land. On top of poor retaining power, these areas may receive totals exceeding half of their average annual rainfall within a day or a few hours.

Figure 2 shows the current agricultural activities as well as the limited irrigation (indicated by the blue lines, and springs by blue circles) system currently in place. There is a 13-million-gallon reservoir uphill of the land (Figure 3) that the Olson Trust is currently repairing in hopes of utilizing stored water in future irrigation projects. A number of pipelines (renovated remnant flume systems used to transport sugar cane for processing) that aim to direct water from the Alili Springs above Wood Valley to the Olson Trust lands are already in place and more

are under construction (Cross, 2013). The available water from springs is estimated to be 3-5 million gallons daily and not all of the water is currently captured by the irrigation system (Melrose & Delparte, 2012, p. 78). Currently, one million gallons of water flow down to Olson Trust land and there is some room for more irrigation.

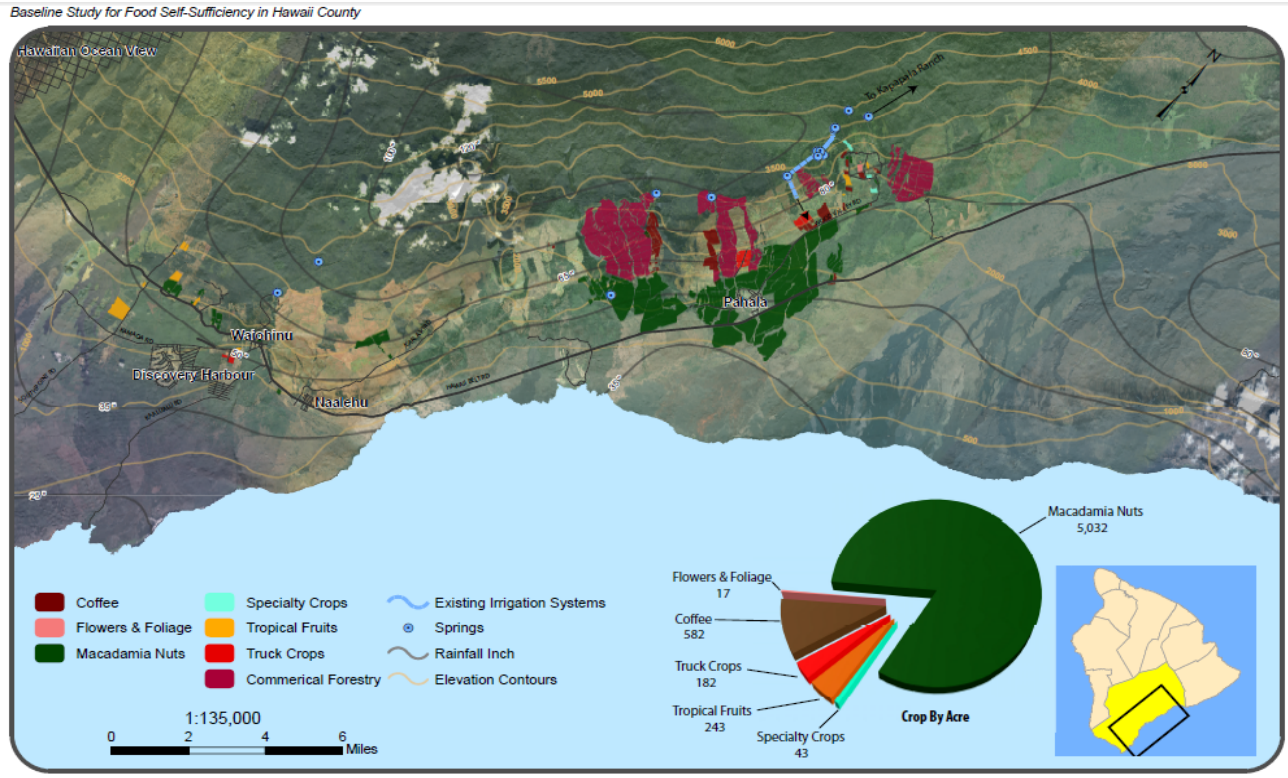

Figure 2. Agricultural crops, irrigation and slopes of the land (Melrose & Delparte, 2012).

Any large-scale agricultural development should consider water as a key limitation. The entire area of the 12,000 acres cannot realistically be irrigated (note concerns listed in "Topography" below). This is made clear by the fact that the current irrigated lands are concentrated near northern region near the reservoir. Irrigation is a challenge for the southern part of the region. Thus, reliance on rainwater should be the primary source of water for any crops being cultivated in this area.

Figure 3. The Reservoir Uphill on Olson Trust Land

2) Soil

Most of the contested land is categorized as "Alpai hydrous silty clay loam, 10-20% slope," which has little to no potential to be the source for topsoil (Natural Resources Conservation Services, 2013). Topsoil and parent material on the 12,000 acres itself are not uniform. Some areas contain parent soil from lava rocks, with other areas contain soil formed from the settling of volcanic ash over time with no parent soil. There are patches of 6-8 inches of topsoil scattered throughout the Olson Land – considered to be fertile areas originating from former lava flows. However, much of the land is marginal, dry, steeply sloped, and rocky; best suited for pasture (Cross, 2013). Short-rooted foliage is most appropriate in terms of plantings due to the minimal parent soil. Natural Resources Conservation Services (NRCS) soil survey does not designate the area as prime farm land (Natural Resources Conservation Services, 2013).

Furthermore, it is estimated that only around 30% of the land is actually tillable, making it extremely difficult for wide-scale cultivation (Cross, 2013). Most, if not all, of the land was once used to cultivate sugar, despite the topographic challenges. However, the land required high amounts of fertilizer inputs due to the virtual lack of nutrients in the porous soil, compounded by the continual downhill runoff into the ocean during rainfalls.

Most of the soils in this area are recommended for use as pasture or woodland. The soils are very rocky, and would be practically impossible to work, so it would be necessary to focus on tree crops for this location. The soil types will only be mentioned by name, as there is so much variance on the mountain slope that it would make a detailed listing cumbersome (Hawaiʻi Agriculture Research Center, 2006).

3) Topography

The elevation of the 12,000 acres changes from 1,700 feet to 3,000 feet (Figure 4). Mr. John Cross, Land Manager of the Olson Trust, noted the historic challenges of cultivating and harvesting sugarcane on such steep slope[3]. Upper elevation pasture lands near the Kaʻū Forest Reserve (to the west of Pāhala) are most ideal for cattle grazing while the lower lands provide productive seasonal agriculture when there is sufficient rainfall (Melrose & Delparte, 2012, p. 78). Thus, the cultivation and harvesting of any agricultural crop at higher elevations with steeper slopes, which is a majority of the land, will pose a challenge. The land seems to fall under the label of "underutilized" mostly due to the topographic features that make it difficult for machinery to access.

4) Vog

Kaʻū's proximity to the Kilauea Volcano contributes to the environmental and health impacts of "vog" (smog produced from volcanic ash that is continually emitted). Negative health impacts in the inhabitants of Kaʻū have been documented over the years, as well as crop losses experienced by several flower growers, ranchers experiencing health issues in their livestock, as well as the burning of eucalyptus tree leaves in surrounding areas and the rapid deterioration of metal fencing (Melrose & Delparte, 2012, p. 78). Thus, crop losses from vog must be considered for any agricultural production in the Kaʻū Region. However, the vog damage was nullified in this report with an assumption that vog will affect all crops equally.

[3] Mr. Cross mentioned that back in the "Big Sugar" days, tractors and combine harvesters were sent uphill in pairs – one that would act as an anchor, with the other tied to it to harvest the sugar cane. Otherwise, tractors and combines would roll down the steep hills. The topography of the region has not since changed.

Current Land Uses

Total Land Area (acres)	Cattle	Macadamia	Coffee	Truck Crop	Total Land Used	Land not Utilized
12,000	6,000	1,300	500	425	8,225	3,775

Table 1. Land Distribution

Cattle Grazing

About 6,000 acres of Olson Trust land are currently used for cattle grazing. Due to the limited tillability of the land combined with the recent increase in demand for grass-fed beef in the state of Hawaiʻi, we expect to see an increase in land use for cattle grazing. This is especially true for the land in Kaʻū as the productivity of the pasture land ranges from 10,000 to 16,000 lbs with an average of 14,000 lbs of cattle per acre per year based on the USGS soil survey. Cattle grazing is not mechanized and there is no input of energy, irrigated water or fertilizer for the operation. As a result, cattle grazing is the least resource intensive activity among other alternatives given that the capacity of the land is not exceeded. However, it should be noted that long term need for irrigation of pasture land for finishing pasture may be necessary as grass-fed beef industry continues to expand.

A majority of the cattle that graze on Olson Trust land are shipped to the mainland for finishing prior to being slaughtered, with the meat shipped back to Hawaiʻi. The rest of the cattle are given finishing feed, which is imported from the mainland (Galimba, 2013). The system boundary for the cattle grazing flow diagram (Figure 4) represents the activities that take place on Olson Trust land.

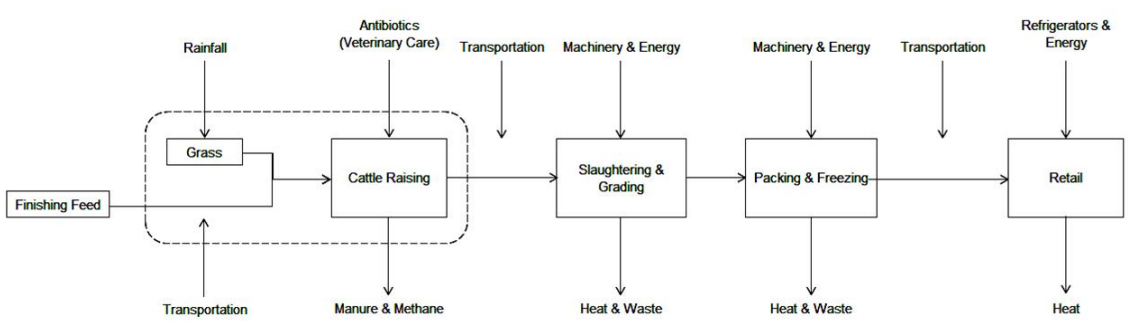

Figure 4. Flow diagram for cattle grazing

Macadamia Nut Production

Macadamia is native to Australia, having been introduced to Hawaiʻi in 1881 primarily for ornamental purposes, and since then Hawaiʻi became the second largest producer of "mac nuts" in the world accounting for 22% of the global market share[4]. One of the first macadamia orchards was planted in the early 1920s in Keauhou, Kona with a little over 7,000 trees (Shiguera & Ooka, 1984, p. 15). Industrial cultivation of macadamia in Hawaiʻi grew during the 1970s and 1980s, and the past decade (2002-2012) has remained steady and unchanged in terms of the number of acres under cultivation (around 17,000 throughout the Hawaiian Islands) though yield per acre has increased significantly (from 2,700 lbs in 2007-08 to 3,300 lbs in 2011-12) as well as a 55.4% increase in the farm value of harvested macadamia nuts[5] (Hawaiʻi Dept. of Ag.; USDA - NASS, 2012).

The yield potential per acre of macadamia in Hawaiʻi varies between regions tremendously according to differences in climate, water, soil conditions, and cultural techniques and field practices (Shiguera & Ooka, 1984, p. 25). Since the 1960's, the Kaʻū Region has well-established macadamia orchards originating from C. Brewer & Co.[6] (Melrose & Delparte, 2012, p. 77). The optimal number of trees planted per acre was determined to be about 70 trees per acre, though initial plantings were at 97 trees per acre with alternate elimination of trees once they grew to a certain size in order to reduce canopy cover for well-performing trees (Shiguera & Ooka, 1984, p. 46).

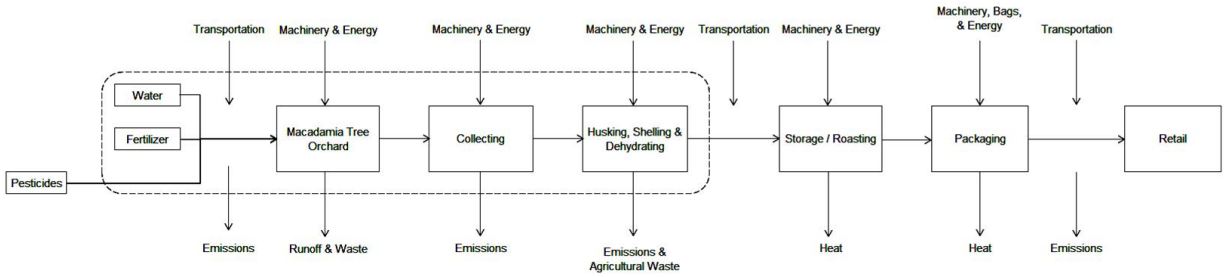

Figure 5. Flow diagram for macadamia nuts

[4] History of macadamia in Hawaiʻi according to the Royal Hawaiian Orchards. Australia is now the largest producer of macadamias, accounting for 37% of global production. [http://www.mlmacadamia.com/history.html]

[5] Farm value of macadamia for 2007-08 crop year was $24,600,000. Farm value of macadamia for 2011-12 crop year was $38,220,000. (Hawaiʻi Dept. of Ag.; USDA - NASS, 2012)

[6] C. Brewer & Co. is the oldest company in Hawaiʻi, having traded sandalwood to China in the 1800s, entering the sugar cane industry in 1863 to become one of Hawaiʻi's "Big Five" companies. C. Brewer & Co. entered the macadamia industry in the 1960s in order to diversify its business and produced a majority of the world's macadamia nuts under the Mauna Loa brand.

Based on macadamia nut yield figures gathered by National Agriculture Statistic Service (NASS), macadamia nut production figures for 2011-12 can be assumed based on the fact that the macadamia trees on Olson Trust lands are between 7-10 years old and yield 34.02-47.14 lbs of macadamia nut per tree per year[7]. We estimate current macadamia yield from 1,300 acres on Olson Trust land to be around 4.3 million lbs for crop year 2011-12[8]. Hence, an estimated value of $3.4 million will be earned the farmer by supplying the crops to the processors.

The flow diagram for macadamia nuts (Figure 5) was constructed based on our conversation with Mr. Cross, observations while in Kaʻū, and literature research. The system boundary encompasses the inputs (water, fertilizer, and pesticides) involved in cultivating macadamia orchards, collecting fallen nuts, and the on-site husking and shelling of nuts prior to transporting them to processing facilities (Melrose & Delparte, 2012, p. 77).

Irrigated water is a major input to macadamia cultivation, requiring about 5,500 gallons of water per acre per day. The porous ʻaʻā-type soil of Kaʻū requires at least 80-110 inches of rainfall for macadamia if not irrigated. The climate conditions indicate that Kaʻū can only receive 40 inches of rainfall per year on average (Dept. of Tropical Plant & Soil Sciences at Univ. of Hawaiʻi at Mānoa, 2002).

Coffee Production

Coffee production makes up 9.5% of Pāhala's agricultural production, with 500 acres currently in cultivation on the Olson Trust land (primarily run by the Kaʻū Coffee Mill) (Cross, 2013). Coffea arabica is cultivated in this region due to the higher market value and conducive local conditions. Figure 6 represents the flow diagram for coffee cultivation and production, with the system boundary placed around all activities carried out in full on the Olson Trust land.

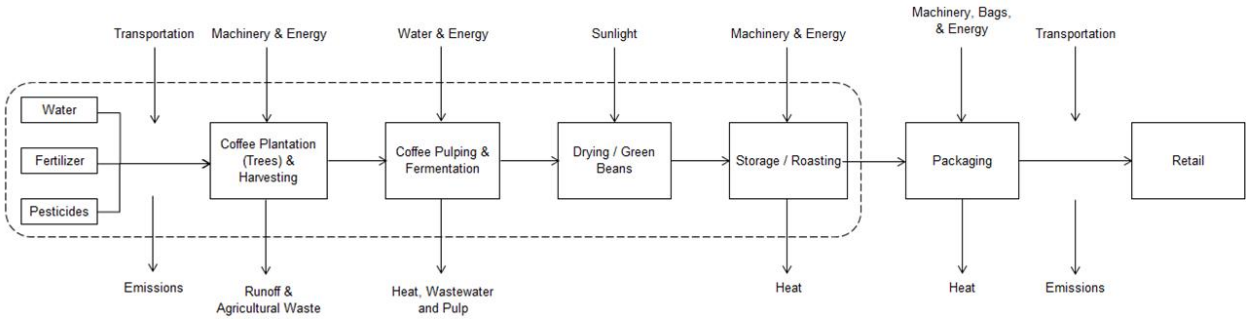

Figure 6. Flow diagram for coffee cultivation and production

[7] 3,300 lbs per acre yielded in 2011-12 (Hawaiʻi Dept. of Ag.; USDA - NASS, 2012) divided by 70 to 97 trees/acre in Kaʻū (Shiguera & Ooka, 1984): more mature trees at 70 trees/acre = 47.14 lb/acre, less mature trees at 97 trees/acre = 34.02 lb/acre. Table showing the age of trees according to yield from Shiguera & Ooka (1984, p. 25).

[8] Based on net yield of 49 million lbs for crop year 2011-12 valued at $38.2 million for the entire state of Hawaiʻi (Hawaiʻi Dept. of Ag.; USDA - NASS, 2012, p. 1).

The most recent average selling price of parchment equivalent sales for farm-grown coffee in Hawai‘i is around $10.15/lb, which we assume to give an acre of coffee in this region a gross economic value of $5,425/year (Hawaii Dept of Ag., 2012).

For our LCA scenarios, we have used a standard production estimate average of the past five years for Hawai‘i, which had production levels of 534 lbs/acre. To measure our other input scenarios, such as water for processing and fertilizer use, we used data from a life cycle assessment (LCA) of Kona coffee farm.

The water requirement for cultivation is on an average of 70 inches/year; the average water requirement per acre for the cultivation of coffee is estimated to be 1,900,801 gallon/acre/year (Coltro, et. al., 2006). The average rainfall of the area is 40 inches/year, which converts to only 1,086,172 gallon/acre, leaving the remaining water requirement from irrigation or other sources to be 814,629 gallon/acre/year.

Truck Crops

About 425 acres of the land are used for cultivating “truck crops.” Truck crops include vegetables such as bok choy, lettuce, beets, and radishes, which are sold to local markets. Truck crops are a part of a vibrant and growing market for fresh produce on Hawai‘i Island. Regardless of their opportunity to become the main stream of agriculture in Ka‘ū, it is assumed that water capacity is rather limited to expand. Due to its variety, the water demand was averaged to cope with different water demand for each type of crops and fruits. Average figure for truck crops and fruits was about 90 inches of water per year. And besides the amount gained from rainfall, the water requirement for truck crops was calculated to be 1,358,000 gallons/acre/year.

‘Āina Koa Pono

‘Āina Koa Pono (AKP) is a Hawai‘i-based biofuels company that proposed to construct and maintain a biofuels production facility in Ka‘ū[9]. AKP posits that it would provide biodiesel for power generation to the Hawai‘i Electric Light Company (HELCO). To achieve these goals, AKP plans to lease and use all 12,000 acres of land owned by the Olson and Mallick Trusts.

According to AKP’s second proposal, AKP speculated to produce 900 dry tons of biomass per day, which would produce 16 million gallons of biodiesel annually. Of the annual production, two-thirds would be sent to HELCO and one third would be used as biogasoline for

[9] About AKP [http://www.ainakoapono.com/?page_id=100]

commercial transportation and other uses. AKP also expected to create 26 megawatts of electricity for its own power needs to run the biofuel feedstock refinery to be built on the Olson Trust land (Figure 7) (Hawaiian Electric Company, 2011).

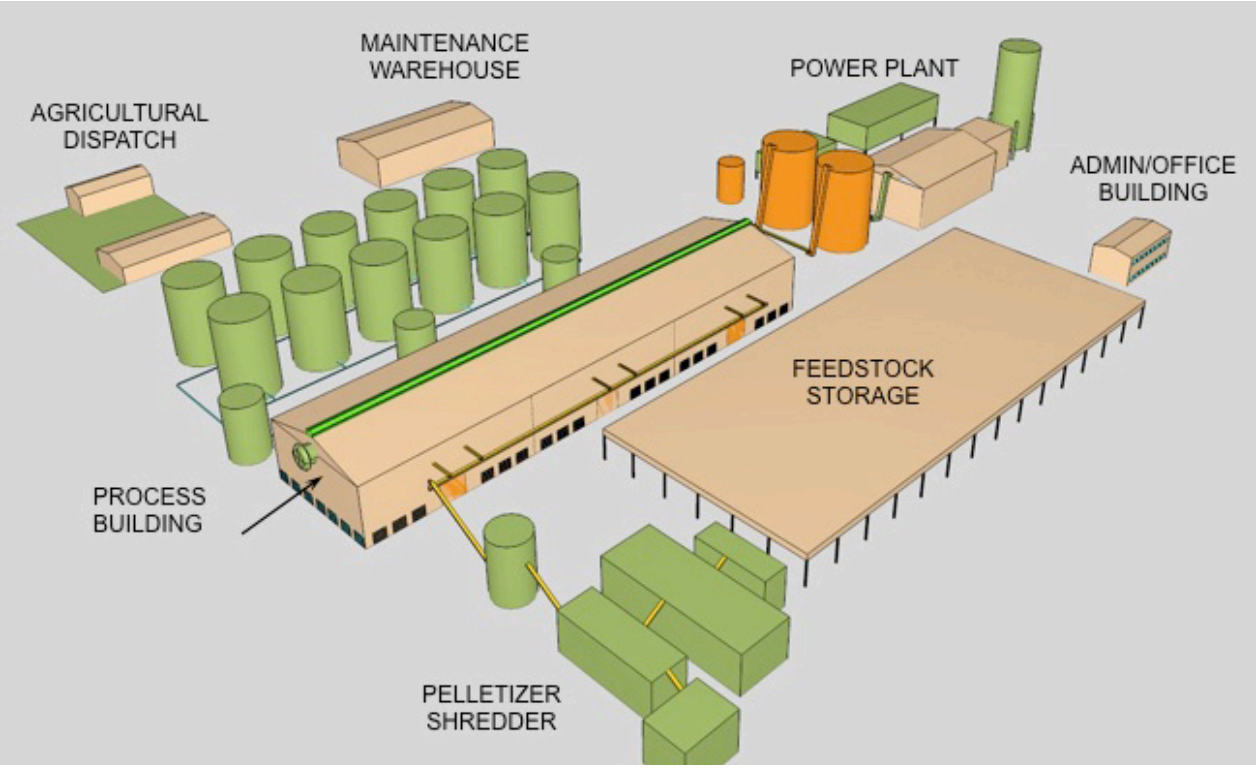

Figure 7. Schematic of proposed on-site biofuel feedstock refinery (Aina Koa Pono, 2013)

Proposed Biofuel Feedstock Cultivation

The proposal states that AKP would first harvest invasive species like Christmas berry, eucalyptus trees, and collect green waste products including macadamia nut shells and fruit pulp for the feedstock refinery. After that, it would cultivate local non-seeding, bana grass, switch grass, napier grass and tested sterile grasses, though specific feedstock grasses to be cultivated have yet been identified by AKP. In the following report calculations, bana grass was used as the feedstock specie. For the calculations in this report, bana grass yield is estimated to be ten tons per acre year if dried, and 50 tons per acre per year in its natural state.

Switch grass	Bana grass
As an addition to its environmental benefits as an alternative energy crop, switch grass can also provide warm season pasture to most ruminants. Switch grass can also be burned with coal. It also is good for highly erodible lands, as it can prevent soil erosion. It is drought-tolerant and grows in clumps from 3 to 6 feet in height (Center for Integrated Agricultural Systems, 2001). It has average yields of 8-12 tons/acre (Biofuels Digest, 2010).	Bana grass has yields of 12.1 tons/acre, with well-fertilized yields able to reach 34.4 tons/acre and can grow up to 22 feet high, but due to its protein content, harvesting is best around 8 weeks. (Purdue University, 1998). 9.4 tons/acre was noted in another study (Koster, Meissner, & Coertze, 1992). Bana grass is also drought tolerant. As a perennial, it does not need replanting after harvest. Its root can grow up to 5.9 feet, and so is good for soil stabilization (Mackay Green Energy, 2011).

In addition to significantly reducing greenhouse gas emissions, this would provide employment opportunities of 200 direct and permanent operation and farming jobs as well as 400 construction jobs over three years[10]. Biofuel production would make steps towards Hawaiʻi's state mandates of 40% of energy use coming from renewable energies.

Criteria to grow grasses for biomass include annual rainfall, sunlight, slope, zoning, and contiguous land area. Biomass grasses are cultivated using similar techniques to traditional agriculture crops like hay forage for cattle. First, seeding grasses is not required every year. Rather, the acres should be reseeded every five to ten years[11] (Nagata, 2013). The seeding varies depending on weather conditions each year: in a desert climate like Kaʻū, grasses will suffer less severe temperature fluctuations and can likely survive closer to ten years before reseeding is necessary. If seeding on a large scale, soil must be tilled using a mechanized plow or ripper, which would prove difficult given the topography.

[10] These figures have been questioned by the County of Hawaiʻi (for more details see Docket No. 2012-0185 at http://dms.puc.hawaii.gov/dms/DocketSearch?V_DocketNumber=2012-0185&QuickLink=1)

[11] See also https://bioenergy.ornl.gov/papers/misc/switgrs.html; http://www.ucsusa.org/clean_energy/smart-energy-solutions/increase-renewables/growing-energy-on-the-farm.html.

Water is also a crucial factor for successfully harvesting biomass grasses. The water input required for growing bana grass is similar to that required for sugarcane. For optimal growth, bana grass needs 70 inches of water per acre annually[12]. Besides the naturally gained water from rainfall, additional water for successful growth – on annual basis, approximately 814,800 gallons per acre – is needed. Thus, AKP would need to irrigate the land unless rain cycles change significantly as discussed above, the Kaʻū region has limited rainfall (Nagata, 2013) (Cross, 2013).

Grasses for biomass are usually harvested using mechanized cutting. On slopes greater than 5%, grasses may be harvested with sickle blade cutters. This method requires human labor and would be very labor intensive (Nagata, 2013).

Microwave Catalytic Depolymerization (Micro Dee)

Microwave Catalytic Depolymerization (Micro Dee) is a process that AKP proposes to use that would convert agricultural feedstock and woody biomass into fuel and biochar. After being ground and pelletized, the feedstock is combined with a proprietary catalyst. The pellets enter a pre-warming stage that removes excess moisture, after which the material is moved to a microwave reactor chamber that removes all remaining free water. This dried feedstock is then fed into another oxygen-free microwave reactor in which the temperature creates an oil steam from which diesel and other fuels can be extracted. The remaining cooled material is the biochar byproduct.

Depending on the feedstock type, one ton of waste feedstock would produce a range of 80-120 gallons of refined diesel fuel. As byproduct, a range of 300-900 lbs of biochar will be produced from the pelletizing process, along with water vapor.

The Micro Dee process takes place in modules, in which each single module can produce 33.3 tons/day of biomass. For the project in question in Pāhala, AKP has predicted that this technology can produce 3,500 gallons/acre. However, AKP seems to be overestimating its biomass and biofuel production values, based on our research.

Because of the broad ranged figures from AKP, and without certainty of the final feedstock or crop yields, we will use AKP's average estimates of diesel fuel and biochar byproduct for every ton of feedstock input. Thus, we assume that one ton of bana grass feedstock will produce 100 gallons of refined diesel fuel, and 600 lbs of biochar when produced with this Micro Dee system (Aina Koa Pono, 2012).

[12] Hawaii Renewable: Bioenergy Crops and Technologies, http://www.hawaiirenewable.com/wp-content/uploads/2009/12/10.-Bioenergy-Crops-and-Technologies-A.pdf.

Ecological Analysis

Scope of Analysis

Though most information and data regarding the various inputs to diversified agriculture and biofuel cultivation were available, the data sources were highly variable and not necessarily specific to the Kaʻū region (or Hawaiʻi Island). Thus, a more in depth analysis of water inputs was conducted due to the consistency of available water sources and limitations in Kaʻū and on Olson Trust lands for all activities occurring on the land at present day, as well as proposed.

Modeling Scenarios

Modeling scenarios (Table 2) were created based on low-end and high-end estimations of tillable land. The amount of tillable land for low-end scenarios was determined to be 30% (3,600 acres) and for high-end scenarios determined to be 50% (6,000 acres) of the total 12,000 acres (Cross, 2013). Tillable land is defined to be land that can be used for crop agricultural purposes; for coffee, macadamia, truck crops, and biofuel feedstock. Also, tillable land was defined into low-end and high-end estimation due to possibility of non-cultivable land owing to topographical difficulties, soil texture, and water accessibility. Acreage allocations were made for proposed and current land uses (biofuel feedstock, coffee, and macadamia nut cultivation, and cattle grazing). The assumption for the maximum usable land was set 10,000 instead of 12,000 due to topographical limitations and other possible needs for road, spaces, and utility function purposes.

	Total Land	Total Usable Land	Tillable Land	Biofuel Feedstock	Cattle Grazing	Crop Agriculture		
						Coffee	Macadamia	Truck
Scenario 1	12,000	10,000	-	0	6,000	500	1,300	420
Scenario 2	12,000	10,000	6,000 (50%)	0	6,000	2,280	1,300	420
Scenario 3	12,000	10,000	6,000 (50%)	3,780	4,000	500	1,300	420
Scenario 4	12,000	10,000	6,000 (50%)	6,000	4,000	0	0	0
Scenario 5	12,000	10,000	3,600 (30%)	3,600	6,400	0	0	0

Table 2. Scenarios based on land allocation.

Scenario 1: Current situation where the land is not used to the maximum and biofuel feedstock cultivation is zero. Serves purpose as a control scenario.

Scenario 2: High-tillable land scenario. While retaining the current agriculture's land allocation, the remaining land is used for more coffee production as it is highly valuable and less water consuming.

Scenario 3: High-tillable land scenario. While retaining the crop agriculture's land allocation, some of the cattle-grazing capacity is reduced accordingly, to be used for biofuel feedstock cultivation.

Scenario 4: High-tillable land scenario. All of the tillable land was allocated to biofuel feedstock cultivation. The remainder of the land was allocated to cattle grazing due to the high relative productivity yield and value of grass-fed beef compared to the zero inputs required for growth and maintenance of pasture. This scenario overrules the previous assumption that the crop land will remain the same and maximizes the biofuel feedstock production.

Scenario 5: Low-tillable land scenario. This scenario also overrules the John Cross' will to maintain the land allocation unchanged as much as possible and maximizes the biofuel feedstock production and focused on cattle grazing for the same reason for scenario 4.

Scenario Results

Based on the water demand for different land uses discussed in previous sections and the land use scenarios, the total water demand was estimated for each scenario (Table 3). For biofuel feedstock, only bana grass was considered in this analysis and assumed the water demand for other feedstock to be similar. This water demand already considers the inclusion of 40 inches of water from precipitation.

In general, the results conveyed in table 3 show that biofuel feedstock actually uses less water than crop land does. This is evident when compared with scenario 3 and 4. The only difference between the two is whether the focus is on the biofuel feedstock or crop agriculture production. This is mainly due to the fact that macadamia nuts and truck crop (average of 90 inches) require more water than growing bana grass (average of 70 inches).

However, when considering the water resource that is actually available for irrigation, scenario 1 – current combination of agriculture – is the realistic combination of agriculture activities. The maximum amount of water currently available from nearing water sources is 1,825,000,000 gallons per year and approximately 1,095,000,000 gallons per year from

Hawaiian department of water supply is also available, meaning that about 2,920,000,000 gallons are available annually. Therefore, the production expected by the scenarios can only be feasible if additional water sources are devised. Without additional water sources, only scenario 2 and 5 are realistic, based on water requirements, out of five presented scenarios.

	Biofuel Feedstock	Cattle Grazing	Crop Agriculture			Total Water Demand (gallons/year)
			Coffee	Macadamia	Truck	
Water Demand (gallon/acre/yr.)	814,800	14,600	634,000	921,100	1,358,000	
Scenario 1 (acre)	0	6,000	500	1,300	420	2,172,390,000
Scenario 2 (acre)	0	6,000	2,280	1,300	420	3,300,910,000
Scenario 3 (acre)	3,780	4,000	500	1,300	420	5,223,134,000
Scenario 4 (acre)	6,000	4,000	0	0	0	4,947,200,000
Scenario 5 (acre)	3,600	6,400	0	0	0	3,026,720,000

Table 3. Total water demand under different land use scenarios

Economic Analysis

Farm Land and Revenue

Although it is very important to trace the economic impacts of crops after they enter the market, the primary priority of the report is focused on the crop land itself and its management. Regardless of the possibility of increasing a crop's economic value by using it as a feedstock for another industry or for processed products, only revenues from the feedstock producer's point of view were considered. However, to compare crop revenue with biofuel feedstock that has a greater value when processed, we have also included some estimations of the value of the feedstock to fuel conversion.

When considering the water limitations, only scenario 2 and 5 were valid out of the five hypothetical combinations of different land allocations. Then these two scenarios were economically analyzed based on the acreage allocation of ecological analysis. The revenues for cattle grazing and crop agriculture were based on a statistics by USDA National Agricultural Statistics Service's Hawai'i Annual Statistics Bulletin and local farmers' statements. The biofuel feedstock revenue was based upon a statement made by an AECOM Technology

Corporation consultant; a price range between $55 to 65 per ton of feedstock (Ha, 2013). The revenue per acre was calculated by multiplying price per weight by the yield per acre.

The price of biofuel feedstock $3,600 per acre was used in the Ka‘ū agriculture land use modeling. Regarding the biofuel feedstock revenue and the selection of the number, the revenue per acre for bana grass can be altered depending on different approaches. One of these alternative approaches was to see the pricing from an energy perspective that treats biofuel feedstock in relation to the petroleum price and then translates according to the amount of British Thermal Unit (BTU) it can give off. In such a case, one gallon of crude oil will give off approximately 138,095 BTU and the annual revenue per acre can go up to $22,550 per acre. However, this method was not used in this report due to the fact that it also includes the processing costs and offers little decision-making utility when regarding the revenue that purely comes from the intrinsic value of feedstock itself.

Moreover hay, which has similar qualities to the biofuel feedstock, was used as a comparison feedstock for the pricing. Currently, hay is traded at $200 per ton, therefore the price of bana grass should have been around $200 per ton. However, the price was set to $60 per ton which was chosen because of AKP’s technology representative AECOM’s willingness to pay for the feedstock was $60 per ton (Ha, 2013). Based on a different study of bana grass cultivation for energy portfolio diversification purposes, the price can be low as $40 per ton but these studies have been conducted in less developed tropical countries with large land mass where obtaining such crops require less efforts. Hence, price of bana grass at such level would not be feasible for AKP’s use unless this biofuel feedstock was imported.

	Biofuel Feedstock	**Cattle Grazing**	**Crop Agriculture**			**Total**
			Coffee	**Macadamia**	**Truck**	
Acre	0	6,000	2,280	1,300	420	10,000
Revenue per acre ($)	3,000	2,000	4,980	2,574	17,518	-
Expected Revenue ($)	0	12,000,000	11,354,400	3,346,200	7,357,560	**34,058,160**

Table 4.1 Total profit for Scenario 2

	Biofuel Feedstock	Cattle Grazing	Crop Agriculture			Total
			Coffee	Macadamia	Truck	
Acre	3,600	6,400	0	0	0	10,000
Revenue per acre ($)	3,000	2,000	4,980	2,574	17,518	-
Expected Revenue ($)	10,800,000	12,800,000	0	0	0	**23,600,000**

Table 4.2 Total profit for Scenario 5

	Biofuel Feedstock	Cattle Grazing	Crop Agriculture			Total
			Coffee	Macadamia	Truck	
Acre	0	6,000	500	1,300	420	8,220
Revenue per acre ($)	3,000	2,000	4,980	2,574	17,518	-
Expected Revenue ($)	0	12,000,000	2,490,000	3,346,200	7,357,560	**25,193,760**

Table 4.3 Total profit for Scenario 1

Scenario 2 and 5 were similar in terms of water intake, however, revenue from the crops were different. The scenario 2 that maximizes the land use by increasing the coffee production has expected annual revenue of $34,058,160. If the Ka‘ū community is willing to change their main production from macadamia nuts to truck crops, revenue has room to be raised even more (Table 4.1). Scenario 5 did not gain as much revenue since the biofuel feedstock is a low value product. If AKP was willing to pay $200 per ton as it is being traded at the moment, scenario 5 could become a more attractive option to increase revenue from the farm land (Ha, 2013). However, choosing such an option would have skewed the projections for AKP’s biofuel plan since the raw material price would have tripled in their calculations and cost to supply electricity on the island would have increased significantly.

Ironically, the introduction of biofuel feedstock scenario 5 will maximize the land use of tillable land availability (10,000 acres) but it will still not exceed the scenario 1's revenue; a control scenario that currently occupies only 8,220 acres. On the contrary, scenario 2, which maximizes the available tillable land, will increase current revenue by about 35% or about additional $10 million for the community. Therefore, ecologically and economically speaking scenario 2 would align with the community's interest to maximize revenue in limited water environment.

Results and Discussion

The results from the ecological and economic analysis point to the conclusion that maximizing the 12,000-acre site's utility is only possible with a reasonable management of the water as it is a limited resource, and cultivation of biofuel feedstock may not be as economically practical to the community as projected by the AKP's proposal.

AKP's proposal to establish stable self-sufficient energy source from Kaʻū estate needs to be further researched, as a feedstock target yield of 900 ton per day is not viable. With an annual yield of dry 10 ton per acre of bana grass, AKP would require at least 32,850 acres or more of land to be devoted to growing biofuel feedstock. Hence, the biofuel production goal to produce 24 million gallons of renewable biodiesel per year is not plausible. Also if AKP's three-step agricultural approach is applied which requires 30-foot buffer zones between the crop lands, the yield will be lower than what is projected by scenario 5.

If the water availability were to increase, AKP's goal to achieve 900 ton per day may be viable but still lack of land and porous soil structure will make it difficult to accumulate ground water. For all of the land use scenarios the water demand will heavily depend on the irrigation system. The current irrigation system and the existing reservoir can hardly be sufficient for any of four hypothetical scenarios, even when the seasonal variation of water demand is considered. In fact the available water from springs uphill of Pāhala can barely support the water demand for the scenarios[13]. Thus, additional irrigation infrastructure is needed to capture more of the existing available water in Pāhala as well as transfer more water from other lands in order to support the future land use development. Any development of the Kaʻū region must take into consideration the ecosystem values that the watersheds provide because any type of agricultural activity will have difficulties in becoming successful without the aid of reservoir water and irrigation (Crysdale, 2013).

[13] 3-5 million gallons of water per day, but not all are used by the current irrigation system as mentioned in the previous section (Melrose & Delparte, 2012).

Conclusion

The Kaʻū region of Hawaiʻi Island is far removed from the populous areas of Kona and Hilo, but contains a strong community rooted in common histories of land use change. The town of Pāhala has maintained ties to agriculture, being home to expanding coffee, macadamia nut, and grass-fed beef businesses. These activities have taken root in Pāhala over the past two decades after large tracts of land became available post-Big Sugar, and are poised to grow due to market demands. However, the greatest challenge in future development will be in effectively capturing and utilizing the Kaʻū region's limited water resource.

This study aimed to assess the limitations of water on future developments on the 12,000 acres of land owned and managed by Olson Trust and Mallick Trust as AKP proposed biofuel feedstock cultivation and the establishment of a feedstock refinery on these private lands, in order to supply fuel to HELCO for electricity production[14]. AKP's proposal would increase the price of electricity for the people living on Hawaiʻi Island. However, this study did not dig in to the economics of electricity production, but rather the consideration of resource inputs to gaining productivity from the land.

In this study, five scenarios of land use were developed based on availability of tillable land, highlighting the challenges that the 12,000 areas of land presents. Water usage for diversified agriculture, biofuel feedstock cultivation, and cattle grazing were researched and used to calculate total water demand for the different scenarios. Water demands for scenario 3 and 4 that introduce biofuel feedstock cultivation were significantly higher than in the other three scenarios.

A majority of the land is not irrigated, and there are no plans to fully irrigate all 12,000 acres in the future because it is not cost effective given the topography and variable soil quality. Based on the calculations, the amount of water currently available to the region can barely support the scale of biofuel feedstock cultivation proposed by AKP. Additional irrigation infrastructure that taps other water sources outside of Pāhala is necessary to sustainable the proposed cultivation, which will become an added cost to AKP's project.

The results of this study are rough estimates, as not all of the data utilized were specific to the Kaʻū Region (let alone the town of Pāhala). However, the results do provide a starting point from which water as a limited resource can and should be considered in any decisions made for land use. It is also important to note that though AKP's proposal highlights the ability

[14] Since the time of the fieldwork for this study, the Consumer Advocate and HECO/HELCO have proposed that only Oʻahu carry the difference in price between fossil diesel and biodiesel. However, the Department of Research and Development for Hawaiʻi County have calculated that the externalities of the project, including transportation, environmental impacts, mass-balance as well as possible failure of the Technology (resulting in remediation measures), make the 'removal of price differential' still uneconomic and still increase the ultimate price of electricity to the residents of the Island, especially in the town of Pāhala (Will Rolston, pers. comm., June 20, 2013).

to grow biofuel feedstock on underutilized marginal lands, the single test plot currently on the Olson Trust lands was fully irrigated in response to the difficulties of getting the test grasses to propagate (with the exception of bana grass). Therefore, more water might be required than the water demand utilized for the calculated result above. In contrast, the piecemeal growth that the Kaʻū Coffee Mill has currently undertaken provides a means of reducing financial risks while expanding production capacity. The water stored in current reservoirs on the 12,000 acres of land belong to the Olson Trust and are meant to be used for agricultural activities undertaken on Olson Trust lands. It is highly unlikely that an endeavor to procure water from regions outside of Olson Trust lands is a project that the Olson Trust would want to embark upon should a water supply beyond the capacity of the large reservoir be required to support the activities carried out by the lessors.

Furthermore, the economic projection made from estimates of the two ecologically feasible scenarios determined that replacing current agriculture with biofuel feedstock is economically less sensible. Since the economic analysis did not include any collateral costs such as refinery plant building cost, oil-to-biofuel transition cost, and cost to install and remove the agriculture infrastructures for specific crops, there will be an even greater cost associated with the option of introducing biofuel feedstock.

Recommendations

Though AKP is not required to conduct and submit an environmental impact assessment, we recommend that AKP progress toward completing one and making the results known to the public. Also, it is highly recommended that AKP conduct a complete water resource assessment of Pāhala and the Kaʻū Region in order to determine a realistic scale of the biofuel feedstock cultivation within the water limitations. AKP is required to submit detailed financial information for the construction of any infrastructure, and the costs may be much higher than previous estimate if greater amounts of remote water resources are necessary for feedstock cultivation.

Furthermore, this study analyzed the needs and limitations of water. Other resources, such as energy, fertilizer, and pesticides, should be analyzed in future studies for a more comprehensive study of land us in Kaʻū. Though these inputs may be easy to quantify, it may be difficult to attach economic values due to continual price fluctuations and little data collection. Nevertheless, there is value to be had in cross-comparisons of different land use activities in trying to decide the best economic and cultural options for the future growth and development of Kaʻū.

Lastly, AKP's proposal should be confirmed as to whether their capabilities align with the proposal's target and that their projections are accurate. Their projection will be misleading if the projections are based on false forecasts with numbers having gaps with reality. The gap may seem very small at the moment; however, the small gap can accumulate over the next 20 years and induce very different result at the end of project time. Therefore, realistic projections must be made based on a solid fact-checking and estimations to reduce the possible skewing of the Ka'ū project's costs and benefits.

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