Final Scientific/Technical Report Content

The final scientific/technical report must include the following information and any other information identified under Special Instructions on the Federal Assistance Reporting Checklist in your contract documents:

1. Identify the DOE award number; name of recipient; project title; name of project director/principal investigator; and consortium/teaming members.

DOE Award Number: DE-EE0000303
Name of Recipient: County of Hendry
Project Title: Bio Diesel Cellulosic Ethanol Research Project
Name of Project Director/PI: Dr. Edward Hanlon
Team Members: Edward Hanlon, John Capece, Alan Wade Hodges, Sanjay Shukla, Monica Ozores-Hampton, Rob Gilbert, Alan Wright, E. McAvoy, and L. Baucum

2. Display prominently on the cover of the report any authorized distribution limitation notices, such as patentable material or protected data. Reports delivered without such notices may be deemed to have been furnished with unlimited rights, and the Government assumes no liability for the disclosure, use or reproduction of such reports.

The objective of the project is to create the Hendry County Sustainable Biofuels Center and initiate its research, development, and education programs. The mission of the Center is to:

1. Develop engineering and economic assessment methods to evaluate the natural resources impacts of biomass farming and fuel conversion systems.
   a) Tasks 5, 6, 7, and 12
2. Provide sustainability assessments of specific biofuels production proposals.
   a) Task 6

3. Develop biomass farming and fuel conversion systems that are compatible with south Florida ecosystem restoration priorities.
    a) Task 8 and 9
4. Create ecosystem services opportunities and structures to diversify farm income.
    a) Tasks 9 and 7
5. Monitor the range of research and development activities necessary to the creation of sustainable biofuels production systems in south Florida, identify gaps in the regional research, and assist in the development and coordination of additional projects to fill out the required knowledge base.
    a) Tasks 5, 6, 7, 8, and 12
6. Prepare the workforce of southwest Florida for employment in biofuels related professions.
    a) Tasks 10, 11, and 12
7. Assist businesses & government design and realize sustainable biofuels projects.
    a) 12, 7, 8, 9, 6, and 5

3. Provide an executive summary, which includes a discussion of 1) how the research adds to the understanding of the area investigated; 2) the technical effectiveness and economic feasibility of the methods or techniques investigated or demonstrated; or 3) how the project is otherwise of benefit to the public. The discussion should be a

minimum of one paragraph and written in terms understandable by an educated layman. The expected outcomes are from the PMP and should be addressed in the Executive summary.

Outline for this Executive Summary

1. The adoption by local governments, private businesses, NGO's, and educational institutions of new ways to pursue economic development in south Florida, ways that unite economic activity and natural resources protection into successful agro-business models and efficient public lands & water management programs.
2. The establishment and growth of a sustainable biomass production and conversion industry in south Florida that integrates agricultural production and environmental restoration priorities.
3. Creation of compensation programs to provide agribusiness income for the delivery of ecosystem services.
4. An accurate public understanding of both the opportunities for and the trade-offs associated with using biomass for energy production.
5. Viable options for retaining agricultural productivity, industry, and employment in the Everglades Agricultural Area lands targeted for state acquisition to support the Comprehensive Everglades Restoration Program.

4. Provide a comparison of the actual accomplishments with the goals and objectives of the project. Where applicable, address any comparisons of actual results to programmatic technical barriers and milestones.

1. The adoption by local governments, private businesses, NGO's, and educational institutions of new ways to pursue economic development in south Florida, ways that unite economic activity and natural resources protection into successful agro-business models and efficient public lands & water management programs.

The outputs from this work provide an economic (Tasks 12, Economic Development, and 7, Cost-Benefit Analysis) and a comparison of energy-based evaluations (Task 6, Life Cycle Assessment and Emergy). These components have been integrated in the analytical tools of Task 5, Analytical Tools Development, and demonstrate that selected approaches to compensation of additional actions while producing biofuel feedstocks (Task 9, Ecosystem Services Compensation) can in part improve sustainability of the entire production system and address environmental issues.

2. The establishment and growth of a sustainable biomass production and conversion industry in south Florida that integrates agricultural production and environmental restoration priorities.

The research into energy and economic components indicate that changes from food and fiber, the traditional crops for humans and animal production, would be in direct competition with biofuels. Said another way, the land use changes require an either/or scenario (Task 7, Cost-Benefit Analysis). The work within Tasks 6, Life Cycle Assessment and Emergy, and 7, Cost-Benefit Analysis, suggest that biofuel production on mineral soils are or can be made to be more sustainable through the selection of selected alternative farming practices. Similar changes to organic soil-based crop production still carry with it the soil subsidence issue and the resulting carbon dioxide contribution to the atmosphere. However, switching from food production to biofuel feedstock production has proven to be at the expense of existing markets, traditional cultural practices, and increased production and market risks for growers. This finding suggests that implementation should be done slowly, if at all, and with cooperation among growers, researchers, and crop consultants to ensure that risks remain acceptable.

3. Creation of compensation programs to provide agribusiness income for the delivery of ecosystem services.

This exploration of compensation programs (Task 9, Ecosystem Services Compensation) was combined with many of the other Tasks. The environmental community supports such an approach in general and growers are interested in the concept; however, Floridians as a whole have not supported any payment system for environmental services due to the economic downturn, resistance to any payments based on taxation, and lack of a willingness to reduce currently funded programs to create this compensation program with the tax-neutral environment.

Researchers associated with grant have given numerous presentations, created outreach documents, and displayed posters showing their work on this issue (See Section 6). At this point, the work sponsored by this grant, confirmed that a compensation program should be considered seriously when Florida attempts to comply with the federally mandated actions related to the Clean Water Act. For example, the West Caloosahatchee Basin, a Florida Department of Environmental Protection designation, now has a functioning Basin Management Action Plan

(BMAP), which will cost considerably more to treat the water through utilities compared to recycling these nutrients through agricultural operations promulgated a suitable compensation program (Section 6).

4. An accurate public understanding of both the opportunities for and the trade-offs associated with using biomass for energy production.

The discussion of biomass for energy production was carried out by all Co-PIs on this grant and contained a considerable effort by E. McAvoy and L. Baucum, Hendry County Extension faculty members. The biofuels discussion reached county ag tours by the busloads, posters from several of the Co-PIs were displayed prominently at public locations and at the main halls in several UF Research and Education Centers that usually host more than 3,000 visitors per year, in addition to workshops and symposia given at those same sites. Research and Extension presentations and posters were given and/or shown at Research Forums on the main campus and at national professional meetings. Lastly, the Community Involvement Committee (CIC) was formed and met during the grant period. CIC participants were selected to represent a wide cross-section of Hendry and Glades Counties, as well as urban, environmental, and agricultural sectors. In a visioning exercise, the CIC created a template for the Hendry County that should exist some 20 years in the future (See Section 6 of this report, Next Steps as Suggested by the CIC Attendees, http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/BiofuelsNextStepsSuggestedCICAttendees.pdf). CIC members reported additional discussions with elected officials and other groups in southwest Florida concerning these visioning outcomes and related issues to agriculture and biofuels.

5. Viable options for retaining agricultural productivity, industry, and employment in the Everglades Agricultural Area lands targeted for state acquisition to support the Comprehensive Everglades Restoration Program.

The Hendry County Sustainable Biofuels Center (HCSBC) has created information that can be used by agriculture, state and county agencies, and interested parties to indicate the benefits and problems associated with feedstock biofuels being produced in southern Florida with subsequent conversion to ethanol via distillation technology. No work was planned or attempted on cellulosic conversion as a part of the grant.

The findings show that biofuel feedstock can be produced in this area; however, the cultural management process would need to be refined to improve sustainability. The grant addressed the organic and mineral soils production practices for growing sugarcane for sugar with the assumption that similar practices could be used for specifically developed biofuel sugarcane cultivars. Researchers also studied other potential feedstocks including sweet sorghum, Arundo Donax, Miscanthus, Switchgrass, Sorghum, Corn, Elephantgrass, Sugarcane, Energycane, and Eucalyptus. Many of these crops were addressed in several of the Tasks, while others were studied in only one or two Tasks.

Land use is also a major issue in that most of the land is already in use for agricultural or other human uses and the pressure for development is predicted to increase with time. The conversion of all farmable land in southern Florida to biofuel using current technology will only supply a small percentage of the energy used by Floridians. Thus, there is a trade-off in land use; simply put food or biofuel.

The economic considerations were found to be quite similar in many respects to the Life Cycle Assessment (LCA) and emergy (EM) methods used to evaluate production management strategies, environmental stress, if any, and potential alternative cultural management scenarios. The cost of developing a biofuels infrastructure was found to be high and the trade from food production to biofuels production will change the infrastructure that currently exists for food production.

Models have been developed for LCA, EM, and the process for the economics evaluation has been documented. The HCSBC has developed these models (economic, LCA, and EM) by using the research that has been sponsored by other centers working within the biofuels area, leveraging the findings of others to create these useful models. While developed specifically for use within Hendry County, the models have much wider applicability. These models may be used to provide an independent analysis of proposed biofuels systems leading to implementation with appropriate changes toward increased sustainability that includes positive economic and environmental outcomes. These models were designed for governments that are considering new industry in their region, so that informed decisions can be made on the facts and appropriate funding and other support from the public sector is invested wisely and with confidence. The HCSBC can provide this independent evaluation.

To maintain a viable agriculture within Hendry County, the HCSBC has developed two levels of educational training for aspiring students. All of the schools (6th through

12th grades) in Hendry and one in Glades County were represented in teacher training and subsequent biofuel lesson development and taught to students.

The University of Florida worked with Edison State College using a range of professionals, instructors, and employers within their institutions and Hendry County to develop suggested changes to current curriculum and the development of a new course that would result in a structured approach to environmental and agricultural technically trained students who would also be eligible to use the so-called 2-plus-2 program to finish their BS degrees at the University of Florida.

5. Summarize project activities for the entire period of funding, including original hypotheses, approaches used, problems encountered and departure from planned methodology, and an assessment of their impact on the project results. Include, if applicable, facts, figures, analyses, and assumptions used during the life of the project to support the conclusions.

TASK 1.0 [PROJECT MANAGEMENT AND REPORTING]

The Project Management Plan (PMP) shall be modified and updated by the Recipient as necessary with direction from the DOE Project Officer. The DOE Project Officer will review the PMP and provide comments. After receipt of comments, the final PMP shall be submitted to the DOE Project Manager for review and approval. A Milestone Plan, mutually agreed upon by the Recipient and DOE, is established as a part of the approved Statement of Project Objectives (SOPO) for the project. This Milestone Plan shall be used as a planning tool to establish the time schedule for accomplishing the planned work. The Milestone Plan will serve as the baseline for tracking performance of the project and identifies critical path project milestones (no less than 2 per calendar year) for the entire project. During project performance, the Recipient will report the Milestone Status as part of the required quarterly Progress Report as prescribed in the Federal Assistance Reporting Checklist.

The PMP was finalized and used as the template for all project management and reporting. All quarterly reports were completed and uploaded following the end of a quarterly reporting period. These quarterly reports were shared with Hendry County and the narrations placed on the SWFREC Hendry County Sustainable Biofuels Center web site accessible to the public.

TASK 2.0 [DEVELOP STAKEHOLDER CONSENSUS]

No consensus currently exists in south Florida that a systems sustainability analysis approach should serve as the basis for biofuels industrial development. Agro-businesses continue to use commodity market signals combined with regulatory compliance as the primary driving forces behind their business decisions. Similarly, environmental organizations lack neither confidence that agriculture can contribute to ecological restoration in south Florida, nor have they accepted that any such local compatibility is required to achieve both regional and global environmental protection goals. Therefore a primary task of the Hendry County Sustainable Biofuels Center (HCSBC) is to build a consensus among stakeholders that a sustainability approach to biofuels development is the required path for the region and that dual-service agricultural industries can be and should be part of the long term land use plan for south Florida. Public workshops and presentations will be provided to stakeholders on at least a quarterly basis to build towards a sustainability-driven decision and compensation systems for biofuels in south Florida.

An Extension grower meeting, organized by E.A. Hanlon, PI, and F. Roka, agriculture economist, dealing with the economics of carbon, nitrogen, and phosphorus credit trading and water storage payment potential was organized in early 2010. More than 107 growers participated in the 7-speaker agenda. Five of the seven presenters were Biofuels Center team members. Interest in agriculturally-based ecosystem services and alternative farming system practices was high; both topics are a part of the Biofuels Center efforts. A pre/post instrument confirmed that participants increased their knowledge levels regarding credit trading, marketing, and alternative farming systems.

J. Capece, co-PI, and E.A. Hanlon, PI, organized and presented at a break-out session at the 2010 Everglades Coalition meeting. The session featured six presentations addressing agriculturally-based ecosystem services as related to alternative farming systems practices focused on the Everglades Agricultural Area. All presenters were Biofuels Center team members or cooperators (See Presentations, section 6 b.

J. Capece, Co-PI and R. Gilbert, Co-PI with S. Jennewein, MS student with this grant, led an environmental group from eastern peninsular Florida and several groups from western peninsular Florida have been discussing Everglades National Park issues and sharing ideas and approaches. The HCSBC was asked to discuss biofuels, alternative farming systems, and the potential impacts of both on water quality and quantity.

E.A. Hanlon, PI, presented biofuels, alternative farming systems, and the potential impacts of both on water quality and quantity information to a Florida Fish and Wildlife Commission, Cooperative Conservation Blueprint Regional Pilot Project: Advisory Group Meeting. Subsequently, two other invited presentations were made to this group on biofuels.

The HCSBC PI served as one of three presenters in panel discussion at the January 2011 Everglades Coalition, Weston, FL reviewing the related economics of agriculture that included ecosystem services. The Everglades Coalition invited the HCSBC to participate in a panel discussion.

Discussion of the HCSBC and related efforts on agriculturally-based ecosystems services and alternative farming systems have been the topics of a number of Hendry County Cooperative Extension Service public events: the LaBelle Rotary Club, six busloads of people on farm tours in Hendry County, participants of the Big O Bird Festival in Clewiston, and the Hendry Glades Youth Leadership class of 2011, as well as several farmers and ranchers.

Due to popular support, the so-called Stakeholder Framing Committee was renamed the Community Involvement Committee (CIC). A large list of more than 100 businesses associated with agricultural production, consulting, and supply industries, biofuel entities in southern Florida and sustainability NGOs, as well as influential individuals in the environmental and conservation efforts within Florida was created. Some 60 responded positively and most participated in two scheduled meetings of the CIC. Both meetings were held at the Hendry County Extension office, LaBelle, FL.

The first 1-day CIC meeting dealt with the goals of the HCSBC, updates on all 12 Tasks of the grant, and then a lengthy question and answer session at the end of the day.

The second and final meeting of the CIC, held some 3 months after the first meeting, included a short update followed by a 5-hour envisioning session during which the CIC was split into three sub-groups and following the scenarios of the nationally know Green World: Blue World venue. The facilitator was J. Hazell, a trained professional in eliciting focused responses from group and specifically trained in this venue.

The outcome of this visioning was a list of items that defined expectations for the future of Hendry County and its potential role in agriculture and especially in biofuel production (URL: http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/CIC VisioningSummaryRpt_Apr12.pdf).

As a result of CIC involvement and independent activities, the information has led to a sharing of field and research farm tours, interest in related biofuel issues at the national level, and discussions with elected officials about the links involving increased county-level employment and agriculture.

Presentations requested by NGOs and environmental groups, such as the Southwest Florida Watershed Council, a group of concerned citizens and professionals from throughout Southwest Florida focusing on building consensus with respect to environmental issues, and the Southwest Florida Resource Conservation and Development Committee, composed of representatives from agricultural and County natural systems agencies are listed in Section 6 of this report. These two groups are composed of regional leaders and capture the spectrum of environmental and industrial activity within Southwest Florida. Response from these two committees has been supportive as indicated by their follow-up recommendations in the form of letters in support of HCSBC activities related to biofuels, alternative farming practices, and water use and quality.

Dr. J. Capece, Co-PI, and E.A. Hanlon, PI, met with the leadership staff members of the Everglades Foundation to discuss the objectives of The HCSBC and overlapping topics promoted by the Everglades Foundation. The Everglades Foundation immediately confirmed its support for the alternative farming systems and energy approaches used by this grant.

In addition to a number of presentations (see Section 6 of this summary report), L. Baucum, Co-PI, and E. McAvoy, Co-PI, planned and conducted the 2012 South Florida Ag Expo, which included learning sessions on feedstock and ethanol. More than 1,500 participants attended this Expo. 300 participants in 6 bus tours attended the feedstock and ethanol learning session.

These two Co-PIs also made presentations to the Hendry Glades Youth Leadership Group (18) and participants of the Big O Birding Festival – (85).

J. Capece, Co-PI, was invited to give a presentation to the 2011 Hendry/Glades Leadership Course (25 participants). The lecture focused on water issues of the

Caloosahatchee Basin. As part of the presentation, Dr. Capece explained many of the basic issues being considered by the HCSBC and its relationship to regional water management.

As the work advanced in Task 6, Life Cycle Analysis, the energy flow diagrams using sugarcane as the feedstock were used in several presentations. Sweet sorghum was also used as a feedstock for similar energy flow diagrams used in presentations and posters at national symposia and County extension venues.

Co-PIs E. McAvoy and L. Baucum have throughout this grant given presentations to diverse audiences. By way of example, the Farming flyers received a tour of the Everglades Agricultural Area and the links between biofuel production and food production, as well as the effect on both agriculture and ecosystem services.

The Hendry County Farm City Tour, which usually includes 100 participants, is a regularly scheduled event and participants received the latest information about biofuels and their effects on Hendry County at each of these events.

Another regularly scheduled event is the South Florida Ag Expo in which the co-PIs held a feedstock/ethanol-based learning sessions.

Other regular venues included: Leadership Glades, FFVA Spring Regulatory Tour, eco-tours of stormwater treatment area five for the Loxahatchee Trail Walkers Association and the ever popular Southwest Florida Research and Education Center Vegetable Field Days held semiannually. Field days for sugarcane producers are usually held quite frequently to update interested growers on focused research topics and L. Baucum included updates regarding the potential for biofuel feedstock production on both organic and mineral soils currently producing cane for sugar. With researchers, more detailed discussions of Life Cycle Assessment and emergy were common topics, especially with graduate students and post docs. The links between energy and cultural practices provided researchers with both the energy use and the effects on final sugar production.

E. McAvoy, Co-PI, and E. Hanlon, PI, conducted semester-based tours for Florida Gulf Coast University students taking a comprehensive colloquium course. Typically 20 to 30 undergraduates spent 1.5 hours touring and discussing agricultural activities and visiting commercial operations, which included discussions of biofuels topics.
L. Baucum consulted with selected sugarcane growers to discuss sugarcane fertility recommendations, primarily for plant cane. This information was used in Task 6: Life

Cycle Analysis and Emergy, to update the final version of the models dealing with energy for production of feedstock sugarcane.

TASK 3.0 [TEAM DEVELOPMENT]

A diverse team of specialists was required to properly address the full range of challenges in creating sustainable biofuels systems. Therefore a primary priority for the project is to assembly a team of specialists who focused on the component science, engineering, economics, planning, and education projects in furtherance of the HCSBC mission.

After the final list of Co-PIs was complete, the group met regularly via Polycom during the first few months of the grant. A web site was created and all products were displayed and assigned a URL for easy location (this information is provided as a table in Section 6 of this Final Summary Report).

J. Capece, Co-PI and President of Intelligencia International, created a mechanism for interns from the US and other countries to participate in the HCSBC activities and created assignments for the interns regarding their interests and as a function of grant need within each Task. This program created a learning environment for the interns and assisted in numerous ways with most of the Task objectives. Typically, four interns would be assigned to this grant at any one time, and each intern would serve from four to six months. More than 20 interns have contributed to this grant directly.

E. Hanlon, PI, also participated in one M.S. final examination, which was conducted in French via Polycom with other graduate student committee members at her University in Paris. Selected interns also gave exit seminars at the UF Southwest Florida REC to faculty and staff members. Interns were housed at Intelligentsia International or later on at the office provided by Edison State College, LaBelle Campus.

All Co-PIs, graduate students, and post-docs participated in Polycom meetings. This approach allowed quarterly or special-event scheduling without travel costs and time. These meetings were scheduled during the first year of the grant before the quarterly reports were due.

Additional special-need meetings were held among the post docs, graduate students, and selected Co-PIs as data were discussed, LCA and emergy models were assembled, and training with PE International specialists for training and operation of the GaBi software and datasets.

Interns, graduate students, and post docs with selected Co-PIs participated in seminars of visiting scientists, usually held at the Southwest Florida Research and Education Ctr., Immokalee, FL.
Graduate students, postdocs, and most of the co-PIs participated in the two meetings of the Community Involvement Committee (CIC). Postdocs presented information regarding Their Efforts with Respect to LCA and emergy to the CIC.
The Biofuels web site (http://swfrec.ifas.ufl.edu/soil_water/biofuels/hcsbc/default.aspx) and section 6 of this report list all products produced by the team. Summary versions were created for use in section 5.

TASK 4.0 [CENTER FACILITIES PLANNING]

SITE EVALUATION REPORT (SUMMARY)

The goal of this study is to determine the location of the future Biofuels Research Center in Western Hendry County. This report describes eleven potential sites. Site attributes have been catalogued and ranked according to multiple criteria sets to determine which site is the best location for the Center.
Six sites (Figure 1)are located in Port LaBelle, and five in LaBelle. In Port LaBelle are (1) CHL Sales Office, (2) Welcome Center, (4) CHL Commercial Lot, (5) Edison State College Campus, (6) Old Duda City Grove, and (11) Site 11. In LaBelle: (3) Bonita Bay Office, (7) Empty Strip Mall, (8) Empty Corner Lot, (9) Old Real Estate Office, and (1) Edison State Curtis House.

Figure 1: Candidate sites considered during the HCSBC site

CHL Sales Office

CHL Sales Office (Figure 2) is located along the State Road 80. The site belongs to CHL Holdings Inc. and has a taxable value of $434,000. The area of the parcel is 1,064,000 square feet and the area of the four existing buildings (CHL office and model homes) is 8,000 square feet. The existing buildings include the CHL Sales Office, two model homes, a gazebo, and a garage/workshop with existing pathways. The site is bordered by existing vegetation on the north and the west (mostly trees and high grass) and a wetland that continues to the east of the site. The wetland covers approximately 1/6 of the parcel; it could be used for recreational activities, once the Research Center is built. It is possible to access the site from the SR 80 on South and a view corridor is found through SR 80 and the existing vegetation over the wetland. The accessibility from the SR80 to the site is a consequent advantage. The existing CHL Sales office could be used as an administrative building. A public parking area and an access road would be designed to bring in the public from State Road 80 to the site. It is also planned to set up demonstration plots for the public along the road.

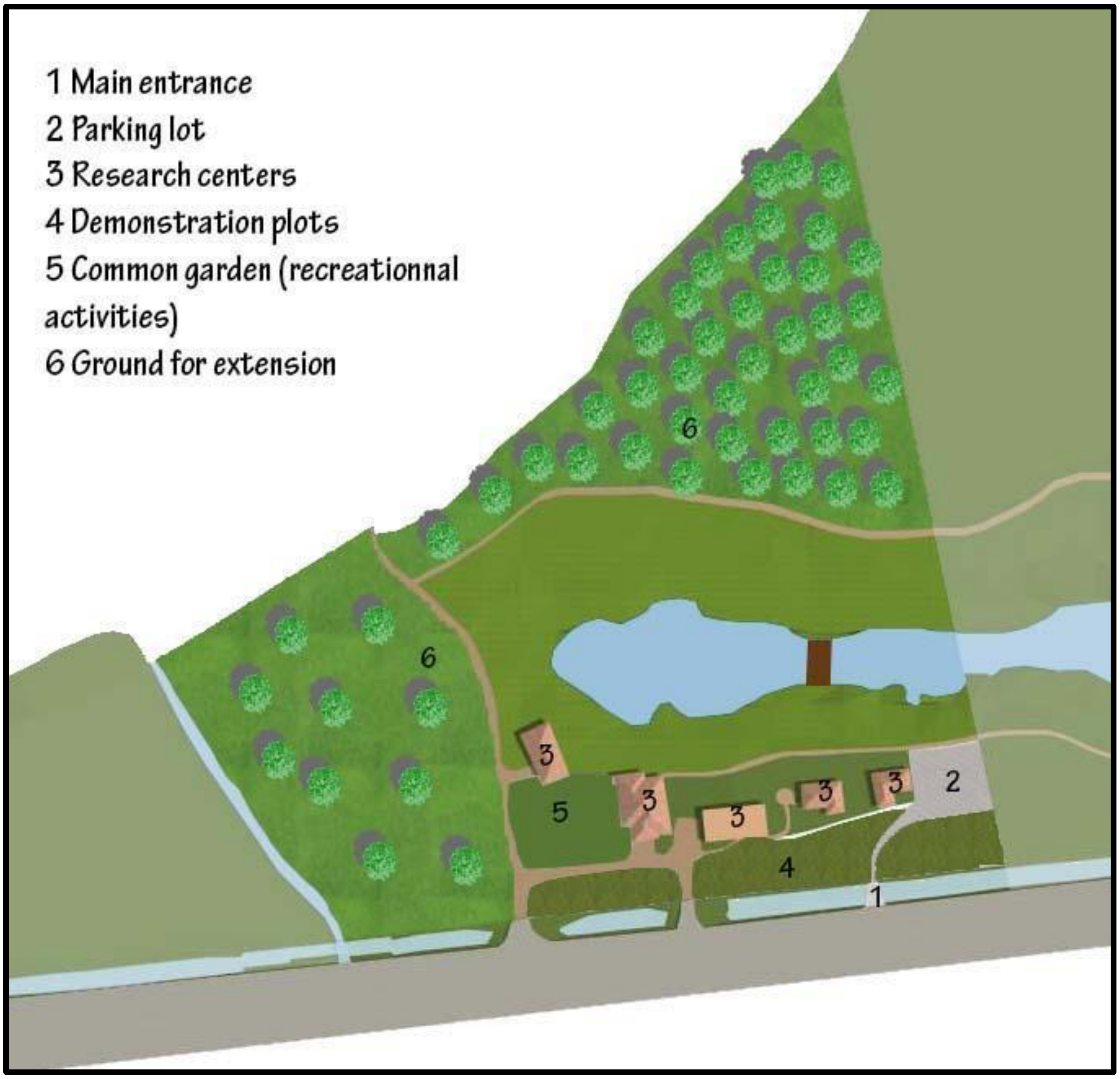

Figure 2: CHL site, location map.

Although the existing buildings are large enough for the architectural brief, another building is needed, which would be visible from the road. The proposed building should resemble a research center appropriate for farming system research in Southwest Florida. Situated in front of these buildings will be the demonstration plots. It is the first thing people will see when they drive along State Road 80. Short crops will be planted in front of the buildings and the high crops will be planted in front of the parking lot. Since the research center is comprised of several buildings, a common garden is laid out between them to create an outside area where visitors and researchers can meet. The area around the lake can also be designed as a place for environmental experiences as well as entertainment. This lake would eventually be used for the irrigation of the crops. The north and west parts of the site are conserved as areas for an eventual extension.

Welcome Center

The Welcome Center (Figure 3) is located along the State Road 80. The site belongs to HKH Partnership and has a taxable value of $196,000 dollars. The area of the parcel is 580,000 square feet and the area of the existing building is about 3,400 square feet. The existing building was previously used as a church. Adjacent to the building is a patio, which would be convenient for the public to eat outside and enjoy nature. The site is accessed from the SR 80 on the South and from Birchwood Pkwy on the West and North. A pathway runs through the site, from the North to the State Road 80. The highway access is a significant criterion that must be considered in choosing the most convenient site for the future Research Center. The open land will host an outdoor exhibition space to teach people about agriculture. The educational facilities with demonstration plots would be a good way to reconnect Americans to the land and teach them about energy and the environment in Florida.

The Welcome Center is a site where almost everything needed is already present (building, accessibility road, parking lot, etc.), so the objective is to take advantage of these existing facilities. The existing buildings are located in the center of the site on a small hill, high enough to have a great view of the surrounding lands. The existing buildings, especially the former church, will be conserved and partly re-designed. The main building, formerly a church, would be the first place people would visit to learn about the farming system in southwest Florida. Then they would view the demonstration plots along the outside promenade. One of the great benefits of the Welcome Center is the beautiful clearing at the west of the church and down the stairs. This shady, bucolic place would be the perfect spot for a pavilion and an outside classroom, built under the live oak trees. This location would be the place where visitors and researchers could learn, meet, eat, and rest.

Figure 3: Welcome Center, site map and concept drawings

Bonita Bay Office

The Bonita Bay Office is located along the State Road 80 in LaBelle. The site is part of the Resource Conservation Properties Inc. and has a taxable value of $900,900. The area of the parcel is 300,000 square feet and the area of the existing building is about 3,300 square feet. The existing building was built in 1967, which is quite old. Some renovations might have to be done if this site is chosen as the place of the future Research Center. The advantages of the site are the accessibility of State Road 80 and the spaciousness of the site, which is necessary for the crops and demonstration plots. Room for expansion is also available if needed. Parking is already available, which is necessary for visitors coming to learn about Biofuels.

Since the major portion of the site is located behind the house, demonstration plots for exhibition will be placed adjacent to the northern edge of the site, so it will be easily visible from the road. The existing building may be too small or inconvenient to accommodate all the activities of the research center, so another building may be built. Once visitors arrive, they would enter the building to learn about sustainable farming systems in southwest Florida, listen to presentations, etc. Afterwards they would have the opportunity to visit the crops in the demonstration plots located behind the buildings. The demonstration plots are rectangular, for easier maintenance and outlined by paths where the visitors can walk. At the intersection of each path, there will be shelters whose functions include outside classrooms, dining shelter that can double as a classroom, experimentation area, and outside exhibitions.

CHL Commercial Lot & Barron WCD Lands

The CHL commercial lot and Barron WCD Lands is located along NE Eucalyptus Boulevard in Port LaBelle. The site belongs to CHL Holdings Inc. and has a taxable value of $25,740. The area of the parcel is 123,000 square feet. There are no existing buildings on this site. All the facilities required for the Research Center would have to be built, which could be costly. However, the fact that the place doesn't have any buildings allows the architect a lot of freedom. The site is accessed from Eucalyptus Boulevard, which is a disadvantage as the site is not located along a major road. However, since this location is less than 0.3 miles away from State Road 80, a path could be designed to connect the site to the highway. The lake nearby could be used for recreational activities.

Since the parcel doesn't have any existing buildings, a design will have to be made for the entire project. The areas with the trees (in green on the scheme) have to be preserved. Since the site's landscape is flat, there is a high risk of flooding. By laying out the site properly, flooding can be avoided at the demonstration plots. The lake can also be used to irrigate the crops, and for recreational use. The building will be located adjacent to the lake, so visitors will enjoy the view. The access road from State Road 80 will lead the visitors to the parking lot behind the building, so people traveling on that road will only see the lake, the building, and the demonstration plots. A promenade will be created, providing visitors information about the farming system in Southwest Florida.

Edison State College Campus

The Edison State College Campus is located along Forrey Drive and Cowboy Way in Port LaBelle. The site belongs to the Edison State College Foundation, Inc. and has a taxable value of $1,614,600. The area of the parcel is 823,000 square feet and the area of the existing building is 35,000 square feet. One of the most important benefits of this site is the proximity to Edison State College. Integrating education and research within the Center would strongly enhance the appeal and value of the Center to citizens. Teachers could be instrumental in developing new knowledge and technologies to the wider public audience. A parking lot already exists, a recreational area, and ample space available for crops and demonstration plots. However, if one of the goals of the Center is to attract the public, the location of the Edison State College Campus would not be convenient since the campus is not located along a major road.

Although the Edison State College campus is located a distance from State Road 80, its main advantage is the presence of the students, teachers, researchers, and facilities from the college. The center would be located adjacent to one of the college's buildings near the entrance, with the goal of creating a strong connection with the students and researchers, attracting them to the center. The building to be converted into the center is composed of classrooms, laboratories, etc., and patios, which could be converted into "inside demonstration plots". The corridor is large enough to be an exhibition space.

Old Duda Citrus Grove

The Old Duda citrus grove is located along the State Road 80 in Port LaBelle. The site belongs to HUPA, Inc. and a taxable value of $37,590 (agricultural exemption). The area of the parcel is 7,780,000 square feet. There are no existing buildings on this site so all the facilities required for the Research Center would have to be built. The buildings would most likely be constructed next to the tree area. Not all of the parcel would be needed for the Research Center; only 4,000 square feet for the buildings and 5,000 square feet for the demonstration plot and the crops. There is no need to buy the entire parcel. The major part of the site consists of flat ground with grasses. There's a small lake surrounded by trees on the northwest corner of the site, with a small river crossing the parcel, and irrigating the lake. One of the goals of the site plan would be to take advantage of the small lake and the river, so that it can be used for pleasure, irrigation, and flood control. By excavation, the pond can be transformed into an attractive amenity. By doing so, we can reproduce in a small scale, a typical Southwest Florida landscape, with lakes, live oaks, high grass, and crops. The access to the site is from State Road 80. The building is adjacent to the parking lot, and near the road, making it highly visible from the road. The demonstration plots (and the eventual extension areas) are located throughout the site, exhibiting a variety of crops. Since State Road 80 is a little bit higher than the parcel, all of the demonstration plots are visible from the road. The research center would be located across from the parking lot. An outside exhibition/promenade would surround the lake, providing educational activities, entertainment, and rest areas. Four bridges will enable visitors to cross the lake at selected points.

Empty Strip Mall

The Empty Strip Mall is located along State Road 80 in LaBelle. The site belongs to the SAND CAPITAL XI, LLC and has a taxable value of $786,320. The area of the parcel is 131,000 square feet and the area of the existing building is 20,000 square feet. The site is accessed from the SR 80 on the north. The highway access is a significant criterion that must be considered in choosing the most convenient site for the future Research Center. Only a part of the strip mall would have to be bought (4,000 square meter approximately, or 1/5 of the current building). The open land would provide an outdoor exhibition space to teach people about agriculture. The educational facilities with demonstration plots would be a good way to reconnect Americans to the land and teach them about energy and the environment in Florida.

Since the building was initially designed to be a mall, there are many disadvantages. Due to the shape and the size of the building, and the type of façade, buying a part of the building (equivalent to 4,000 square feet), wouldn't allow enough windows for each room. The design of the building can't accommodate dorm rooms. Therefore, there are no design propositions for this site.

Empty Corner Lot

The Empty Corner Lot is located along State Road 80 in LaBelle. The site belongs to the EAGLE FL I SPE, LLC and has a taxable value of $777,600. The area of the parcel is 206,000 square feet. There are no existing buildings on this parcel, so all the facilities required for the Research Center would have to be built. The advantage of this site is the proximity of a Commercial center, adjacent to the site. There is a Bar & Grill, which would allow the researchers and visitors to meet and socialize without leaving the grounds.

The Empty Corner Lot is located along State Road 80, just after the city limits of LaBelle, making this location a highly visible site. The parcel is adjacent to a mall with restaurants and facilities. Although, the site doesn't contain any buildings, it is big enough to plan all the demonstration plots, with some eventual extensions. We are trying to take advantage of the mall next to the parcel, so the entrance and the parking lot should be on the south side of the site. The Research Center should be located next to the parking lot, so it can be visible from State Road 80. The building will be the starting point of the outside exhibition. The demonstration plots may be situated on the edges of the site, to ensure visibility from the road. A lake may be excavated in the middle of the site, providing an outside place where people can meet, eat, talk, and learn. The lake may also be used for the irrigation and flood control.

Old Real Estate Office

The Old real estate office is located along State Road 80 in LaBelle. The site belongs to the WATT-BGGS BARBARA and a taxable value of $536,100. The area of the parcel is 70,000 square feet. The area of the old real estate office is 5,231 square feet and was built in 2006. There is a commercial center right across State Road 80, with a Bar & Grill Restaurant, which would allow the researchers and visitors to meet and socialize without leaving the grounds. Due to the area of the parcel, extra space would be required for demonstration plots and crops. One possibility would be to use the available space located across the street to the south, but safety issues should be considered. For this site, facilities already exist so there's no design for this site.

Edison State College Curtis House

The Edison State College Curtis house is located along the Ft. Denaud Road in LaBelle. The site belongs to the EDISON STATE COLLEGE FOUNDATION, INC. and a taxable value of $971,600. The area of the parcel is 3,580,000 square feet and the area of the three existing buildings is approximately 5,000 square feet. A lot of space is available on this parcel, but the two artificial lakes, which occupy at least 1/3 of the parcel, constitute a waste of space, even if they could host ecotourism activities. The major disadvantage of this site is its location; it is not situated along a major road (1.1 miles from SR80, 3.8 miles from SR29, and 4.4 miles from SR80A).

Site 11

Site 11 is located along the Ft. Denaud Road in Port LaBelle. The site belongs to the LABELLE COMMERCE CENTER, LLC. and costs $300,000. The area of the parcel is 200,700 square feet and the area of the existing buildings is approximately 3,000 square feet. The site is accessed from Cowboy Way on the south and is located 0.78 miles away from State Road 80.

Table 1. Key advantages and disadvantages of each site are summarized in the below table.

POTENTIAL SITE	ADVANTAGES	DISADVANTAGES
(1) CHL Sales Office	Along SR80 Four Existing buildings Nice surroundings (wetlands)	Not scientific in appearance
(2) Welcome Center	Along SR80 Existing building Nice surroundings (patio)	Not scientific in appearance
(3) Bonita Bay Office	Along SR80 Space for expansion available	Old building No restaurants nearby
(4) CHL Lot & WCD Lands	Space for expansion available Inexpensive area	Not along a major road No existing building Low, wet area
(5) Edison State College Campus	Link to the College: Parking lot Existing buildings Space for expansion Recreation areas	Not on major road
(6) Old Duda Citrus Grove	Ample space Along SR80 Inexpensive	No existing building
(7) Empty Strip Mall	Existing appropriate building Parking lot Space for expansion Along SR80	Building a little oversized
(8) Empty Corner Lot	Space for expansion Along SR80 Restaurant nearby	No existing buildings

(9) Old Real Estate Office	Space for expansion Along SR80 Restaurant nearby One existing building	Expansion not contiguous
(10) Edison College Curtis House	Space for expansion Nice surroundings Ample acreage available	Large lake area Not along a major road

SITE SELECTION CRITERIA

The ranking of the Biofuel Center candidate sites (Table 1)is based on the following factors: Cost, Presence of water bodies, Date the buildings were built, Parcel area, Highway frontage, Amenities proximity, Area of existing buildings, Space for expansion, and Utility access.

Coefficients are assigned to these attributes according to their importance. The first goal would be to attract people to the Center, a place where people come to learn about energy and the environment. Thus, the site needs to be located along the highway. Accessibility from the highly-traveled State Road 80 to the Center would be one of the most important aspects of the overall site planning. Another consideration would be to include recreational facilities; the presence of water or restaurants on or near the site would be an advantage. A matrix has been created with the different criteria and their coefficient, based upon their relative importance (Table 2).

Table 2. Matrix with assigned relative importance criteria for each site.

		1	2	3	4	5	6	7	8	9	10	11
Criteria	**Coefficient**	CHL Sales Office	Welcome Cente	Bonita Bay Office	WCD Lands	Edison State Col.	Old Dudda Grov	Empty Strip Mall	Corner Lot	Real Estate Office	Curtis House	Site 11

			r				e					
Cost	**3**	7	8	2	10	1	9	3	3	5	6	8
Water	**3**	4	0	0	0	0	0	0	0	0	5	0
Year built	**1**	8	2	2	0	5	0	10	0	8	3	5
Parcel area	**1**	7	6	5	1	9	10	3	4	1	9	4
Nearby amenities	**3**	2	2	2	0	1	1	7	10	10	2	1
Highway access	**9**	10	10	10	6	4	10	10	10	10	3	3
Space for expansion	**3**	5	4	4	4	4	5	4	3	2	5	5
Existing buildings	**4**	7	4	4	0	8	0	10	0	7	6	6
Use	**1**	8	4	4	4	10	4	8	3	5	5	4
	TOTAL	**195**	**160**	**141**	**101**	**110**	**149**	**193**	**145**	**183**	**122**	**106**

If one of the principal goals is to promote biofuels with the public, the CHL Sales Office is the most convenient site, followed by the Empty Strip Mall. A second goal would be a connection to a college/university. Integrating education and research within the Center would enhance the vitality of the Center to citizens. A large area would be required, since the site would have to include classrooms, an auditorium, a library, and a conference room. The highway access would not as important a factor, since the main goal would be education and research, not promotion of biofuels to the public. Given those arguments, the ranking of the eleven sites is a bit different. If the main goal is to promote biofuels with the students via education and research the ranking matrix would be altered and the Edison State College Campus would be the most convenient site for the future location of the Center.

Instead of opening the site to the public or to the students, the Center could remain a private facility, where the main consideration is given to research itself. The Center would be like an office accessible to workers only. In that case, the highway access or the presence of schools nearby would not be necessary. The main criteria would be the cost and the parcel area. Exhibits could still take place once or twice a year to show the local population the progress of their research projects. In this case the CHL Sales Office, the Old Real Estate Office, and the Welcome Center would be potential sites chosen for the Research Center, since they are not too expensive.

ZONING AND LAND USE

To choose one of the eleven preselected sites as the best location for the future Research Center, it is judicious to learn about the zoning of Hendry County and the City of LaBelle (Table 3). The city of LaBelle Future Land Use Map and the Zoning Map, as well as Hendry County Zoning Maps, give a general mapping description of the city and the County. It presents a framework for decisions about land use and development patterns.

Six of the eleven preselected sites are not located in LaBelle. For that reason, it is necessary to look at the Hendry County Zoning Maps. From Hendryprop.com, it is possible to determine the land use of the eleven preselected sites for the future Center. Some information differs from the Henry County Future Land Use map.

Table 3. Zoning for 11 considered HCSBC sites.

Site	Use description	Details
1 CHL sales office	Residential	Single family
2 Welcome Center	Commercial	Office, 1 story
3 Bonita Bay Office	Residential	Single family
4 CHL Lot & Barron WCD Lands	Residential	Vacant residential
5 Edison State College	Public	Private college
6 Old Duda Citrus Grove	Agricultural	Semi-improved pasture
7 Empty strip mall	Commercial	Stores, one story
8 Empty corner lot	Residential	Vacant residential
9 Old real estate office	Commercial	Office, 1 story
10 Edison State College Curtis house	Agricultural	Pasture
Site 11	Commercial	Office 1 story

On the Hendry County Future Land Use Map, the uses of the sites are somewhat different from the uses designated on Hendryprop.com (Table 4).

Table 4. Zoning for the 11 HCSBC sites from the Hendry County Future Land Use Map.

Site	Use description
1 CHL sales office	Recreational
2 Welcome Center	Residential, special density and use
4 CHL Commercial lot & barren WCD lands	Residential, special density and use
5 Edison State College	Residential, special density and use
6 Old Duda Citrus Grove	Residential, Medium density
10 Edison State College Curtis House	Residential, Rural Estates

The City of LaBelle Future Land Use map gives a general mapping description of the city. It presents a framework for decisions about land use and development patterns.

Site 3 (Bonita Bay Office): Outlying - Mixed use district
Site 7 (Empty Strip Mall): Commercial
Site 8 (Empty corner lot): Outlying – Mixed use district
Site 9 (old real estate office): Commercial

According to the “LaBelle Adopted Comprehensive Plan” from www.citylabelle.com website, “it has been determined that the Outlying Mixed Use category is an applicable category for several different areas of LaBelle where a mixed development pattern should be encouraged. The density and intensity of allowable development is based on parcel size categorization”. “The proposed changes to the Outlying Mixed Use are an attempt to attract residential development to the existing areas that can best support and address a need for an increase in population.” Since the sites 3 and 8 belong to the “Outlying Mixed Use category”, it could be an advantage to choose one of these sites for the Research Center building, because “mixed development pattern should be encouraged” in those areas. The future Center would not be considered only agricultural or commercial or educational. There is a “mixed-use” category that would handle all those uses.

Site 3 (Bonita Bay Office): PUD (Planned Unit Development)
Site 7 (Empty Strip Mall): B-2 (Business)
Site 8 (Empty Corner Lot): PUD
Site 9 (Old Real Estate Office): B-2

Two of the preselected sites are "PUD" (Planned Unit Development) and the others are B-2 (Business). According to the Municode, the intent and purpose of the planned unit development (PUD) district is to preserve land for mixed use (commercial and residential) and large scale development and provide an opportunity for specialized and unique design.. Hence, since the eighth site (Empty Corner lot) and the third site (Bonita Bay Office) are PUD, it seems more judicious to choose one of these sites for the location of the future Research Center instead of the other sites (which are B-2), because the regulations and requirements applying to a PUD zoning district shall be sufficiently flexible so as to encourage creative and imaginative design in planning and development.

CONCLUSION

Having provided a literature review on Biofuels facilities in the United States and analyzing the eleven selected sites in regards to cost, area, and existing buildings, this study provides ideas concerning the mission philosophy of the future Center, and has assessed attributes that have been catalogued and ranked according to multiple criteria sets. If it is decided that the goal is to promote biofuels with the public, the CHL Sales Office is the most convenient site for the future Biofuels Research Center. However, if it is decided that the goal is to promote biofuels with the students, the Edison State College Campus is the best location of the Research Center. The project of building a Biofuel Research Center in Hendry County is challenging since no funds have been found as yet. However, it is important to keep fighting for this project, because the potential for biofuels in addressing a looming global energy crisis is significant.

TASK 5.0 [ANALYTICAL TOOLS DEVELOPMENT]

Existing analytical tools used in economics, ecology, and engineering will be assembled and adapted to the task of evaluating the sustainability of proposed biofuels production systems. As experience with use of these tools develops, they will be refined and enhanced to better address current needs. These tools will be used to assess the natural resources implications of biomass production and conversion systems, including impacts upon water, soils, nutrients, arable lands, energy, and greenhouse gasses.

LAND USE REQUIREMENTS FOR PRODUCTION OF BIOFUELS IN FLORIDA

This study establishes relationships between production of various biofuels crops (Miscanthus, Switchgrass, Sorghum, Corn, Elephantgrass, Sugarcane, Energycane, and Eucalyptus), associated biomass and bioethanol yields, land use requirements for these crops, biomass-to-biofuels conversion methods, and the overall fuel demands, particularly in Florida's transportation sector.

Methodology

Florida has been experimenting with various crops for its bioethanol production (Table 5 and Table 6). The focus has been mostly on high biomass yield crops (some sugar-bearing), including Miscanthus, Switchgrass, Sweet Sorghum, Corn, Elephantgrass, Sugarcane and Energycane as well as short rotation woody crops such as Eucalyptus. There exist other bioethanol candidates (e.g. Sugar Beets, Cassava, Wheat, etc.), but these potential feedstocks are not produced in Florida and therefore were not included in this study.

Biomass and bioethanol yields used in this study are only for the crops planted in Florida. Some crops considered in this study (e.g. corn) might have higher yields in different conditions (e.g. cooler climate zone and different soils types in the mid-western Corn Belt) than in Florida, but for this study results produced in Florida form the basis of this summary. However, generic values for biomass to bioethanol conversions were used, as technology in this case is not dependent on climate.

Six subsequent equations are used for bioethanol demand estimation for transportation needs in Florida. Given values include E10 fuel consumption, number of registered vehicles, population, the number of miles traveled on E10, and fossil fuel to bioethanol efficiency. Calculated values represent annual mileage per vehicle, vehicle mileage per gallon of E10, volume of E10 needed per year per vehicle, volume of E100 needed per year per vehicle, number of vehicles per person and volume of E100 needed per year per person.

We divide the estimated volume of E100 needed per year per person by bioethanol production yields from different crops and were able to estimate the annual land requirement to meet bioethanol needs of the Florida transportation sector for the E100 scenario.

We calculated energy content (BTU) and volumes (gallons) of various blended fuels (and their fossil fuel and ethanol fuel components) needed to travel the same given distance. Increasing ethanol concentration in fuel blends decreases the energy content of those blends (linear relationship), but the relationship between the total volumes of fuel blends needed to travel the same distance is non-linear.

We then quantify land requirements for bioethanol crops to cover Florida transportation energy using selected modeled scenarios (E10, E15, E20, E85, and E100).

We did not include in our estimation the varying engine performance in miles per joule between different fuel blends. While refining the modeling approach in such fashion has a logical basis, it would go beyond the scope of this paper.

Biofuels production

Florida bioethanol crops - biomass and bioethanol yields

For bioethanol production, Florida has been experimenting with various crops. The focus has been mostly on high biomass yield crops (some sugar-bearing), including Miscanthus, Switchgrass, Sweet Sorghum, Corn, Elephantgrass, Sugarcane and Energycane. Citrus growers' by-products, such as orange peels, seeds, and molasses are being investigated as well, but since these have an existing use in well-established markets (animal feed, essential oils), their potential for bioethanol production was not considered. Short rotation woody crops such as Eucalyptus get attention as well, mostly due to their high biomass yields. There are more than 16.1 million acres of forests and woodlands in Florida (Mulkey et al., 2008) that could be partially converted to different types of forest, with relatively minor changes in land use scenarios. There is a consensus that sustainable production of bioethanol in the long term will need to utilize cellulosic materials (and thus develop second generation biofuels) rather than utilize food crops with their competing uses (and continuation of unsustainable first generation biofuels). Unfortunately, the uncertainty of a commercially viable cellulosic bioethanol is persistent.

Miscanthus (*Miscanthus x giganteus*) is a genus of tall perennial grass species, used primarily for combustion in power plants so far. Miscanthus also receives attention as a biofuel crop because this crop has relatively high dry biomass yields (5–15 tons per acre) across a range of environmental and soil conditions, and thus a potential for lignocellulosic conversion to bioethanol and other biofuels. However, UF/IFAS researchers found that *Miscanthus x giganteus* was not well adapted for photoperiods and temperatures in Florida and that biomass yield potentials for Florida were lower (4–8 dry tons per acre) compared to other growing areas. Ongoing breeding efforts may eventually create varieties of Miscanthus better adapted for Florida (Erickson, 2012). Current general cellulosic biomass conversion to bioethanol of 50 gallons/dry ton of biomass (Stricker et al., 1993; Mark et al., 2009) was used for the ethanol yield estimation. In this scenario, 300 gallons of ethanol per acre appear to be a realistic yield.

Switchgrass (*Panicum virgatum*) is a perennial grass identified as a potential bioenergy feedstock. While Switchgrass has been mostly directed toward biomass production as a combustion fuel to supplement coal for generation of electricity so far, it is also a potential feedstock for lignocellulosic bioethanol production. Several cultivars (Miami, Stuart, and Alamo) are recommended for Florida and even in low fertility conditions have reasonable dry matter production potential (1.8-3.6 tons per acre). If fertilized, yields in Florida have exceeded 5.4 tons/acre. One dry ton of Switchgrass typically yields between 70 and 90 gallons of bioethanol (Newman et al., 2011; Helsel and Alvarez, 2011). A typical yield is around 290 gallons of ethanol per acre. Less is known about Switchgrass production in Florida than other biofuel crops that have been more widely studied in the state. It is known though that diverse mixtures of grasses produce on average more biomass than the same land planted with single prairie plant species, including Switchgrass (National Science Foundation, 2006).

The term 'Sweet sorghum' is used to describe varieties of sorghum (*Sorghum bicolor*), a annual, which has a high concentration of soluble sugars in the plant sap or juice. Its advantages are easy accessibility of readily fermentable sugars and high yields of green biomass. Juice from sweet sorghum can be converted to bioethanol using fermentation. The bagasse (crushed stalks) that remains after removal of the juice can be burnt to generate electricity (or steam) as part of a co-generation scheme or utilized as a feedstock, if the technology for cellulosic bioethanol production becomes viable on a commercial scale. In Florida, sorghum is grown for grain and silage. Typically, sweet sorghum varieties have low grain yield, but new varieties with more balanced grain/sugar production have been developed. These varieties can be used as a dual-purpose crop, where the grain is harvested for human or animal consumption and the sugars are fermented to ethanol. Alternatively, these varieties can be used as a dedicated bioenergy crop, where both the sugars and the grain are used for ethanol production (Vermerris et al., 2011). According to UF/IFAS sweet sorghum field trials at locations across Florida, plant crop green yields (without grain heads) for high-production sweet sorghum cultivars averaged 31.3 wet tons per acre. Sugar content averaged about 14.8%, but was lower for all cultivars grown on muck soils in the Everglades Agricultural Area. These data resulted in estimated sugar yields of 5,075 lbs. per acre (approximately 400 gallons of ethanol per acre) from a single crop (Vermerris et al., 2011). Other research shows that biomass yields of sweet sorghums ranges from 10 to 13 dry tons per acre and juice content ranges from 65% to 80% (Lindsey, 2005). The combined sugar content of the juice varies between 9%–20%. Sugar yields vary from 1.6 to 6.9 tons per acre and fermentation of the sugar in the juice yields between 400–600 gallons of bioethanol per acre (Vermerris et al., 2011). According to Rahmani and Hodges (2009), one acre of sorghum (Rio cultivar) can produce 364 gallons of ethanol, whereas the next best cultivar (M35-1) produced about 166 gallons of ethanol per acre. Based on this data, 1 ton of sorghum can yield 22 to 48 gallons of ethanol, so the best potential scenario for bioethanol yield for sweet sorghum in Florida is estimated at 400 gallons/acre. Clearly, different cultivars show various yields for stem and for grain per acre – higher stem yields usually equals to lower grain yield and vice versa. In addition to the fermentable sugars contained in sweet sorghum, the bagasse (biomass remaining after the juice is extracted) could be used for conversion to cellulosic bioethanol directly. The ethanol yield is 158 L per ton of sorghum bagasse (Gnansounou et al., 2005). With bagasse being 30% of each one unit of crushed sorghum and using 11.5 ton/acre biomass yields in Florida, additional theoretical 144 gallons cellulosic ethanol per acre could be produced from sorghum bagasse. The efficiency (expressed as the ratio of the amount of ethanol produced to the maximum theoretical ethanol recovery) reaches 80% for sorghum (Gnansounou et al., 2005), so a realistic estimate is around 115 gallons of cellulosic ethanol per acre. Yields of more than 500 gallons/acre are theoretically possible by combining both ethanol production paths (from juices and from bagasse),. Without a sorghum-to-ethanol conversion facility, any estimates may be somehow speculative though.

Corn (*Zea mays)* is a predominant source for the production of about 4 billion gallons of bioethanol in the United States (mostly produced in Midwest states). However, its production cost in Florida is almost twice that for the major U.S. corn-producing states, thus not economically viable. There is currently a plan by some investors to buy corn from the U.S. Midwestern states as feedstock for corn-to-ethanol production in Florida, but it will take time to find out how economically feasible this commercial endeavor would be. The major obstacle seems to be the fact that the corn has to be transported to/from Florida by trucks or rail (thus increasing production costs), since raw ethanol is corrosive to pipelines. Assuming a scenario of an average yield of 150 bushels of irrigated corn per acre in Florida and 2.7 gallons of bioethanol produced from 1 bushel of grain using established technologies, the grain yield is 4.2 tons/acre and the bioethanol yield is 405 gallons/acre (Rahmani and Hodges, 2009; USDA, 2006). Although removing corn stover can lead to severe water and wind erosion and lowering soil organic matter or carbon levels, cellulosic ethanol production from corn stover is being considered as well. Assuming 4.5 dry tons of stover produced from 150 bushels/acre corn field (Nielsen, 1995) and a theoretical ethanol yield of 143 L/ton of corn stover (Gnansounou et al., 2005), 170 gallons of cellulosic ethanol could be produced per acre theoretically. However, assuming ethanol recovery of 80% and keeping in mind that the best collection method (shredding and raking) harvests only 80% of available stover (Lang, 2002), 109 gallons of cellulosic ethanol per acre is a more realistic value. Approximately 8 tons/acre of biomass can be collected from a typical corn field, comprised of 4.2 tons/acre of grain and 3.6 dry tons of stover. Theoretically, combining both ethanol production paths for corn (from grain and from stover) could yield in excess of 500 gallons/acre.

Elephantgrass (*Pennisetum purpureum*), also called Napiergrass, is a perennial bunchgrass with large stiff stems at maturity. Woodard and Sollenberger (2012) show its biomass yield of 14 to 18 tons/acre, Prine and Woodard (1995) documents an average yield of 13.7 tons/acre at four locations in Florida. While Elephant Grass is the highest-yielding perennial grass for biomass production in Florida, there are no commercial facilities converting it to bioenergy. There are several issues - in northern and central Florida it creates environmental concerns due to its need for high N fertilization and thus nitrate leaching. In south Florida it is not planted at all due to its potential for invasiveness (Woodard and Sollenberger, 2012).

Elephantgrass ethanol yield in Florida was estimated at 35 gallons/dry ton by Mielenz (1997). Since technological knowledge has progressed, current general cellulosic biomass conversion to bioethanol of 50 gallons/dry ton of biomass (Stricker et al., 1993; Mark et al., 2009) was used for the ethanol yield estimation. Given such a scenario, 800 gallons of ethanol per acre appear as a realistic yet theoretical yield, given the currently existing red flag for Elephantgrass production in Florida.

Sugarcane (*Saccharum* spp.) is a perennial grass and one of Florida's major crops that can be grown throughout the State. Average sugarcane yields range from 32 to 38 tons of green biomass per acre (Rainbolt, 2010). Dry weight to fresh weight ratios are 28-29% for green leaves, 17-20% for stalks, and 39-64% for brown leaves (Zhao et al., 2010). Green leaves and top represent approximately 10% of a mature sugarcane plant dry biomass, mature stalk 85% and dry leaves 5% (communication with L. Baucum, Agronomic Extension Agent, UF/IFAS). Based on these values, dry biomass yield for sugarcane is estimated as 6.77 to 8.04 tons/acre. Conversion rates for sugarcane juice to bioethanol may vary based on sugar content; varieties with higher sugar content produce more bioethanol. Sugar yields are typically 200 to 300 lbs. of sugar per ton of green biomass. The sugars extracted from sugarcane can be easily fermented to produce bioethanol, 13 lbs. of sugar converts into 1 gallon of bioethanol. In other words, 670 gallons of bioethanol can be produced from 1 acre using the molasses sugar (Miller, 2010). Other sources (Shapouri and Salassi, 2006) show (using 141 gallons per ton of sucrose conversion factor) that roughly 19.5 gallons of bioethanol can be produced from 1 ton of sugarcane (12.24% raw sugar recovery rate, plus 41.6 pounds of sucrose from cane molasses = 235.0 pounds of sucrose from raw sugar and 41.6 lbs. of sucrose from molasses = 19.5 gallons of bioethanol). Using these estimates, bioethanol yield from fermentable sugars in Florida’s sugarcane is between 624 and 741 gallons/acre. In addition to the fermentable sugars contained in sugarcane, the bagasse (biomass remaining after the juice is extracted from the stalks) is used by sugar mills to generate steam or electricity. There is also an ongoing effort to ferment sugarcane sucrose to bioethanol or convert sugarcane biomass to cellulosic bioethanol directly. Generally, 280 kg of humid (45-55%) bagasse is generated from 1 ton of sugarcane. A significant quantity of post-harvest sugarcane leaves is also generated (250 kg dry weight per ton of sugarcane). Despite major research efforts to promote sugarcane bagasse as a bioenergy material, commercial use on an industrial scale has yet to be explored. Theoretically, a single ton of sugarcane bagasse could yield up to 300 L of ethanol. With 28% bagasse/sugarcane ratio and estimated 7.4 tons/ac sugarcane yield, 164 gallons of cellulosic ethanol per acre of sugarcane could be theoretically produced (Chandel et al., 2012). However, there are several parameters that directly affect ethanol yield, such as the quality of bagasse, the process employed for ethanol production and ethanol recovery rate. Realistic estimate is therefore somewhat lower at 130 gallons of cellulosic ethanol per acre. If bagasse were used on a large scale for ethanol production, other sources would have to be found to generate heat and electricity for plant operations (Pancholy et al., 2011). Theoretically, if both the sugarcane juices and bagasse were processed for ethanol production, 723 to 905 gallons of ethanol/acre could be produced. An estimated 12,000 to 15,000 L of ethanol per hectare (= 1,285 – 1,306 gal/acre) could be produced in the future (Chandel et al., 2012). This amount could be even higher if sugarcane leaves were employed in the process as well. Clearly, "mixed" approach of sugarcane juices & molasses and cellulose bioethanol production could potentially generate a much higher yield in bioethanol compared to the present production just from the juices. In addition to current technological constrains, large volumes of water are needed for cane washing, creating thus high biochemical-oxygen-demand (BOD) wastewater for disposal. This water can't be released without thorough treatment to the sensitive environment especially in south Florida.

Energycane is from the same genus like sugarcane, *Saccharum*, a hybrid cross between sugarcane (*Saccharum officinarum*) that produces thick stems and a related grass species (*Saccharum spontaneum*) that is adapted to a drier and cooler climate. The major difference between the two is that Energycane is bred for high fiber content, while Sugarcane is bred for low fiber content but high sugar content. Energycane cultivars grown in central Florida demonstrated average yields of 20 to 25 tons/acre of dry biomass (80 to 100 tons fresh weight/acre) (Rainbolt, 2010). Using the current estimate of biomass cellulosic conversion to bioethanol of 50 to 60 gallons/dry ton of biomass (Stricker et al., 1993; Mark et al., 2009), ethanol yield in excess of 1100 gallons/acre appears possible. As cellulosic bioethanol plants and technology approach commercialization, the efficiency rate could be even higher (90 gallons/dry ton of biomass) (Schnepf, 2010). Some scientists are excited about the Energycane prospects in Florida. Others don't anticipate any Energycane being grown in the traditional sugarcane growing areas of Florida though, as Sugarcane seems better suited to the region's soil types and subtropical climate (USDA, 2012).

Florida's long growing season and abundant moisture results in highly productive short rotation woody crops. Potential oven-dry annual biomass yields of promising species are: 8.9 ton/acre for cottonwood (*Populus deltoides*), 10.3 ton/acre for closely-spaced slash pine (*Pinus elliottii*), 14.0 ton/acre for leucaena (*Leucaena leucocephala*), 11.2

ton/acre for intensively managed *Eucalyptus amplifolia* in north Florida, and 16.1 ton/acre for *Eucalyptus grandis* in central and south Florida (Stricker et al., 2000). Some of these are considered as a viable source of renewable woody biomass, since Eucalyptus species including *Eucalyptus grandis* have been grown in Florida with success for several decades with no signs of invasiveness. Its energy-wood may be utilized for example by co-firing with coal for electricity generation by many utilities in Florida. Conversions to bioethanol are still being tested, but with estimates of biomass yields in Florida of 10 to 15 dry tons per acre and with bioethanol yields of 85 gallons/ton, they promise high potential bioethanol yields (Hinchee et al., 2011; Gonzalez et al., 2011; Duke, 1983; Enguidanos et al., 2002). Also, new lignin breakout technologies are being developed and thus the bioethanol potential yields can be much higher (in the future estimated as high as 2250 gallons of bioethanol/acre) (Arborgen Inc., 2010). As of 2007, forests covered 16.9 million acres in Florida. 94% of that area is considered available for timber production and classified as timberland, the remainder is largely reserved (e.g. parks and preserves) or unproductive. Almost half of Florida is made up of timberland of which approximately 10.1 million acres are held by private forest landowners (Florida Department of Agriculture and Consumer Services, 2010). Trees will play a significant role in helping to meet renewable energy standards, but multiple, integrated approaches with a variety of different crops and production systems will be required to meet the total renewable energy objectives.

Table 5: Dry biomass production yields of bioethanol crops in Florida (ton/ac and US ton/ha)

	Low		Medium		High	
	ton/ac	ton/ha	ton/ac	ton/ha	ton/ac	ton/ha
Miscanthus G2	4.00	9.88	6.00	14.82	8.00	19.76
Switchgrass G2	1.80	4.45	3.62	8.94	5.44	13.44
Sorghum G1+G2	10.00	24.70	11.50	28.41	13.00	32.11
Corn G1+G2	6.76*	16.70	7.80*	19.27	8.84*	21.83
Elephantgrass G2	14.00	34.58	16.00	39.52	18.00	44.46
Sugarcane G1+G2	6.77	16.72	7.40	18.28	8.04	19.86
Energycane G2	20.00	49.40	22.50	55.58	25.00	61.75
Eucalyptus G2	11.20	27.66	13.65	33.72	16.10	39.77

** grain only (G1) is 3.6, 4.2 and 4.8 tons*

Table 6: Bioethanol energy crops production yields in Florida (L/ha and gal/ac)

	Low		Medium		High	
	L/ha	gal/ac	L/ha	gal/ac	L/ha	gal/ac
Miscanthus G2	1496	160	2805	300	4488	480
Switchgrass G2	1178	126	2708	290	4578	490
Sorghum G1+G2	2761	295	4841	518	7359	787
Corn G1+G2	3660	391	4806	514	6102	653
Elephantgrass G2	5236	560	7480	800	10098	1080

Sugarcane G1+G2	6229	666	7568	809	9048	968
Energycane G2	7480	800	10519	1125	14025	1500
Eucalyptus G2	7854	840	10848	1160	14301	1530

LAND USE CHANGES

Background

Land Use Change (LUC) is a general term covering two distinct (direct, indirect) means by which land can be altered in the pursuit (in this specific case) of biofuels production.

Direct LUC (dLUC) occurs when land previously used for other purposes is converted to biofuel crops production. This type of change involves changes in land use on sites used for food or fiber production (including also changes in crop rotation patterns, conversion of pasture land and changes in forest management) or conversion of natural ecosystems for bioenergy crops land.

Indirect LUC (iLUC) refers to the changes in land use that take place elsewhere as a consequence of a bioenergy project. For example, displaced food producers may re-establish their operations elsewhere by converting natural ecosystems to agriculture land, or due to macroeconomic factors, the agriculture area may expand to compensate for the losses in food/fiber production caused by a bioenergy project. iLUC is thus defined as the equivalent changes that occur when grassland and forest are converted to cropland or rangeland to meet the demand for commodities displaced by the production of biofuel feedstocks (Berndes, 2002).

In most cases, the effects of iLUC far outweigh those of dLUC and have great un-sustainability effects (Lapola et al., 2010). Unfortunately, there is a lack of standards and policies across the industry, leading to estimations that are difficult to compare. Many older studies either completely ignored the implications of LUC or mentioned this issue only briefly to explain the difficulty faced in quantifying the effects. Newer analytical studies assess the expected changes in land use from increased biofuel demand, but little empirical evidence is yet available on which to base predictions on what, when and how will be directly or indirectly affected (FAO, 2008). LUC as a topic cannot be overlooked, as its importance with time increases. Addressing the ignored gaps is one of the main focuses of this study.

Land use changes and biofuels production

Concerns are being raised regarding several factors related to potential and actual biofuels production, e.g. diversion of land away from use for food, decreased preservation of biodiversity, increased usage of fertilizers, diverting water and other resources, etc. (FAO, 2008). In 2004, about 13.8 million hectares of land was used worldwide to produce biofuels (about 1% of global available arable land).

Rising food demand, which will compete with biofuels for arable and pasture land, will constrain the potential for biofuels output. However, this effect may be partially offset by higher agricultural yields, applying best management practices, better urban planning, better feedstock choices, increased usage of marginal and non-arable land and similar sustainable approaches. Such strategies can be socially, environmentally and economically viable, and can create jobs and opportunities for enhancing the well-being of generations to come.

There is a wide variation in the total amount of biomass (and potentially bioethanol) that can be produced on a unit area of land, depending on species chosen, soil fertility, climate condition, agronomic treatments, etc. For example, high bioethanol yields per hectare of a first-generation biofuel feedstock (e.g. Sugarcane with 550-810 gallons/acre in Florida) hardly rivals with only moderate productivities that have been achieved with growing second-generation biofuel feedstock so far (e.g. Energycane with 800-1500 gallons/acre) in the same geographical area. It is important to consider that only a fraction of the first generation sugarcane biomass is used for liquid fuel production in a first-generation biofuel facility, while nearly all of the above-ground Energycane plant would be used for production of a second-generation biofuel. However, complex economic feasibility of the biofuels production needs to be measured and quantified as well (Langholtz et al., 2006).

Relationship between the biofuels generations and land use efficiency should be considered thoroughly.

First generation biofuels conflict with food supply, having a limited positive effect relative to land use efficiency, as arable land is needed for planting these crops. As a net outcome, first generation biofuels *decrease* land use efficiency, often in an indirect way. An example of an iLUC would be converting forests to cropland in order to meet the demands for edible commodities displaced by the production of biofuel feedstocks.

Second generation biofuels use non-edible plants, so have a potential to *increase* land-use efficiency, as marginal and non-arable land can be used for planting these crops. Dedicated high-yielding lignocellulosic energy crops show promising results in decreasing the land use negative effects. However, there also exists a potential for land competition - not necessarily for land used for food production, but for land used e.g. for ecosystem or other services. Restoration of degraded lands via second generation biomass-energy crops production may be of an interest and an important way forward (Larson, 2008).

Third generation biofuels (derived from microbes and algae) have a great potential to *overcome* major drawbacks of the first and second generation biofuels. It is estimated that replacing all of U.S. oil consumption with algae fuel would probably require 15,000 square miles of production. By comparison, 35,000 square miles of corn production is currently used to meet just 10% of U.S. fuel needs in the form of bioethanol (Shrank, 2010). However, since this is still a very new research area, various potential consequences need be carefully evaluated.

LAND USE CHANGES – FLORIDA CASE STUDY

Land use changes in Florida

Until the end of the 19th century, much of the land cover in Florida remained in a natural state. Only at the beginning of the 20th century, the region opened to extensive residential and commercial development, which dramatically affected local land use (Snyder and Davidson, 1994). Population pressure, rapid urban growth and the need for land to support agricultural activities resulted in significant changes in Florida's land use. Between 1936 and 1995, Florida's population grew more than 8-fold, from 1.7 million to 14.1 million residents. During the same period, Florida's areas occupied by forest land and marsh land decreased 22% and 51%, respectively. The area of cropland, pasture and range lands increased a combined 59% and the area of urban lands increased approximately 628% (Florida Department of Community Affairs, 1997). Florida's population and development growth since then even accelerated (5 million additional people in Florida during last 16 years, so 35% population growth).

Much of the urban development in Florida has been in the form of land-intensive, low-rise, single-family dwellings. Demand for urban land originates primarily from retirees, other in-migrants, and tourists. Residential developments with detached homes and landscaped lots near land-extensive recreational amenities (such as golf courses) increased dramatically during the past decades. Sharp growth in the consumer base increased demand for locally grown produce and thereby encouraged further agricultural development.

A relatively recent (2006) study by Kautz (1997) compares land use changes in Florida between 1985 and 1989 with that of 2003. Of 9.86 million ha of natural and semi-natural land cover types present in Florida in 1985–89, 1.32 million ha (13.3%) were converted to urban, developed, or agricultural land uses by 2003. Conversions to urban and developed lands accounted for 0.61 million ha and conversions to agricultural uses accounted for 0.70 million ha. These results clearly indicate the shift away from natural land to land compatible with urban development and agriculture.

Loss of biological diversity is another consequence of land use changes. Exotic species, pollution, overharvest and diseases are important factors, but the major threat is by far the destruction of natural habitat. 13 vertebrates and 14 vascular plants have been driven to extinction or have been extirpated from Florida, many other species are in danger of extinction or have declining populations, and several natural community types have nearly disappeared (Kautz, 1998). For Floridians who wish to ensure the long-term existence of the remaining components of the state's biological diversity, the next several years will be critical.

Florida has approximately 44,500 farms and ranches (USDA, 2008) operating 10.38 million acres of agricultural lands and woodlands (USDA, 2008). Typical are large farms with repetitive production, which is often driven only by profit. In making land use changes, there is a need to include in the decisions other services, since changes in land use over the next decades can have adverse effects.

Florida has a complex land use regulatory regime. It requires every development permit to be consistent with local land development regulations as well as local comprehensive plans. In turn, local comprehensive plans must be generally consistent with adopted regional plans and regulations (Carriker, 2006). However, arguments like an elimination of state's review of local plans were used in political campaigns lately and by adopting the Florida House Bill 7207 in 2011, dramatic fundamental changes occurred. The authority of local governments to protect the integrity of their plans through limitations on the approval of plan amendments has been greatly reduced, while on the contrary the ability of the development industry and lobby to pursue theirs goals has been greatly increased. With the Department of Community Affairs (DCA), the state land planning agency, being effectively abolished, this newly pursued legal approach represents a major retreat from the state's commitment to comprehensive planning (Pelham, 2011).

Clearly, Florida is uniquely endowed to become a leader in the negative effects (such as GHG emissions) mitigation through the effective management of agriculture, forestry, and natural ecosystems. Realizing this potential requires policymakers to consider competing land uses and their eventual consequences in a long-term vision. With the newly established trend described in the previous paragraph, this long-term vision faces some very serious obstacles.

Energy in Florida

Total energy consumption in Florida in 2010 was 4,382 trillion BTU in equivalent heat energy units (around 4.5% of total US consumption, which is slightly lower usage per person than US' average, assuming Florida has a 6% population share of the total population of the USA), with the largest share for transportation (36%), followed by residential (30%), commercial (23%), and industrial (12%) sectors (EIA, 2012).

Estimating future energy consumption is a complex process, as there are many (sometimes almost immeasurable) factors to consider – e.g. type of fuel and how efficient one is over the other, geographical area or region, income levels, types of housing, technological progress, etc. The U.S. Energy Information Administration (EIA) provides a forecast of energy consumption in the USA up to 2035. According to the EIA's findings, the total energy consumption in 2035 would be 114.5 quadrillion BTU's, which is about a 20% increase from current consumption (Florida Department of Transportation, 2009). Assuming simply 20% energy demands increase in Florida by 2035 would not be correct; some of the factors will increase the energy demands growth, some of them will decrease it. For example, population is expected to grow in Florida by 2035 by over 47% (Florida Department of Transportation, 2010), which is more than double of the estimated national average (Campbell, 1996). On the other hand, modernizing e.g. fuel efficiency (under the Corporate Average Fuel Economy (CAFE) Standards) and increasing the number of miles traveled per unit of fuel for newly built vehicles might have a larger influence in Florida, given its large vehicular fleet. Regardless of the specific growth pace, it is certain that the future energy demands of Florida will be considerably higher than they are currently.

Florida has only minor oil reserves and ranks sixth in the US for total GHG emissions (EIA, 2008; Mulkey, 2007), but has a large forestry and agricultural sector. The State is aggressively pursuing the development of a sustainable biofuel industry, while looking for ways to produce liquid biofuels by using enhanced traditional or new technologies, e.g. by experimenting with high-yield cellulosic crops such as Sugarcane, Energycane, Sweet Sorghum, and others.

Biofuels in Florida

In 2011, the estimated consumption of ethanol in Florida was 19.7 million barrels (= 621 million gallons). 98.5% of the ethanol was used for transportation needs (EIA, 2011).

In 2007, Florida had 8.05 million acres of agricultural area (2.95 million acres of cropland and 5.10 million acres of pastureland) (USDA, 2008) and 16.1 million acres of forests and woodland (Mulkey et al., 2008). With population of around 19 million people (Florida Department of Transportation, 2012b) it translates into only 0.17 ha (0.42 acres) of agricultural land per person – out of which 0.06 ha (0.15 acres) is cropland and 0.11 ha (0.27 acres) pastureland. Agricultural land availability is ultimately the limiting resource for agricultural and biofuels production, both worldwide and even more clearly in Florida.

Still, due to its favorable climatic conditions (mostly abundant rainfall and year-round growing conditions for various crops), advanced research, modern technologies as well as traditional leading role in agricultural production, the potential for production of high-value biofuel crops in Florida is attractive (Greene et al., 2004). Sugarcane is currently being farmed on over 400,000 acres (mostly in the EAA), Sweet Sorghum on 100,000 acres and corn on 70,000 acres (Mulkey, 2008), which in total represents almost 20% of Florida's available agricultural land. There are also plans for introducing cellulosic biofuels farming to south Florida's land currently set aside for future water management and environmental restoration as well as various abandoned farmlands. Studies about hypothetical market for renting and converting forested land into row cropping for biofuel production were conducted and revealed that nearly half of the 1,060 non-industrial landowners sampled in Florida are willing to accept payments for land type conversion (Pancholy et al., 2011). Substitution of fossil fuels with biofuels holds significant promise for reducing GHG emissions, particularly in the light of expected doubled energy demands of Florida by 2030. So clearly, there is an enormous potential for gain.

However, there are clearly also some serious potential consequences that need to be considered and planned for in the future plans. The muck soils of the EAA are a nonrenewable resource and an unaddressed subsidence caused by intensive farming that will seriously affect agricultural productivity (Walker et al., 1997). Other studies reveal that there are consequences for changing climate variability and production yields with increased biofuels crops production as illustrated in the example of maize in the Midwest (Southworth et al., 2000). Biomass has characteristics that lower its economic competitiveness against traditional fossil fuels (i.e. large dispersion across the landscape or seasonal production). Large-scale conversion of land by creating extensive monoculture tracts of biofuel crops might potentially preclude or limit its availability for delivery of other very important services. Similarly, large-scale bioethanol production can require enormous quantities of freshwater, placing a strain on regionally scarce water resources. Shifting the desired biofuels production to other parts of Florida (or even overseas) will inevitably result in the iLUC with its negative effects though.

A detailed investigation of various biofuels crops that could be used to produce bioethanol for transportation in Florida was conducted. First, average transportation needs of a Floridian were calculated. These results were then transformed to estimated land use demands under a scenario that all the transportation needs of Floridians should have been covered by bioethanol. Results presented below indicate that while a solution, where all the transportation needs of Florida would be covered by cellulosic bioethanol, is not viable, it is certainly an approach that needs to be investigated further and considered as a partial or transitional solution for future transportation fuel needs.

<u>Bioethanol potential demands in Florida</u>

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$$\text{□}100\ \text{□□□□□ □□ □□ □□□ □□□□□□□□} \quad [4]$$
$$= 568.0\ \frac{\text{□□□ □}10}{\text{□□□ / □□□□}} + 44.9\% * 568.0\ \frac{\text{□□□ □}10}{\text{□□□ / □□□□}}$$
$$= 823.3\ \frac{\text{□□□ □}100}{\text{□□□ / □□□□}}$$

$$\text{□□□□□□ □□ □□□□□□□□□ □□□ □□□□□□ □□ □□} = \frac{14{,}372{,}807\ \text{□□□}}{18{,}905{,}048\ \text{□□□□□□}} \quad [5]$$
$$= 0.76\,\frac{\text{□□□}}{\text{□□□□□□}}$$

$$\text{□}100\ \text{□□□□□ □□ □□ □□□ □□□□□□□} = 823.3\ \frac{\text{□□□ □}100}{\text{□□□ □□□□}} * 0.76\,\frac{\text{□□□}}{\text{□□□□□□}} \quad [6]$$
$$= 625.7\ \frac{\text{□□□ □}100}{\text{□□□□□□ / □□□□}}$$

Bioethanol land requirements in Florida

The preceding tables (Table 5 and Table 6) document the biomass production yields (ton/acre) and bioethanol production yields (gal/ton of biomass and gal/ac) for eight various biofuels crops considered in this study. To meet bioethanol needs of the Florida transportation sector, annual land requirement per person can be calculated by using the bioethanol production yields for various crops (Table 7).

For example, with the production of Miscanthus, three different bioethanol yields scenarios were estimated (low = 160 gallons/acre, medium = 300 gallons/acre and high = 480 gallons/acre). With estimated need of 626 gallons of bioethanol per person per year, 3.91, 2.09 and 1.30 acres of land per person, respectively would be needed to cover the potential bioethanol (E100) needs of Floridians:

$$\text{□□□□□ □□□□□ □□□ □□□□□□□□□□□□} \; (\text{□□□□□□□}) = \frac{626}{300} = 2.09 \, \frac{\text{□□□□}}{\text{□□□□□□□}}$$ [7]

Table 7. Land requirements for bioethanol crops for E100 in Florida (ac/person and ha/person).

	Low		Medium		High	
	ha/person	ac/person	ha/person	ac/person	ha/person	ac/person
Miscanthus G2	1.58	3.91	0.84	2.09	0.53	1.30
Switchgrass G2	2.01	4.97	0.87	2.16	0.52	1.28
Sorghum G1+G2	0.86	2.12	0.49	1.21	0.32	0.79
Corn G1+G2	0.65	1.60	0.49	1.22	0.39	0.96
Elephantgrass G2	0.45	1.12	0.32	0.78	0.23	0.58
Sugarcane G1+G2	0.38	0.94	0.31	0.77	0.26	0.65
Energycane G2	0.32	0.78	0.23	0.56	0.17	0.42
Eucalyptus G2	0.30	0.74	0.22	0.54	0.17	0.41

Land use trade-offs in Florida

E10 volume needed to cover averaged travel distance of a vehicle in FL (13,348 miles - equation [1]) is 568.0 gallons of E10/vehicle/year (equation [3] above). Given that there is on average 0.76 vehicles per Floridian (equation [5]), E10 needs to cover averaged travel distance of a Floridian is 431.7 gallons of E10/Floridian/year:

$$\square 10\ \square\square\square\square\square\ \square\square\square\ \square\square\square\square\square\square\square\square\square\square\square = 568.0 \frac{\square\square\square\ \square 10}{\square\square\square\square\square\square\square\square\ /\ \square\square\square\square} * 0.76 \frac{\square\square\square}{\square\square\square\square\square\square\square} \quad [8]$$

$$= 431.7 \frac{\square\square\square\ \square 10}{\square\square\square\square\square\square\square\ /\ \square\square\square\square}$$

The volume content of 1 gallon of E10 should be seen as a mixture of 90% fossil fuel gas 10% ethanol. Energy content of gallon of such blend is then 110,300 BTU (102,690 BTU from fossil gas and 7,610 BTU from ethanol). If the ethanol concentration in the fuel mixture is increased to 15% (E15 blend), the energy content of 1 gallon of that blend decreases to 108,400 BTU (96,985 BTU from fossil gas and 11,415 BTU from ethanol).

To quantify eventual land use trade-offs for potentially increased use of bioethanol crops and bioethanol fuel produced in Florida, various scenarios were modeled. As shown in Table 8, by increasing ethanol concentration in fuel blends, the energy content of those blends decreases, so volume of the fuel needed to travel the same distance increases.

Table 8. Energy content of 1 gallon of blended fuels (BTU/gallon) and volume of fossil fuel and ethanol fuel (gallons) per Floridian needed to travel 13,348 miles.

Fuel Blend	Energy content of 1 gallon of Total Blended fuel (BTU/gallon)	Fossil fuel content (gal) to travel 13,348 miles	Ethanol fuel content (gal) to travel 13,348 miles	Total Blended fuel content (gal) to travel 13,348 miles
E0	114,100	417.3	0.0	417.3
E10	110,300	388.5	43.2	431.7
E15	108,400	373.4	65.9	439.2
E20	106,500	357.7	89.4	447.1
E85	81,800	87.3	494.8	582.1
E100	76,100	0.0	625.7	625.7

As shown in the Figure 4, there is a linear relationship between fuel blend vs. its energy content. However, there is a non-linear relationship between the total volumes of fuel blends needed to travel the same distance(Table 8).

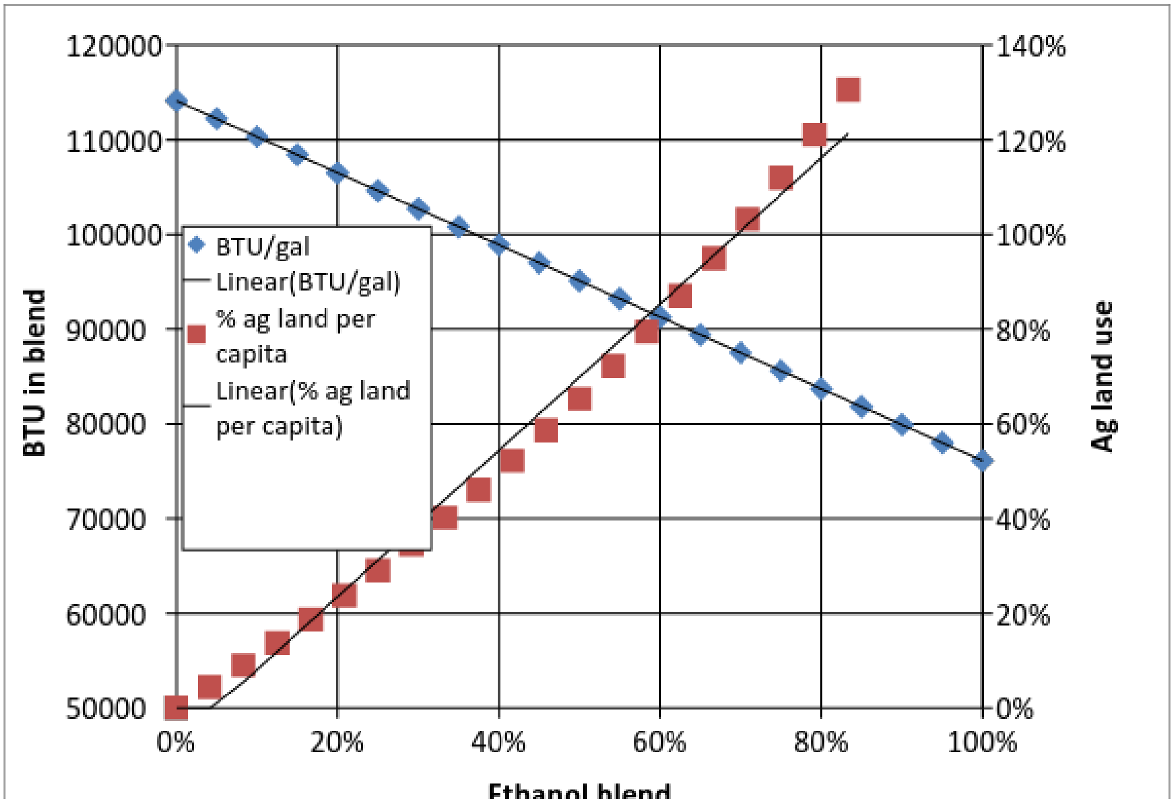


Figure 4:Agricultural land demand in Florida for biofuels crops to cover ethanol volumes in different fuel blends for satisfying annual vehicular transportation needs of Floridians

Knowing the needed volume of blended ethanol per person (Table 8), knowing the volume of ethanol that could be produced from different crops per acre as (Table 6) and knowing the acreage of available agricultural land per Floridian (0.43 acres/person), we estimated how much agricultural land would be needed to produce enough ethanol for different fuel blends (Table 9 and Figure 5).

Table 9. Agricultural land demand in Florida for biofuels crops to cover ethanol volumes in different fuel blends for satisfying annual vehicular transportation needs of Floridians

	E10	E15	E20	E85	E100
Miscanthus G2	34%	52%	70%	387%	490%
Switchgrass G2	35%	53%	72%	401%	507%
Sorghum G1+G2	20%	30%	41%	224%	284%
Corn G1+G2	20%	30%	41%	226%	286%
Elephantgrass G2	13%	19%	26%	145%	184%
Sugarcane G1+G2	13%	19%	26%	143%	181%
Energycane G2	9%	14%	19%	103%	131%
Eucalyptus G2	9%	13%	18%	100%	127%

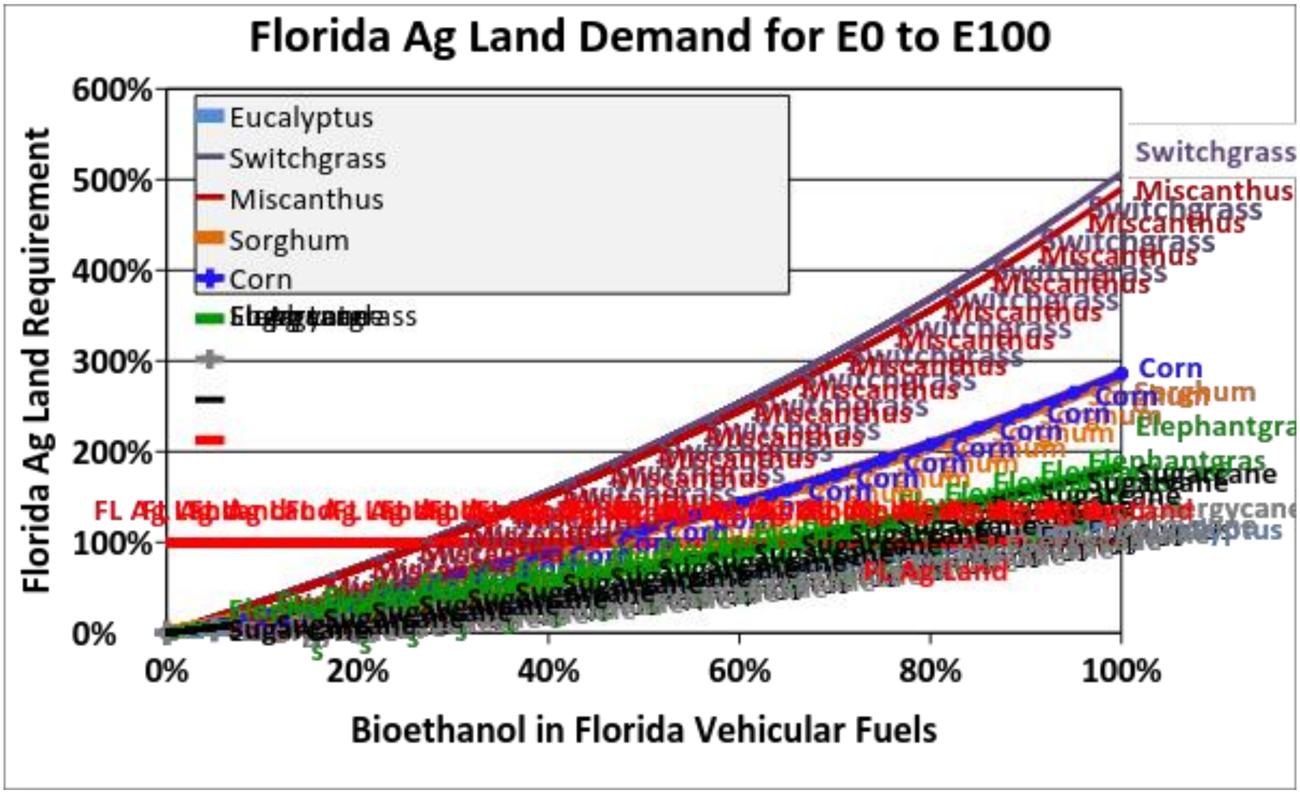


Figure 5: Agricultural land demand in Florida by selected biofuels crops to satisfy annual vehicular transportation fuel needs of Floridians

Conclusions

This study established relationships between production of selected biofuels crops (Miscanthus, Switchgrass, Sorghum, Corn, Elephantgrass, Sugarcane, Energycane, and Eucalyptus), associated biomass and bioethanol yields, land use requirements for these crops, biomass to biofuels conversion methods and the overall fuel demands, particularly in Florida's transportation sector.

Dry biomass production yields of the selected bioethanol crops varied between 22.5 tons/acre (Energycane) and 3.6 tons/acre (Switchgrass).

Ethanol yield from 1 ton of dry biomass for both first and second generation ethanol production paths were included for those crops, where these conversions are possible (Sweet Sorghum, Corn, and Sugarcane) and the results varied between 96 gallons/dry ton (first generation Corn) and 35 gallons/dry ton (second generation Sorghum).

Ethanol production yields from biomass of the selected bioethanol crops were estimated and where possible, a “combined” approach of first and second generation production was used. The results showed that the highest yield of bioethanol is obtained from Eucalyptus (1160 gallons/acre) and Energycane (1125 gallons/acre), followed by Sugarcane (809 gallons/acre), Elephantgrass (800 gallons/acre), Sorghum (518 gallons/acre), Corn (514 gallons/acre), Miscanthus (300 gallons/acre) and Switchgrass (290 gallons/acre).

Florida has 18,905,048 inhabitants, 14,372,807 registered vehicles with an average annual mileage of 13,348 miles/vehicle/year, an average E10 fuel consumption of 23.5 miles/gallon. Assuming bioethanol having 66.7% energy content of petroleum-based gasoline per unit volume, an average 625.7 gallons of bioethanol (E100) per year per Floridian would be needed, if only bioethanol was used as a vehicular fuel.

The selected crops and theirs potential land use requirements for covering the E100 scenario were calculated. The lowest land use requirement show Eucalyptus (0.54 acres/person) and Energycane (0.56 acres/person), followed by Sugarcane (0.77 acres/person) and Elephantgrass (0.78 acres/person). Land need of slightly more than 1 acre/person is shown by Sweet Sorghum (1.21 acres/person) and Corn (1.22 acres/person). The highest land requirement is for Miscanthus (2.09 acres/person) and Switchgrass (2.16 acres/person).

Land requirements for bioethanol crops to cover Florida transportation energy using the modeled scenarios (E10, E15, E20, E85 and E100) were quantified. Results at the lower end of ethanol blending vary between 9% (Energycane and Eucalyptus) and 35% (Switchgrass) of agricultural land for the E10 scenario and between 13% (Eucalyptus) and 53% (Switchgrass) for the E15 scenario. Results at the high end of ethanol blending vary between 100% (Eucalyptus) and 401% (Switchgrass) of agricultural land for the E85 scenario and between 127% (Eucalyptus) and 507% (Switchgrass) for the E15 scenario.

The benchmark point varies because of ethanol yields from the crops. In the case of the highest yielding crops (Eucalyptus and Energycane), the “break-even” point appears to be E40 - requiring at least 40% of Florida agricultural land to produce. If less than E40 is considered, slightly less Florida agricultural land (e.g. E10 requires 9% of land). At E85, 100% of the Florida agricultural land must be used to produce biofuels. In case of all the other investigated crops, the benchmark point is lower than E5.

The available agricultural land is clearly a limiting factor to a wide-spread expansion of the biofuels sector in Florida. Even the highest yielding biofuels crops (Energycane, Eucalyptus) would need more than 100% of available agricultural land in Florida in a hypothetical case, where all the transportation needs of Floridians would be covered solely by locally produced bioethanol. Also, vehicular energy represents only 33% of Florida's total energy consumption, so even if Florida gave up all the available agricultural land for whichever of the investigated biofuel crops (or combinations), the highest yielding crops on all that land would produce only that volume of ethanol, which would cover less than one third of Florida's total energy needs.

Bioethanol (primarily cellulosic) produced in Florida could meet a significant portion of the State's transportation needs, but development of the needed technology and infrastructure, negative effects on biodiversity, climate change, and overall land use changes on Florida's limited available land are important factors to be considered for further feasibility studies and analysis.

TASK 6.0 [LIFE CYCLE ANALYSIS]

EMERGY ANALYSIS (EA) OF SUSTAINABLE BIOFUELS

Nana Yaw AMPONSAH

This section of the report details the Emergy tool in evaluating the sustainability of the various farming systems. These farming systems include: sugarcane (on organic and mineral soils), energy cane, and sweet sorghum, both on mineral soils. The primary objective of the study is to compare the relative sustainability matrices of the energy crops and their respective farming systems. These matrices should guide decision and policy makers to determine the overall sustainability of an intended or proposed bioethanol project related to any of these studied crops in the area.

The desire to have a sustainable alternative transportation fuel such as ethanol begins with sustainable agriculture. Whether it is bioethanol or more traditional agriculture on Florida lands, the desire will be to limit the use of pesticides and fertilizer, as well as the processing activities involved in the production of the biomass. Businesses producing biofuels from biomass, appreciate Florida's high volume of biomass feedstock – accounting for 7% of total U.S. biomass output, by some estimates. As such, most of these businesses have approached local farmers, investors, and other stakeholders in Florida to help meet their respective biomass targets. This approach to land-use changes would indeed result in agricultural land expansions, etc. The potential shift of land use will have ecological, environmental and of course economical implications.. However, the foreseeable economic advantages should not overshadow the dangers this expansion might pose to the natural environment. To forestall these occurrences, the project seeks to offer tools and recommendations to decision makers.

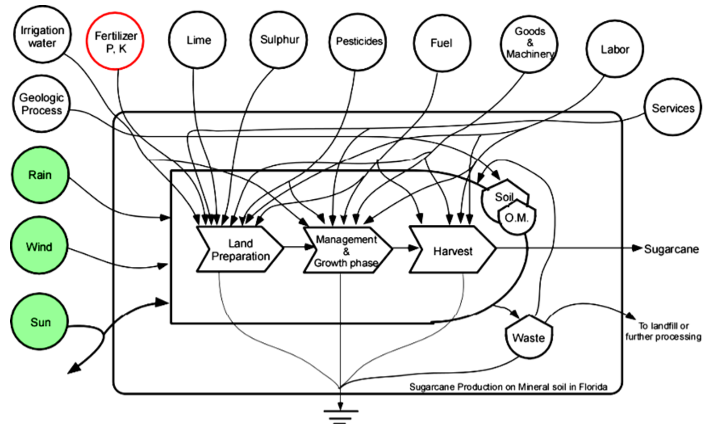
Selected Farming Systems

Our study focused on a farm that grows sugarcane on organic soil, commonly referred to as "muck," and another farm that grows energy cane and sweet sorghum on mineral soils. The analysis considers the production of these crops without its conversion to ethanol. Production data (fertilizer inputs, pesticides demand, etc.) refer to current figures of sugarcane production in South Florida (Enterprise budgets - Roka et al., 2010; Alvarez & Helsel, 2011). Whenever possible, production data have been carefully compared with results from other studies similar to the systems in this study (e.g. Brandt-Williams, 2002; Campbell, 2009). Where there are significant differences due to local specificity, the most appropriate figure has been included in the calculation procedure. This approach ensures that the results represent and reflect realistic performance of the farming systems in the area. This study only presents results for the first year of sugarcane harvesting (cane planting) without the additional ratoon years of production.

Boundaries (The case of sugarcane)

Energy systems diagrams of the investigated processes are shown in Figure 6, where all main steps are drawn from left to right and energy and material flows are indicated. The 5,000-acre farm is located in South Florida. Figure 6 shows the local boundaries of the investigated systems. The systems include Land preparation, crop management (plant tending), and harvesting operations. Goods and energy directly supplied to the process are accounted for at this scale. In this study, inputs needed to manufacture, transport, and supply goods and energy to the process are not considered. Thus, transportation of materials to the farm site is not included in the calculations. It is assumed that all materials needed at each stage of the production are locally available on the farm. Thus, transformity and specific emergy values selected for the calculations do not also include transportation. Analysis was carried out at a 1-ha scale for each of the two farming systems.

(a)



(b)

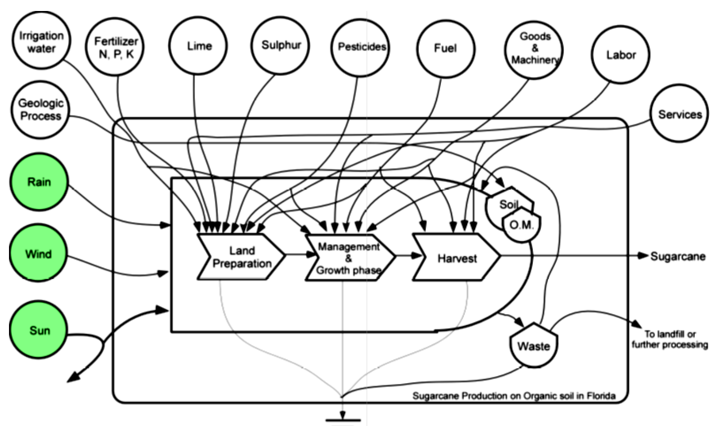


Figure 6: Energy systems diagram showing the main driving forces of sugarcane production – (a) on Mineral soil (b) Organic soil.

Data sources and emergy evaluation

The data were taken primarily from the sugarcane enterprise budgets for Southern Florida (Roka et al., 2010; Alvarez and Helsel, 2011) in which the authors presented results of a preliminary study to determine the economic potential of several types of energy crops identified as suitable for agricultural production in the state of Florida. The main basis and data sources used in the analyses are listed in Table 10 and Table 11.

Results and Discussion

The following tables contain the basis on which Figure 7, Figure 8, and Figure 9 were constructed.

Table 10: Emergy Evaluation of Sugarcane on mineral soil, per ha per year

Note	Item	Unit	Data (units/yr)	Unit Solar EMERGY* (sej/unit)	Solar EMERGY (E13 sej/yr)
RENEWABLE RESOURCES					
1	Sun	J	6.35E+13	1	6
2	Rain	J	6.18E+10	3.02E+04	187
3	Et	J	5.48E+10	2.59E+04	142
4	Water (irrigation)	l	7.29E+06	2.25E+05	0.2
NONRENEWABLE STORAGES					
5	Net Topsoil Loss	J	6.33E+08	1.24E+05	8
	Sum of free inputs (sun, rain omitted)				150
PURCHASED INPUTS					
Operational inputs					
6	Fuel (diesel, gasoline, lubricants)	J	5.46E+09	1.11E+05	61
7	Electricity	J	0.00E+00	2.69E+05	0
8	Machinery	g	5.54E+04	1.12E+10	62
9	Potash	g K	1.78E+05	1.85E+09	33
10	Dolomite (Lime)	g	5.60E+05	1.68E+09	94
11	Slag	g	8.41E+05	6.01E+06	0.5
12	Pesticides (insecticides, herbicides)	$	2.32E+02	1.95E+12	45
13	Phosphate	g P	1.32E+04	3.70E+10	49
14	Nitrogen	g N	4.40E+04	4.05E+10	178
15	Micronutrients (Fe, Mg, Mn, Zn)	g	2.24E+04	1.45E+10	33
16	Labor	J	2.71E+08	4.45E+06	120
17	Services	$	5.21E+02	1.95E+12	102
	Sum of purchased inputs				777
	Total Emergy				927

Table 11: Emergy Evaluation of sugarcane on organic soil, per ha per year (2009)

Note	Item	Unit	Data (units/yr)	Unit Solar EMERGY* (sej/unit)	Solar EMERGY (E13 sej/yr)
RENEWABLE RESOURCES					
1	Sun	J	6.35E+13	1	6
2	Rain	J	6.18E+10	3.02E+04	187
3	Et	J	5.48E+10	2.59E+04	142
4	Water (irrigation)	l	7.29E+06	2.25E+05	0.2
NONRENEWABLE STORAGES					
5	Net Topsoil Loss	J	4.25E+10	1.24E+05	527
	Sum of free inputs (sun, rain omitted)				669
PURCHASED INPUTS					
Operational inputs					
6	Fuel (diesel, gasoline, lubricants)	J	5.46E+09	1.11E+05	61
7	Electricity	J	0.00E+00	2.69E+05	0
8	Machinery	g	5.54E+04	1.12E+10	62
9	Potash	g K	3.26E+04	1.85E+09	6
10	Dolomite (Lime)	g	0.00E+00	1.68E+09	0
11	Slag	g	6.73E+06	6.01E+06	4
12	Pesticides (insecticides, herbicides)	g	1.76E+02	1.95E+12	34
13	Phosphate	g P	3.95E+03	3.70E+10	15
14	Nitrogen	g N	0.00E+00	4.05E+10	0
15	Micronutrients (Fe, Mg, Mn, Zn)	g	1.68E+04	1.45E+10	24
16	Labor	J	2.71E+08	4.45E+06	120
17	Services	$	4.35E+02	1.95E+12	85
	Sum of purchased inputs				411
	Total Emergy				1080

Figure 7(also known as emergy signature) shows the relative importance of the main emergy flows supporting the sugarcane production process for both farming systems.

The information collected covers one year (2009) for organic soil and 2010 for mineral soil. The results clearly show that the largest emergy flows for organic soil sugarcane production were associated with soil erosion or subsidence and services (Table 11, items 5 and 17).

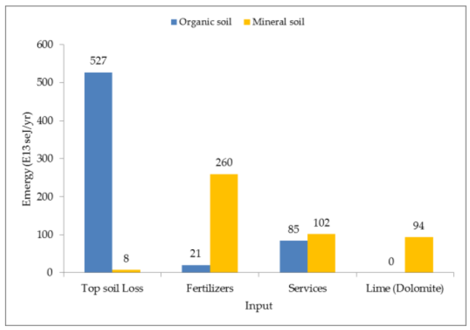


Figure 7: Emergy Signature for Sugarcane Production on Mineral and Organic soils.

However, for mineral soil sugarcane production, the largest contributions were lime (dolomite), fertilizers, and services (Table 10). The results of mineral soil sugarcane production show a drastic reduction of soil loss due to the absence of enriched organic material coupled with other factors that are the main causes of soil subsidence in the Everglades Agricultural Area (EAA) of South Florida. Purchased energy was dominated by fuel (diesel, gasoline, oil) for both organic and mineral soils. Again, the current practice of adding lime to enhance the soil quality (pH) of mineral soils introduced a significant impact on the results. It is important to note that organic soil sugarcane demanded a higher total emergy input (1080E13 sej/yr) than mineral soil sugarcane (927E13 sej/yr) making sugarcane mineral soil farming system a relatively efficient system. Figure 8 shows a comparative view of the sustainability ratios for the two farming systems.

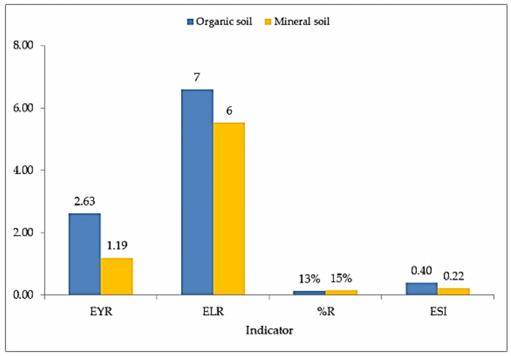


Figure 8: Emergy Indicators for mineral and organic soil sugarcane production.

The % renewable emergy flows were 13% for organic soil, 15% for mineral soil sugarcane production. The Emergy Yield Ratio (EYR) gives organic soil sugarcane production an edge in its economic competitiveness compared to mineral soil production. The environmental loading ratio (ELR) is a direct inverse function of the fraction renewable (Ulgiati and Brown, 1998). The closeness in the ELR values is depicted in their closeness in percentage renewability. The two systems relatively provide similar environmental stress. However, the Emergy Sustainability Index (ESI), indicate that the organic soil sugarcane system had the greatest level of sustainability. This measure assumes that the objective function for sustainability is to obtain the highest EYR while minimizing ELR (Ulgiati and Brown, 1998). This result indicated that the organic soil sugarcane system performed slightly better than the mineral soil sugarcane feedstock production systems. However, since the inputs for the mineral soil are quite available and copious compared with the annual loss of organic soil (which is not replaceable), organic soil sugarcane feedstock production remains environmentally unfavorable.

Emergy Analysis of Energy cane on Sandy soils in South Florida

This work analyzed the environmental/economic pros and cons of energy cane production in South Florida using the emergy methodology (Table 12). The calculations and data sources follow a similar path as in the case of sugarcane described above, since energy cane production sequence follows that of sugarcane closely.

Table 12. Application of the Emergy methodology to energy cane creating Indices.

Name of Index	Expression	Quantity
% Renewability	(R)/(Y)	14%
Emergy Yield Ratio	Y/(P +S)	1.17
Environmental Loading Ratio	(N +F)/R	6
Emergy Sustainability Index	EYR/ELR	0.21

Emergy Analysis of Sweet sorghum on Mineral soils in South Florida

Currently, sweet sorghum is not produced in Florida on a commercial basis, so there is limited information on production costs. However, grain and silage/forage sorghum are produced in North Florida and their production costs are likely similar. Information can be found at http://nfrec.ifas.ufl.edu/programs/enterprise_budgets.shtml#field_crops.

Compared to many other crops, sweet sorghum has high water- and nutrient-use efficiencies and is considered environmentally sustainable (Table 13). Unlike some proposed high biomass energy crops, sweet sorghum is not a threat to become an invasive weed in Florida.

Table 13. Application of the Emergy methodology to sweet sorghum creating Indices.

Name of Index	Expression	Quantity
% Renewability	(R)/(Y)	9%
Emergy Yield Ratio	Y/(P +S)	1.14
Environmental Loading Ratio	(N +F)/R	9
Emergy Sustainability Index	EYR/ELR	0.12

Comparative Emergy Analysis – Sugarcane, Energy cane, and Sweet sorghum on Mineral soils

Selected energy crop farming systems have been compared and have shown that varying production input quantities supplied at any point in time to the farming sequence give significant energy, economic or environmental advantages or disadvantages. Figure 9 a and b show the comparative view for selected crops grown on mineral soils.

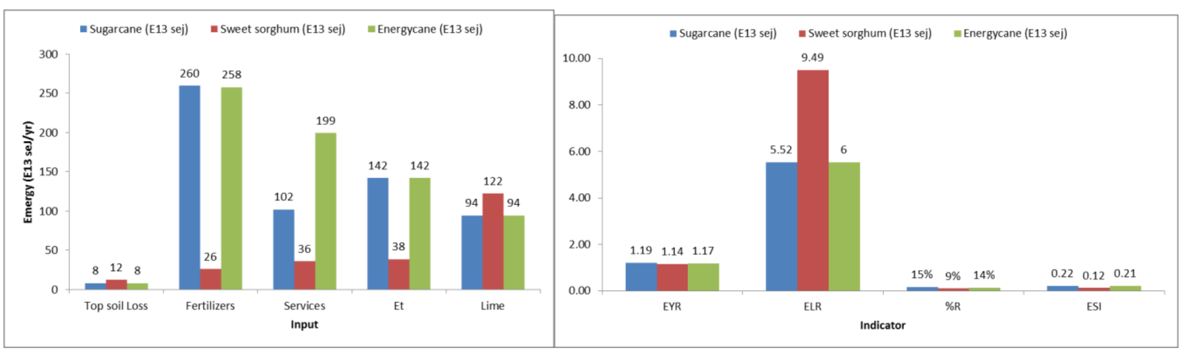


Figure 9 a and b: Emergy inputs and Indicators for sugarcane, energy cane, and sweet sorghum produced on mineral soils

Data for sweet sorghum might not be comprehensive and thus less accurate than that of the other crops. However, the picture drawn from this analysis points the direction of further research. It is quite clear that considering the total emergy input (407E13 sej/yr) for sweet sorghum production, it is the most efficient farming system. However, its low evapotranspiration reduces its renewable input quite significantly, increasing the ELR to a significant value, making sweet sorghum relatively lower in the overall sustainability (ESI).

Concluding Remarks

The aim of this study was to use Odum (1996) emergy method to compare the resource use and environmental impact of potential energy crops farming systems by measuring their relative sustainability. This study aids policy makers and stakeholders by identifying where sustainability might be improved by altering some of the current farming methods. The results provide as much insight into the assumptions inherent in this approach as they do into the farming systems in this study. As discussed, the sugarcane industry in South Florida is moving towards a more sustainable production system in terms of both on- and off-farm considerations. At this stage, alternative farming system practices as outlined in the detailed report (expansion on mineral soils with modified practices) have not been fully adapted to a great extent, but growers are rapidly adopting components of the system. For example, the past few years have seen large increases in the area sown to fallow legumes, substantial increases in the area using reduced tillage for the establishment of both legumes and plant cane crops, and a realization that controlled traffic is essential to overcome the adverse effects of compaction.

Initiatives in terms of improved water use efficiency, nutrient management, and integrated pest control are all being discussed and implemented. Most importantly, with the potential expansion of biofuel industries, the sugarcane industry has realized that it cannot continue to survive with a system based on yesterday's value in terms of production strategies and environmental responsibility.

For all of these crops studied (sugarcane, energy cane and sweet sorghum), excessive tillage, high inputs of chemicals and fertilizers, and long-term monoculture must pass into history. It will obviously take time to get appropriate systems in place but steps in the correct direction must certainly be taken and these positive actions should be acknowledged.

References are available in the detailed Report, which is listed in section 6 of this report

LIFE CYCLE ASSESSMENT OF SUSTAINABLE BIOFUELS

Sugarcane Feedstock Produced on Organic and Mineral Soils in Southern Florida

In this study, we applied the Life Cycle Assessment (LCA) approach to estimate the Carbon Footprint (CFP) of biofuel feedstocks using the GaBi software system with related datasets (PE International, Inc) Since sugarcane for sugar is already a significant crop in southern Florida, we explored the use of sugarcane produced on mineral (sandy) and organic (muck) soils in Florida as a biofuel feedstock.

Introduction

The popularity of biofuels as an alternative to fossil fuels has risen in the last decades. Its popularity started with the oil crisis of the 1970s and increased again in the 1980s and has remained of interest presently, mainly due to people's consciousness about climate change. As a result, production of biofuels faced a progressive increase, especially in the last decade. Even though an increase in oil prices might have contributed to the popularity of biofuels, government policies, targets, and subsidies have played an important role, especially when considering energy security and climate change (Janda et al., 2012).

To help reduce the future extent of climate change, greenhouse gas emissions can be either reduced or sequestered and studying options to affect GHG through agriculture have received increasing attention (Schneider and Kumar, 2008). In the U.S. there is a growing need for all productive sectors to develop techniques to mitigate GHG emissions and reduce the enhanced greenhouse effect (McCarl and Schneider, 2001). However, the challenge to the agricultural sector is to reduce net emissions and at the same time to increase feedstock production to meet growing demands for food, fiber, and biofuel.

One of the initial steps in developing these mitigation techniques, according to Lebel and Lorek (2008), is to look into the environmental impact assessments of agro-industrial products throughout a life cycle assessment (LCA) and carbon footprint (CFP). LCA and CFP approaches were introduced as tools to quantify and subsequently to mitigate greenhouse gas emissions (Scipioni et al., 2012). LCA is a standardized scientific method for systematic analysis of flows (i.e. mass and energy) associated with the life cycle of a specific technology, service, manufacturing process, or agricultural production system. The CFP represents the sum of all greenhouse gases released during the life cycle or part of the life cycle of a product, expressed as CO_2 equivalents (CO_2e).

Florida is one of the largest producers of sugarcane producing 13.3 million tons of sugarcane in 2009, harvested on 156,613 hectares, representing 46.6% of the total national production and 44.3% of the total land area dedicated to sugarcane in the U.S. (Hilliard et al., 2012). To know the contribution of sugarcane biofuel production to the emission of greenhouse gases is thus important. Estimation of the greenhouse gas emissions, otherwise known as the carbon footprint, is an essential part of any sustainability study.

Previous studies show a range of CFP values for sugarcane production, for example de Figueiredo et al. (2010), show a value of 0.027 kg CO_2e $kg^{-1}y^{-1}$ for sugarcane produced in southern Brazil; Yuthithum et al. (2011) report a value of 0.49 kg CO_2e $kg^{-1}y^{-1}$ for sugarcane produced in eastern Thailand; and Murphy et al. (2010) report a CFP value of 0.047 kg CO_2e $kg^{-1}y^{-1}$ for the entire United States. The difference among these CFP values is due in part to production practices used in different countries and also the boundaries and the types of products and technologies considered. Our study is part of a farming sustainability program, and for comparison purposes, more studies covering the production of other biofuel feedstock systems will be performed considering a standard of CFP estimate. Consequently, the reported CFP values will tell us how the different products are being generated regarding their GHG emissions, i.e. alternative methods of producing biofuel feedstock with relatively lower GHG emissions will be found.

The objective of this study was to compare the CFP for sugarcane production grown in either mineral (sandy) or organic (muck) soils in the state of Florida. This comparison will provide information on production efficiency of biofuel sugarcane and the potential of reducing GHG emissions.

Study site and sugarcane cultivation

This study estimates emissions from biofuel sugarcane production activities in mineral and organic soil in the Everglades Agricultural Area (EAA) of Florida from data obtained during the cropping years 2007/2008 and 2009/2010 for mineral soil and 2008/2009 for biofuel sugarcane produced in organic soils.

Sugarcane is planted between August and January and the harvest takes place at yearly intervals from October to April. During the entire biofuel sugarcane production process, several pieces of equipment are used (heavy and light disc harrows, laser level, combine harvester, etc.). Soil conditioners such as calcium silicate slag (slag) and dolomite (lime) are usually applied during land preparation of mineral soils; while only slag is applied in organic soils. Chemical fertilizers (N, P, and K for mineral soils and P and K for organic soils) are applied only once as a composite fertilizer. Sugarcane fields in Florida are irrigated and drained by subirrigation (seepage irrigation) and open ditch drainage. Subirrigation is defined as supplying water to the crop root zones by controlling the water table (Lang et al., 2002). Herbicide and insecticide are applied three times per crop to control weeds and insects.

System boundaries

The CFP was estimated considering the results obtained after the LCA of biofuel sugarcane production in both types of soils (Figure 10). The CFP presented in this study includes carbon emissions from raw material preparation up to the biofuel sugarcane produced and left in the field (consistent with the "cradle to gate" approach) (ISO, 2009). The GHGs considered are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (CO_2, CH_4, and N_2O having GWP of 1, 25 and 298, respectively) (IPCC, 2006; PE International, 2012). Values were standardized to kilograms of carbon dioxide equivalents per kilogram of biofuel sugarcane produced per year (kg CO_2e $kg^{-1}y^{-1}$).

Figure 10: The system boundaries and a simplified process flow for biofuel sugarcane life cycle, including land

preparation, planting, crop management, and harvesting.

GHG emissions were estimated from the production and use of energy (diesel and electricity), the utilization of equipment, the production and application of fertilizers, herbicides and insecticides, the pre-harvesting biomass burning and the organic land utilization. The data used for this study comes from information collected from the growers and published in cost and returns reports (Álvarez and Helsel, 2011a; Roka et al., 2009; Roka et al., 2010). In cases where primary data were not available, secondary data from literature and previous LCA studies were used. To model the environmental emissions of ancillary processes, existing datasets were used for the analysis (PE International, 2012).

CO_2 emissions from biomass burning were not accounted for because it was assumed that CO_2 is reabsorbed when sugarcane plants are regrown in the next cropping season. Diesel used during fertilizers and pesticides application, tillage, and irrigation was included as energy expenditure. The impact potentials were calculated using TRACI (Tools for the Reduction and Assessment of Chemical and Other Environmental Impacts) characterization factors published by the U.S. Environmental Protection Agency (Bare, 2011).

To calculate total emissions from organic land use (Table 14), we considered the emission factor for annual losses of carbon from organic soils located in a warm temperate climate, which is estimated to be 10 tons (10,000 kg) of C $ha^{-1}y^{-1}$ (IPCC, 2006, Table 5.6). The atomic mass of carbon is 12 and that of oxygen is 16, thus the molecular mass of CO_2 is 44 and the mass ratio of CO_2 to C is 3.7 (44 divided by 12).

Results

Information on the general features of biofuel sugarcane production operations, yields by soil type, and energy utilization reflected on the amount of resource inputs for each type of soil as shown in Table 12.

Table 14: Some characteristics of biofuel sugarcane production in mineral and organic soils in Florida

Characteristics	Soil Type	
	Mineral	Organic
Fraction to total (%)	20	80
Total area (ha)	29,947	119,787
Yield (kg ha^{-1})	69,000	86,000
Diesel for machine use (L ha^{-1})		
Land Preparation	115	115
Planting	164	164
Crop Management	333	333

Harvesting	89	111
Electricity (kWh ha^{-1})	118	118
Soil conditioners and synthetic fertilizers (kg ha^{-1})		
Calcium Silicate Slag	3,363	3,363
Dolomite	2,242	-
Nitrogen (N)	207	-
Phosphate (P_2O_5)	56	34
Potash (K_2O)	214	95
Pesticides (kg ha^{-1})		
Herbicides	14	15
Insecticide	8	8

Diesel usage is similar for both types of soil and used dominantly for cultural practices and planting (Table 14). Emissions from electricity (Table 14) are used in 10% of all irrigation operations. Even though electricity is more efficient than diesel in terms of GHG values, diesel is independent of the transmission lines/power plant, offering the grower some security regarding water, but at the cost of increased GHG emissions.

For both types of soils, more than half of the emissions for equipment use correspond to cultural practices (61% for mineral soils and 58% for organic soils) because most of the crop management activities are performed during this phase.

Table 15: Summary of greenhouse gas emissions (kg CO_2e kg^{-1} y^{-1}) per kg of biofuel sugarcane cultivation in Florida

Sources of GHG Emissions	Emissions in kg CO_2e kg^{-1} of biofuel sugarcane y^{-1}	
	Mineral soil	Organic Soil
Energy (Diesel & Electricity)	**4.6E-03**	**3.9E-03**
Land Preparation	3.2E-04	2.3E-04
Planting	4.6E-04	3.7E-04
Crop management	2.3E-03	1.9E-03
Harvesting	4.1E-04	5.1E-04
Electricity	1.1E-03	9.2E-04
Equipment	**1.5E-02**	**1.2E-02**
Land preparation	1.5E-03	1.1E-03
Planting	2.2E-03	1.8E-03
Crop management	9.0E-03	7.2E-03
Harvesting	1.9E-03	2.4E-03
Fertilizers & Soil Conditioners	**1.2E-02**	**1.9E-03**
Calcium silicate slag	7.7E-04	6.2E-04
Dolomite	4.4E-03	0.0E+00

Nitrogen (N)	4.5E-03	0.0E+00
Phosphate (P_2O_5)	9.4E-04	4.5E-04
Potash (K_2O)	4.8E-04	1.7E-04
Micronutrients	1.0E-03	6.1E-04
Pesticides	**3.8E-04**	**3.0E-04**
Herbicides	1.1E-04	8.8E-05
Insecticides	2.7E-04	2.2E-04
Biomass Burning	**1.2E-02**	**1.2E-02**
Organic Soil Use	**0.0E+00**	**4.3E-01**
TOTAL	**4.4E-02**	**4.6E-01**

Soil conditioners (amendments) and fertilizers contribute a notable portion of the GHG emissions and differ in their proportions based upon soil type (Table 15). Pesticide applications, on the other hand, are similar for both soil types.

As expected, burning of the crop before harvesting resulted in 27% and 3% of total greenhouse gas emissions for sugarcane produced in mineral and organic soils, respectively. The percentage is considerably lower in organic soils since burning is such a small portion of the emissions compared to soil subsidence.

The CFP of biofuel sugarcane found in this study was 0.044 kg CO_2e $kg^{-1}y^{-1}$ for mineral soils and 0.46 kg CO_2e $kg^{-1}y^{-1}$ for organic soils (Table 15). For tomato production in Florida, GHG emissions ranged from 0.19 to 0.27 kg CO_2e kg $fruit^{-1}$ with N fertilizer accounting for between 17.7% and 22.8% (Jones et al., 2012). Thus, the range of CFP for biofuels sugarcane is considerably wider than that of tomato due to the use of widely different soils, since Florida tomato production is on mineral soils only.

For sugar production in southern Brazil was 0.027 kg CO_2e $kg^{-1}y^{-1}$ (de Figueiredo et al., 2010) and in eastern Thailand, a value of 0.49 kg CO_2e $kg^{-1}y^{-1}$ sugarcane was reported (Yuthithum et al., 2011). Murphy *et al.* (2010) reported a value of 17,609 kg CO_2e $ha^{-1}y^{-1}$, representing an average biomass yield of 73 tons per hectare for the whole continental U.S., which is different from the 3,008 and 39,301 kg CO_2e $ha^{-1}y^{-1}$ that we found in our study for biofuel sugarcane production in mineral and organic soils, respectively.

There are other studies (Contreras et al., 2009; Nguyen et al., 2010; Ramjeawon, 2008) that highlight the benefits of using sugarcane by-products such as bagasse and molasses for bio-energy productions, and their potential to reduce GHG emissions. We did not consider this option for GHG emissions reduction in this study because according to our study's system boundaries, carbon emissions include raw material preparation up to the produced biofuel sugarcane and left in the field (consistent with the "cradle to gate" approach).

According to Wright and Hanlon (2013), identification and utilization of best management practices (BMPs) that diminish the loss of carbon from organic soils to the atmosphere can minimize the CFP, and consequently reduce the effects on global warming and increase the longevity of subsiding Histosols for agricultural use. One of the best crops to minimize subsidence in the EAA is biofuel sugarcane due to its tolerance to short-term flooding and rapid canopy closure reducing soil temperatures. More than a few cultivars currently planted in the EAA have the ability to maintain root functionality during short periods of flooded conditions. However, these new cultivars must not only deliver flooding tolerance but also produce commercially viable quantities of sugar to be widely accepted (Wright and Hanlon, 2013).

The following graphs (Figure 11 and Figure 12) use percentages to indicate the origins of GHG by soil type.

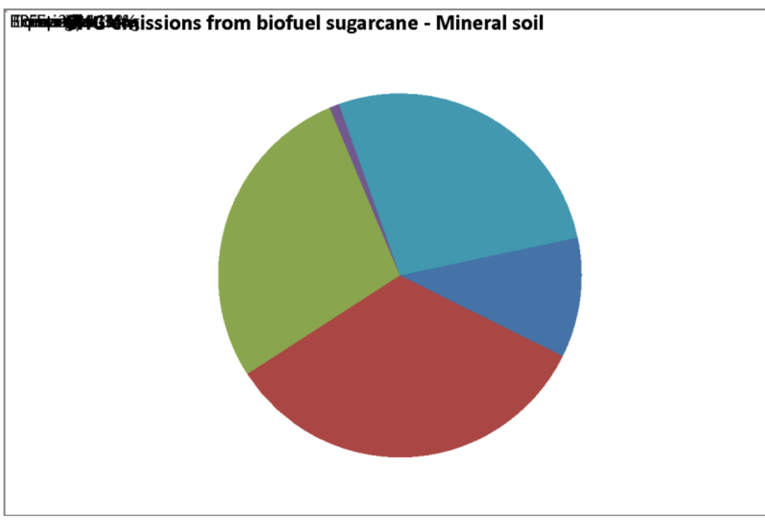


Figure 11. Summary of GHG emissions from Biofuel sugarcane produced in mineral soils

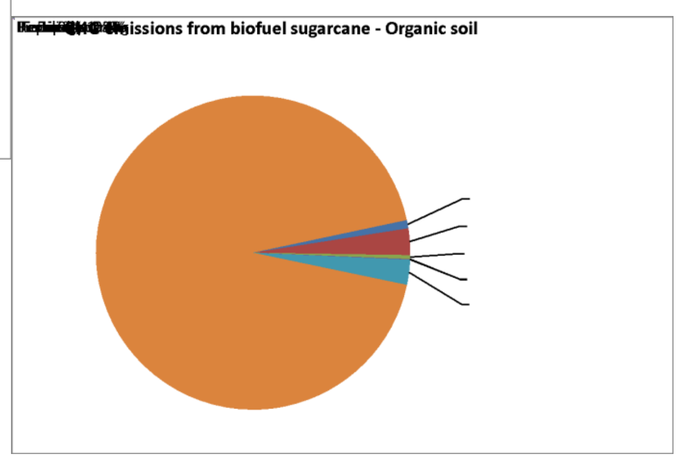


Figure 12. Summary of GHG emissions from Biofuel sugarcane produced in organic soils

Conclusions

This study estimated the CFP from biofuel sugarcane produced in mineral and organic soils of 0.044 kg CO_2e $kg^{-1}y^{-1}$ for mineral soils and 0.46 kg CO_2e $kg^{-1}y^{-1}$ for organic soils. By far, the largest emission for cultivation in organic soil comes from organic land use (93%), 3% from each, equipment use and biomass burning, 1% from energy use (mainly fossil fuel), 0.4% from fertilizer production and utilization, and 0.1% from pesticides (herbicides and insecticide). In mineral soils, the largest emission (34%) comes from equipment use, 28% comes from fertilizer production and utilization, 27% from biomass burning, 11% from energy use, and 1% from pesticides. The differences between cultivation in those types of soils are the lack of application of N and dolomite when cultivating in organic soils and, of course, the emissions from organic land use. These CFP results could represent an important source of information about the cultivation practices. For example, farmers could significantly affect the value of the CFP changing to more sustainable practices.

Based on these findings, the focus for selecting potential improvements is different for each soil type. Obviously, slowing soil subsidence should be given highest priority for organic soil production. For mineral soil production of sugarcane biofuels feedstock, efforts can be almost equally split among fertilizers, equipment, and biomass burning before harvesting.

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Summary of Global Warming Potential and Eutrophication Potential of Selected Biofuel Feedstock Crops Produced in Florida: Testing Different Production Scenarios

The entire article from which this summary is taken can be found at:

Izursa, J.L., E.A. Hanlon, N.Y. Amponsah, and J.C. Capece. 2009. Global Warming Potential and Eutrophication Potential of Biofuel Feedstock Crops Produced in Florida , Measured Under Different Scenarios. : 1–18Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/Izursa_LCA_GWP_EP_Biofuel_Feedstocks_Scenarios_Feb13.pdf.

Climate change accelerated by the greenhouse gas (GHG) emissions and its effects like increased frequency and severity of extreme events and different patterns in weather and water distribution, could affect food and fiber production in several ways (Godfray et al., 2011). As a result, new studies have focused on the adaptation of production systems to reduce the negative impacts associated with climate change. Especial efforts have been made to develop alternative sustainable energy sources (Lisboa et al., 2011). Replacing fossil fuels with biofuels derived from agricultural crops could mitigate the greenhouse effect by reducing GHG emissions; reductions of up to 85% have been observed in some cases (Boorjesson, 2009).

Crop-derived first-generation biofuels are becoming important biomass energy sources. For instance, they account for a proportion of liquid fuel, Several previous studies have been based on a life cycle assessment (LCA) of energy crops, including maize (Zea mays), soybean (Glycine max), wheat (Triticum aestivum), sugarcane (Saccharum officinarum) and. sugar beet (Beta vulgaris L. subsp. vulgaris) and , and sorghum (Sorghum bicolor (L.) Moench) and. These studies have shown the effects of bioethanol on the reduction of the environmental impact of factors such as GHG emissions and fossil energy consumption. Meanwhile, energy crop production for bioethanol has recently come into question with respect to its sustainability and influence on food crops. Overall, biofuels have a limited capacity to resolve energy problems unless some changes are made to increase their production and reduce their GHG emission contribution. Then, he challenge to the agricultural sector is to reduce net emissions and at the same time to increase feedstock production to meet growing demands for food, fiber, and biofuel.

A large number of different activities can contribute to other emissions that cause problems other than the greenhouse effect, such as eutrophication. N_2O emissions from agricultural lands range from fertilizer application to methods of irrigation and tillage.

Flessa et al. (2002) reported that a conversion from conventional to organic farming resulted in reduced emissions per hectare of farm and field area, contributing to the reduction of greenhouse gas (GHG) emissions from agriculture.

In 2010, greenhouse gas emissions from agriculture accounted for approximately 7% of total U.S. greenhouse gas emissions. Greenhouse gas emissions from agriculture have increased by approximately 13% since 1990. The biggest driver for this increase has been the 51% growth in combined CH4 and N2O emissions from livestock manure management systems, reflecting the increased use of emission-intensive liquid systems over this time period. Emissions from other agricultural sources have either remained flat or increased by a relatively small amount since 1990.

The adoption of conservationist management practices would result in significant changes in the GHG balance due to the reduced consumption of diesel fuel in mobile sources and due to increases in soil carbon stock (Bayer & Mielniczuk, 1997). Moreover, it has been argued that when crop rotation is adopted, N-fixing crops (leguminous) could help reduce soil N_2O emissions (Urquiaga et al., 2010). Due to the need to adapt existing productive systems to reduce their impact on GHG emissions, our challenge is to propose new alternatives that would result in a lower GHG emission balance. Thus, there is no universally applicable list of mitigation practices; instead, the proposed practices will need to be evaluated according to the specific climatic conditions, edaphic characteristics, social context, and historical land use and management of individual agricultural systems (IPCC, 2007b).

Several studies have shown the potential for improvements in the environmental efficiency of energy crop cultivation, and LCA has been applied to assess the improvements in energy crops. However, in these studies, the analyses of the improvements were of a broad scope. Thus, an in-depth assessment of the feasibility and practicality of improvement is necessary for an appropriate evaluation of the first-generation biofuels. There are few similar studies that have used an LCA to assess the potential for improvement in crop cultivation. The difficulty in assessing crop cultivation is attributable to the variability of the results of different studies, as most biofuel production studies that have focused on energy balance and GHG emission show a wide variety of results. According to Whitaker (2010), there are 3 sources of variability in the LCAs of energy crop production. The first is the diversity of agricultural processes and material inputs; this diversity is dependent on location, which determines the climatic and edaphic factors of cultivation.

Florida is one of the largest producers of sugarcane in the U.S. In 2009 it produced 13.3 million tons of sugarcane, harvested on 156,613 hectares, representing 46.6% of the total national production and 44.3% of the total land area dedicated to sugarcane in the U.S. (Hilliard et al., 2012). To know the contribution of sugarcane biofuel production to the emission of greenhouse gases is thus important. Estimation of the greenhouse gas emissions, otherwise known as the carbon footprint, is an essential part of any sustainability study.

Previous studies show a range of CFP values for sugarcane production, for example de Figueiredo et al. (2010), show a value of 0.027 kg CO_2e kg^{-1} for sugarcane produced in southern Brazil; Yuttitham et al. (2011) report a value of 0.49 kg CO_2e kg^{-1} for sugarcane produced in eastern Thailand; and Murphy et al. (2010) report a CFP value of 0.047 kg CO_2e kg^{-1} y^{-1} for the entire United States.

The objective of this study was to estimate the global warming potential (GWP) and eutrophication potential (EP) balance resulting from alternative scenarios of biofuel sugarcane, energycane and sweet sorghum produced in mineral soils in Florida and identify which production system would result in a smaller GWP and EP emissions balance. The study focused on estimating emissions in four production scenarios, including a production with conventional tillage (scenario 1), reduced tillage associated with conventional pre-harvest burning (scenario 2), controlled-release fertilizer associated with conventional tillage and pre-harvest burning and green harvest associated with conventional tillage (scenario 4).

Materials and Methods

Our research considers emissions from the production activities of three biofuel feedstock: sugarcane (*Saccharum officinarum* L.), energycane a cross of commercial sugarcane (*Saccharum officinarum* L.) with *Saccharum spontaneum* L. and sweet sorghum

[*Sorghum bicolor* (L.) *Moench*] cultivated in mineral soil in the Everglades Agricultural Area (EAA) of Florida. The data used in our study were obtained primarily from enterprise budgets published by the Institute of Food and Agricultural Sciences at the University of Florida (UF/IFAS) for the cropping years 2007/2008 and 2009/2010 for biofuel sugarcane (José Álvarez & Zane R Helsel, 2011; Roka *et al.*, 2009) , 2008/2009 for energycane (José Álvarez & Zane R. Helsel, 2011) and 2009/2010 for sweet sorghum (Helsel & Alvarez, 2011). As stated previously 2009 sugarcane cultivation in Florida represents approximately 47% of the total sugarcane planted in the United States (Hilliard *et al.*, 2012). At present, there is no significant commercial production of sweet sorghum in the EAA, but grain sorghum and forage sorghums for silage are produced in other parts of Florida (Helsel & Alvarez, 2011). Energycane has been grown for cellulosic ethanol production as an experimental crop in the north of Lake Okeechobee in Highlands County near the Brighton Indian Reservation.
Specific details of all cultural practices and other energy-using components of production were either described or can be found in the original document (Izursa, J.L., E.A. Hanlon, N.Y. Amponsah, and J.C. Capece. 2009. Global Warming Potential and Eutrophication Potential of Biofuel Feedstock Crops Produced in Florida , Measured Under Different Scenarios. : 1–18. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/Izursa_LCA_GWP_EP_Biofuel_Feedstocks_Scenarios_Feb13.pdf

System boundaries

The GWP and EP were estimated based on the results obtained from the LCA of biofuel sugarcane, energycane, and sweet sorghum produced in mineral (sandy) soils, and use essentially the same model as for the previous study comparing soil types for sugarcane feedstock (Figure 13). All components followed the same conversions to carbon dioxide equivalents (CO_2 e) and nitrogen equivalents (N-e) emissions from raw material preparation up to the biofuel feedstock produced and left in the field (consistent with the "cradle to gate" approach) (ISO, 2009).

Figure 13. The above diagram shows the system boundaries and a simplified process flow for each of the biofuel feedstock (sugarcane, energycane and sweet sorghum) life cycles, which includes land preparation, planting, crop management, and harvesting.

The functional units for gases was the same as the previous study except that gases considered for the EP are nitrogen oxides (NOx), ammonium (NH4+), nitrogen N, phosphate (PO_4^{3-}), phosphorus (P), and chemical oxygen demand (COD). In a similar manner for GWP, each gas is converted into an N-equivalent value to estimate EP using specialized LCA software (IPCC, 2006; PE International, 2012).

In this study, adjustments were made for cropping systems. For biofuel sugarcane, approximately one fourth of the land is in fallow (i.e. no sugarcane or any other crop growing); and it is the area where the land preparation takes place. Another one fourth of the land area is planted with seed cane to produce both biofuel sugarcane and additional seed cane. This area represents the plant cane crop. The remaining half portion of the land is used to grow ratoon or stubble crops. Ratoon or stubble is cane that have re-grown from previous cane plantings and represents second, third, or fourth ratoons (Roka *et al.*, 2009; Salassi & Deliberto, 2009). For energycane, the total net area is equally distributed in seven parts in a similar manner. For sweet sorghum, it is assumed that it is ratooned for an additional crop during the year; therefore, land preparation and planting are considered for one hectare but crop management and harvest for two hectares.

Scenario 1 – Business as usual

GWP and EP emissions for the three biofuel feedstocks were estimated as described above. Our analyses included the production and use of energy (diesel and electricity), the utilization of equipment, the production and application of fertilizers, herbicides, fungicides and insecticides, and in the case of biofuel sugarcane, the pre-harvesting biomass burning.
Biofuel sugarcane in Florida is burned before harvesting to reduce harvest cost and facilitate subsequent land preparation.
CO_2 emissions from biomass burning were not accounted for because it was assumed that CO_2 is reabsorbed when sugarcane plants are regrown in the next cropping season. Also, diesel used during fertilizers and pesticides application, tillage, and irrigation was included as an energy expenditure.

Scenario 2 – Reduced tillage

The assumption for this scenario is to model a reduced use of equipment for all three biofuel feedstock crops (Judice et al., 2006; Izursa et al., 2013).

Scenario 3 – Controlled-release Nitrogen

Considering the use of controlled-released nitrogen fertilizers, we modeled biofuel feedstock production with the use of 2/3 of the traditional amount for either biofuel sugarcane or energycane and one half of the traditional amount for sweet sorghum, keeping all the other inputs like in the business as usual scenario.

Scenario 4 – Green harvesting

Traditionally, biofuel sugarcane in Florida is burned before harvesting to speed harvesting (Gilbert et al., 2010); however, so-called green cane harvesting allows the farmers to recycle nitrogen in the plant by leaving trash cuttings from harvesting in the field. In our study, we consider this scenario for the biofuel sugarcane since burning prior harvesting is practiced only for this crop. All the operations during land preparation, planting and crop management remain the same as in our business as usual scenario but in the harvesting phase we eliminate the pre-harvest burning.

The impact potentials for all the scenarios were calculated using TRACI (Tools for the Reduction and Assessment of Chemical and Other Environmental Impacts) characterization factors published by the U.S. Environmental Protection Agency (Bare, 2011). Since the soils are being cultivated for several years, the emissions from land use change to biofuel sugarcane were not considered in this study. Biofuel sugarcane yield for the purpose of our study was presumed to be left on the field, in loader containers.

In cases where primary data were not available, secondary data from literature and previous LCA studies were used. To model the environmental emissions of ancillary processes, existing datasets were used for the analysis (PE International, 2012).

Results

The amount of energy (diesel and electricity) and ancillary materials utilized and the amount of other resource inputs during the production operations of biofuel feedstocks and for the different scenarios are shown in

Table 16. The average yields for each crop were 69,000; 66,000; and 45,000 kg $ha^{-1}y^{-1}$ for biofuel sugarcane, energy cane, and sweet sorghum, respectively.

Table 16. Some characteristics of biofuel sugarcane production in mineral and organic soils in Florida

	Biofuel feedstock											
	Biofuel Sugarcane				**Energycane**				**Sweet sorghum**			
Characteristics	**Scenario 1 Business as usual**	**Scenario 2 Reduced tillage**	**Scenario 3 Control-release N**	**Scenario 4 Green harvest**	**Scenario 1 Business as usual**	**Scenario 2 Reduced tillage**	**Scenario 3 Control-release N**	**Scenario 4 Green harvest**	**Scenario 1 Business as usual**	**Scenario 2 Reduced tillage**	**Scenario 3 Control-release N**	**Scenario 4 Green harvest**
Diesel for machine use (L ha^{-1})												
Land Preparation	115	71	115	115	115	71	115	115	42	28	42	42
Planting	164	89	164	164	164	89	164	164	45	23	45	45
Crop Management	289	182	289	289	289	182	289	289	137	105	137	137
Harvesting	89	88	89	89	89	88	89	89	76	62	76	76
Electricity (kWh ha^{-1})	118	118	118	118	118	118	118	118	118	118	118	118
Soil conditioners (kg ha^{-1})												
Calcium Silicate Slag	3,363	3,363	3,363	3,363	3,363	3,363	3,363	3,363	0	0	0	0
Dolomite	2,242	2,242	2,242	2,242	2,242	2,242	2,242	2,242	2,242	2,242	2,242	2,242
Synthetic fertilizers (kg ha^{-1})												
Nitrogen (N)	207	207	138	207	207	207	138	207	202	202	101	202
Phosphate (P_2O_5)	56	56	56	56	56	56	56	56	135	135	135	135
Potash (K_2O)	214	214	214	214	214	214	214	214	202	202	202	202
Micronutrients	95	95	95	95	95	95	95	95	34	34	34	34
Pesticides (kg ha^{-1})												
Herbicides	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	11.7	11.7	11.7	11.7
Insecticide	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	11	11	11	11
Fungicides	0	0	0	0	0	0	0	0	2.24	2.24	2.24	2.24
Pre-harvest burn (%)	75	0	75	75	0	0	75	0	0	0	0	0

Energy required for irrigation pumps were diesel and electricity. The average irrigation rate in this region, for each feedstock crop was 7,290 m^3 ha^{-1} y^{-1}.

Contributions of Global Warming and Eutrophication Potentials

GWP: Scenario 1 "Business as usual"

GHG emissions, as GWP from use of equipment for production of biofuel feedstock crops in mineral soils, are one of the largest contributors. Although sweet sorghum does not require as much use of equipment to produce one hectare, it shows a higher number because it is produced twice per year, hence equipment is used more times for crop management and harvesting. (Figure 14). In all three crops, 40% for sweet sorghum, 59 for energycane, and 55% for sugarcane, correspond to crop management

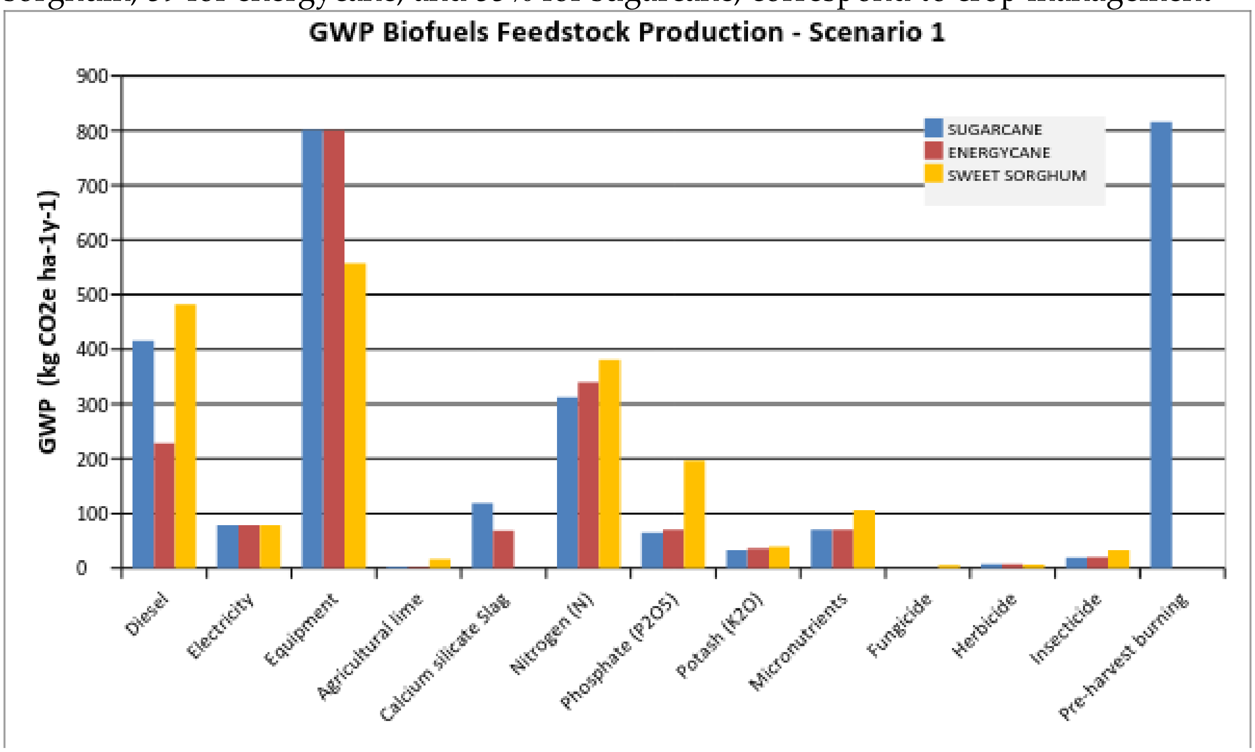

Figure 14: GWP from biofuel feedstock (sugarcane, energycane and sweet sorghum) produced in mineral soils in Florida. Scenario 1, "business as usual", expressed in kilograms of dioxide equivalents per hectare

GWP emissions from the use of soil conditioners (carbon silicate slag, and agricultural lime) add 121.8 kg CO_2e ha^{-1} y^{-1} for biofuel sugarcane, 69.6 kg CO_2e ha^{-1} y^{-1} for energycane and 15.6 kg CO_2e ha^{-1} y^{-1} for sweet sorghum (Table 16).

The fertilizers rates (Table 16) applied during biofuel feedstock crops production are used to ameliorate soil deficiencies (Rice and Gilbert, 2006; Agritech Portal, 2008).

As a result, the GWP emissions from N, P, and K were estimated at 410 kg CO_2e ha^{-1} y^{-1} for biofuel sugarcane, 446 kg CO_2e ha^{-1} y^{-1} for energycane and 615 kg CO_2e ha^{-1} y^{-1}

from sweet sorghum production. GWP emissions from micronutrients were 70 kg CO_2e ha^{-1} y^{-1} from biofuel sugarcane, 70 kg CO_2e ha^{-1} y^{-1} from energycane and 105 kg CO_2e ha^{-1} y^{-1} from sweet sorghum production.
From the three biofuel feedstock crop used in our study, pre-harvest burning occurs in Florida only when biofuel sugarcane is produced. Considering the fraction of area to be harvested (0.75 ha – section 2.4) and the amount of biomass burned, it was estimated that the total GWP emissions are 816 kg CO_2e ha^{-1} y^{-1}. Pre-harvest burning represents 30% of total greenhouse gas emissions for biofuel sugarcane produced in Florida.

GWP: Scenario 2 Reduced Tillage

Because a large part of the GWP emissions come from use of equipment, we explored an alternative, modeling a scenario considering that reduced tillage is practiced.

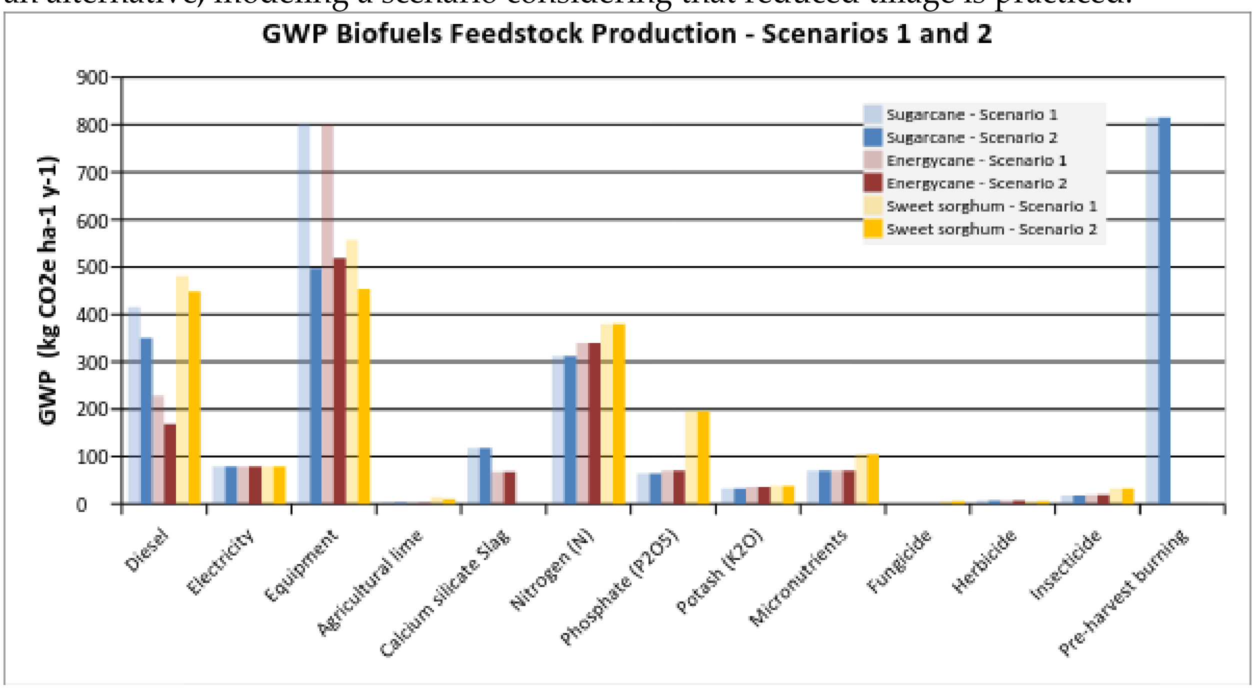

Figure 15. GWP from biofuel feedstock (sugarcane, energycane and sweet sorghum) produced in mineral soils in Florida. Comparison of scenario 2 "reduced tillage" versus scenario 1 "business as usual" (faded colors), expressed in kilograms of dioxide equivalents per hectare per year

To apply the reduced tillage scenario in our model, we assumed the use of 430 liters ha^{-1} y^{-1} for biofuel sugarcane and energycane, each and 217 liters ha^{-1} y^{-1} for sweet sorghum (Table 16).

As a result, emissions from diesel decrease to 351, 169, and 448 kg CO_2e ha^{-1} y^{-1} for biofuel sugarcane, energycane, and sweet sorghum, respectively. If practical, this potential change could reduce emissions by 16% compared to use in the business as usual scenario.

The largest difference comparing scenarios 1 and 2 is that equipment use emissions are 31% lower when applying reduced tillage: 496, 519, and 454 kg CO_2e ha^{-1} y^{-1} for biofuel sugarcane, energycane and sweet sorghum (Figure 15).

<u>EP: Scenario 3 Controlled-release Nitrogen</u>

For modeling purposes, we assumed the use of 138 kg N ha^{-1} for biofuel sugarcane and energycane, which represents 2/3 of the conventional amount used and 101 kg N ha^{-1} for sweet sorghum, which is one half of the amount of N used in the business as usual scenario (Table 16).

Considering the controlled-release nitrogen scenario, emissions from are 0.222, 0.120, and 0.172 kg N-e ha^{-1} y^{-1} for biofuel sugarcane, energycane and sweet sorghum, respectively. Diesel usage decreased an average of 12% less than the emissions from diesel in the business as usual scenario (Figure 16). However, the values for the emissions from equipment use are 9% higher with the new scenario, presumably because the amount of equipment used is the same but the material (nitrogen) applied is less. And the emissions from nitrogen application are 31% lower comparing to the business as usual scenario.

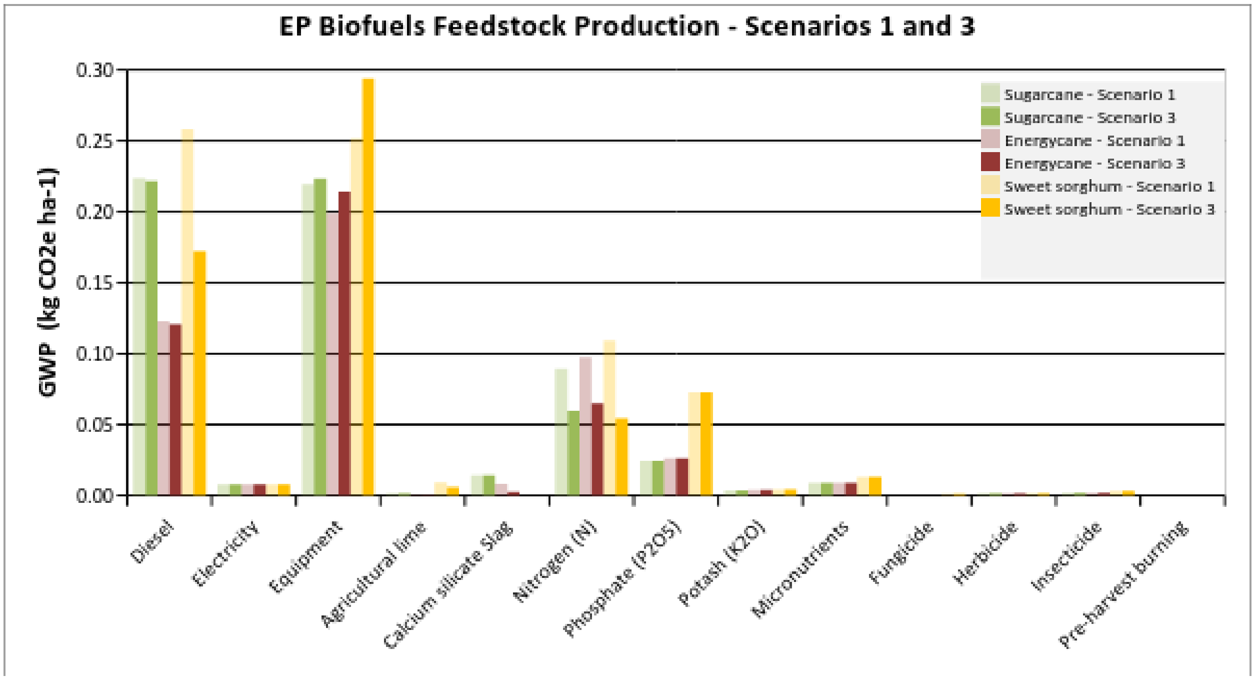

Figure 16. EP from biofuel feedstock (sugarcane, energycane and sweet sorghum) produced in mineral soils in Florida. Comparison of scenario 3 "Controlled-release Nitrogen" versus scenario 1 "business as usual" (faded colors), expressed in kilograms of nitrogen equivalents per hectare per year

GWP: Scenario 4 Green Harvesting

The pre-harvest biomass burning practiced for biofuel sugarcane crops in Florida, considering the normal practices (scenario 1) contributes with 30% (816 kg CO_2e ha^{-1} y^{-1}) of the total emissions (Figure 17). For cultivation of energycane and sweet sorghum as biofuel feedstock, this practice is not implemented.

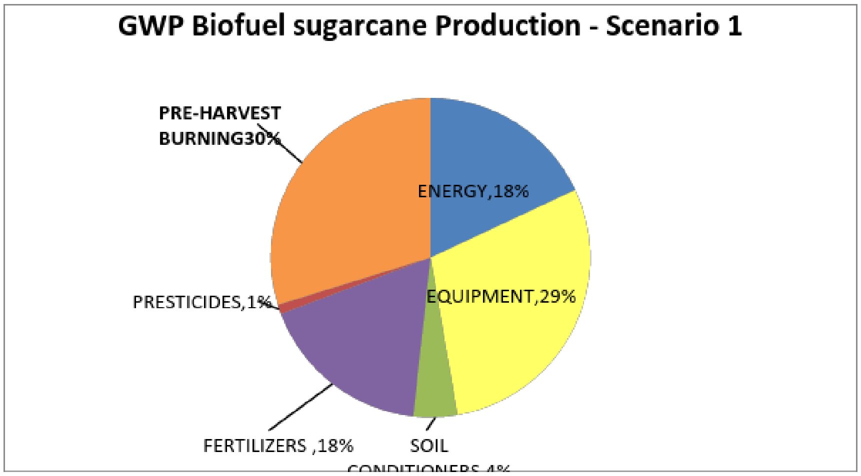

Figure 17. Percentage of GWP emissions from biofuel sugarcane produced in mineral soils in Florida. Considering pre-harvest biomass burning as part of the scenario 1 "business as usual", expressed in kilograms of dioxide equivalents per hectare per year

Results of modeling the fourth scenario, without pre-harvest burning, show that the main contributor is the use of equipment (42%). Other important sources of emission are energy (26%) and the use of fertilizers (25%) (Figure 18).

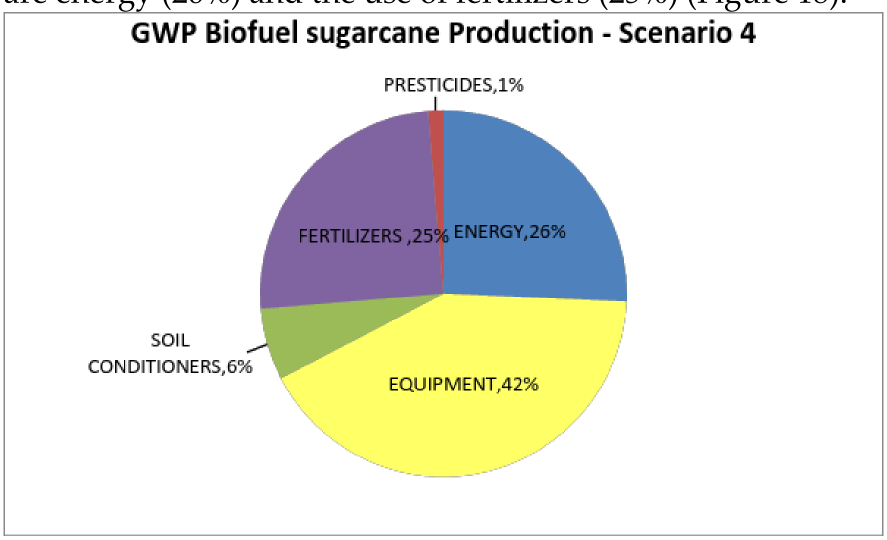

Figure 18. Percentage of GWP emissions from biofuel sugarcane produced in mineral soils in Florida. Without considering pre-harvest biomass burning, as part of the scenario 4 "green harvest", expressed in kilograms of dioxide equivalents per hectare per year

Summary of GWP emissions from biofuel feedstock crops cultivation

The total emissions of CO_2e to produce one ha of biofuel from the three biofuel feedstocks using the business as usual scenario creates the highest emissions (Table 15).

On the other hand, the lowest emissions for each crop are when the following scenarios are applied (Table 17).

1. For sugarcane, scenario 4 (green harvest) reduces the CO_2 contributions by 30%.
2. For energycane, the best production scenario is when "reduced tillage" is practiced, reducing the CO_2 emissions by 23%.
3. For sweet sorghum, the "controlled- release nitrogen" is the best scenario because it reduces emissions by 19%.
4.

Table 17. Summary of GWP emissions from biofuel sugarcane, energycane, and sweet sorghum production in mineral soils in Florida. Expressed in kg CO_2e ha^{-1} y^{-1}

Emission source	SUGARCANE				ENERGYCANE				SWEET SORGHUM			
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Energy	494	430	490	494	307	248	355	307	560	527	398	560
Equipment	802	496	784	802	800	519	784	800	558	454	574	558
Soil Conditioners	122	122	122	122	70	70	7	70	16	11	11	16
Fertilizers	480	480	376	480	586	516	403	586	736	720	530	736
Pesticides	26	26	26	26	28	28	28	28	40	46	40	40
Pre-harvest burning	816	816	816	0	0	0	0	0	0	0	0	0
TOTAL	**2,740**	**2,370**	**2,615**	**1,924**	**1,791**	**1,381**	**1,577**	**1,791**	**1,910**	**1,759**	**1,553**	**1,910**

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TASK 7.0 [COST-BENEFIT ANALYSIS]

Monetary costs and returns from a proposed biofuels production and conversions process are the standard way to determine if a system (business model) is viable. Biofuels production and processing systems being implemented in south Florida should explicitly consider all external system costs (water consumption, pollution, soil loss, carbon balance, energy balance, etc.) by using economic benefit-cost analysis, replacement cost analysis, and contingent valuation studies. Evaluation of output, employment, and value added or income impacts of economic development will be conducted using regional economic models utilizing Input-Output Analysis and Social Accounting Matrix techniques (I-O/SAM, IMPLAN) by estimating regional multiplier effects arising from development of local industries and substitution of local resources for imported goods and services. The regional economic models will also be coupled to national environmental accounting matrices for energy use and emissions of greenhouse gases (CO_2, CH_4, N_2O, and CFC), conventional pollutants (SO_x, NO_x) and toxics releases.

Economic Analysis of Biofuels Production in Hendry County, Florida

Introduction

The economic analysis of the Hendry County (FL) Biofuel Project is summarized in two sections. The first section includes the economic analysis of relevant biofuel crops that can be grown in the area and converted to biofuel (ethanol), as well as the regional economic impacts for Hendry County. The second section includes the economic analysis of water storage and treatment system, since changes to agricultural practices for growing biofuel crops will have an effect on water resource use in Hendry County. Additional information can be found in the original project reports submitted for each task.

Economic Analysis of Potential Biofuel Crops

At the present time, sugarcane is the only crop grown in the area that may be used for conversion to biofuel (ethanol). In South Florida, sugarcane is grown mostly on muck soils, which are rich in nutrients and highly suitable. To develop a biofuels industry in this region, it is assumed that, in addition to sugarcane, there will be other crops that can serve as a year-round source for producing biofuel feedstock to fully utilize the processing plant infrastructure. Crops in consideration are sugarcane, sweet sorghum, and switchgrass. Due to environmental concerns, crops such as elephantgrass are ruled out because of concerns about invasiveness and currently are listed as “do not plant” for South Florida (Woodard & Sollenberger, 2011).

For economic analysis, costs and returns for sugarcane, sweet sorghum, and switchgrass were developed. Sugarcane has been grown commercially in South Florida and converted to sugar for many years. Sweet sorghum and switchgrass will be new crops in the area and therefore there are no commercial data on these crops in the region, so data on costs and returns were taken from research studies and semi-commercial results in other states. Since there is no conversion facility for sugarcane to ethanol in the region, data for conversion of sugarcane to ethanol are also taken from other sources. Sugarcane and sweet sorghum can be converted to ethanol using conventional saccharrous fermentation technology. Since cellulosic conversion technology has yet to be commercially applied at scale, switchgrass can not be considered as a biofuel crop for ethanol at the present time; however, switchgrass may be converted to electricity using combustion technologies.

Costs and returns per acre were estimated for conversion of sugarcane and sweet sorghum to ethanol, and conversion of switchgrass to electricity. The construction cost of conversion facilities for producing ethanol and electricity at economic capacity will be a major component of the costs and returns for the proposed biofuels industry in South Florida. Based on the conversion ratio of sugarcane and sweet sorghum to ethanol and switchgrass to electricity, the total amount of feedstock necessary for a 50 million gallon ethanol plant and 50 MW electricity plant were estimated (BB International, 2001; Rahmani, 2009). Based on yield per acre of the crops in the biofuels feedstock mix, the total acreages for each of the crops was assessed, and the total costs and returns for each option were compared. Costs and returns to the existing sugar industry are used as a baseline for the opportunity cost of the proposed biofuels industry development in the sugarcane growing region of South Florida.

Sugarcane is a commercially grown crop in South Florida, where soil and climatic conditions are highly favorable. Sugarcane is one of Florida's major crops, grown on nearly 400,000 acres, with total production of 14.4 million tons in the 2009–10 production season (USDA-NASS, 2010). Average sugarcane yields per acre were estimated at 36.7 tons by USDA, however, yields range from 32 to 38 tons per acre based on soil type, crop year, harvesting, and other agricultural practices. Table 1 shows the cost of sugarcane production, ethanol yields, and the cost of ethanol from sugarcane based on sugarcane crop studies in South Florida (Roka et al., 2009 and 2010; Alvarez et al., 2011; Rahmani and Hodges, 2006).

From an agronomic point of view, South Florida has favorable conditions for growing sweet sorghum; however, there has been no experience on a commercial scale for growing this crop in the region. There are several studies on sweet sorghum as a biofuel crop in other states and other parts of the world (China and India). A recent study on sweet sorghum in South Florida (Helsel and Alvarez, 2011) provides the most relevant data for growing sweet sorghum and compares its ethanol yield to that for sugarcane. Results indicate that sugarcane is a preferred feedstock in South Florida because it has a higher sugar percentage, does not have to be planted each year, and has lower harvest and transport costs. Based on all available data, the cost of ethanol from sugarcane and sweet sorghum are estimated and shown in

Table 18.

Table 18: Cost of sugarcane and sweet sorghum production, ethanol yield and cost of ethanol

Crop	Total Production Cost of Sugarcane	Ethanol Yield	Feedstock Cost of Ethanol	Total Cost of Ethanol *
Sugarcane	$30.25 – $36.89 /*ton*	19.5 (gallons/ton)	$1.55 – $1.89/*gallon*	$2.05 – $2.39/*gallon*
Sweet Sorghum	$1,620.00/*acre*	500 – 600 (*gallons/acre*)	$2.70 – $3.24/*gallon*	$3.31 – $3.65/*gallon*

Source: Roka et al., 2009, 2010; Alvarez et al., 2011; Rahmani and Hodges, 2006; Helsel and Alvarez, 2011; Vermerris et al., 2007

*In absence of any conversion plant in the area, the cost of sugarcane conversion to ethanol was estimated at $0.50 per gallon.

*The cost of sweet sorghum conversion to ethanol was estimated at $0.61 per gallon (Frosh et al., 2008).

There is not much experience in Florida growing switchgrass (Newman et al., 2011). However, based on available data from other states, cost of production, heating value, conversion ratio, and cost of electricity for switchgrass were estimated as shown in Table 19.

Note that costs may be higher or lower in Florida. While switchgrass has potential as a biofuel crop in Florida, this grass has significant production challenges. Rust can be a serious problem in South Florida during the wet, humid season, while moisture content and field drying conditions for this crop in Florida are also challenges.

Table 19:Switchgrass cost of production, heating value, conversion ratio, and cost of electricity

Cost of Switchgrass Production (dollars/ton)	Gross Heating value[1] (Btu/ton)	Efficiency[1]	Net Heating value (Btu/ton)	kWh equivalent (*3,413 Btu = 1 kWh*)	Cost of 1 kWh electricity production (including conversion costs)[2]
$111.65 – $113.66[1]	15,500,000	80%	12,400,000	3,633	$0.0767 – $0.0853

Source: Duffy (2007, 2008)(includes transportation and storage costs); Perria at al. (2008) (transportation and storage costs added to the production estimates of $80 per ton).
[1] TechLine, Fuel Value Calculator, Forest Products Laboratory, USDA, 2004.
[2] . Cost of woody material conversion to electricity is based on a 50 MW plant capital cost and yearly operating costs of $.46 to $.54 per kWh (Rahmani and Hodges, 2008).

Regional Economic Impact Analysis of Biofuel Production in South-Central Florida

The value of Florida sugarcane production for sugar was $493 million for 2012, which accounted for 43 percent of the total U.S. value for this crop. (USDA - NASS, 2012). During the past couple of years the price of sugarcane for sugar in the United States increased from an average of $29.50 per short ton in the 2008/09 production season to $41.70 in 2010/11, an increase of 41.4 percent, while in Florida, the average price of sugarcane increased from $30.10 to $38.0, an increase of 26.3 percent (USDA, NASS, 2012). The price of sugar in the world market has also increased significantly during the past couple of years. The increase in the price of sugar has forced the world's major ethanol producing country, Brazil, to reconsider and review its use of sugar for ethanol production.

In the United States, pressure has recently increased on the federal government to relax the EPA mandate for using ethanol mixed with fuel. Some states, including Florida, as well as some agricultural producer groups, have petitioned for a waiver of the EPA mandate on ethanol, but so far, the EPA has denied these requests (AGRI-VIEW, Nov. 21, 2012). As the responsible agency for regulating transportation fuel, the EPA developed the Renewable Fuel Standard (RFS) program regulations, which mandated using 10 percent fuel from renewable sources mixed with fossil fuels.

Regional economic impacts of potential ethanol production in South Florida are based on data from relevant industries in the area. Presently, there is no ethanol industry in

Hendry County in South Florida, so in absence of any actual data, three scenarios were taken into consideration for a 50 million gallon per year (MGY) ethanol facility (minimum size). To construct these scenarios, the following data and assumptions were applied:

1. Average ethanol yield per acre from sugarcane and sweet sorghum crop were estimated at 500 gallons.
2. To produce 50 MGY ethanol 100,000 acres of sugarcane or sweet sorghum should be allocated.
3. Average sugar yield per acre of sugarcane (quoted by various sources from 7,200 lbs. to 8,000 lbs.) is 7,500 pounds.
4. Average price of hydrated ethanol at plant site is estimated at $1.75 per gallon.
5. Sugar price has been volatile recently; however, based on commodity price sources, $0.28 per pound is taken as an average.
6. References for the assumptions in these scenarios: Shapouri et.al., 2006; Salassi and Deliberto, 2011; Baucum and Rice, 2009: Alvarez and Helsel, 2011.

Scenario 1: Using part of the presently grown sugarcane crop for conversion to ethanol. It is assumed that 100,000 acres of sugarcane would be converted to ethanol. Based on available data, this change can produce as much as 50 million gallons of ethanol. Economically, this option results in a loss for Hendry County ($87.5 million of ethanol versus $210.0 million of sugar)

Scenario 2: Growing sweet sorghum instead of sugarcane on the 100,000 acres of presently growing sugarcane for conversion to 50 million gallons of ethanol. This option would also result in a loss for Hendry County.

Scenario 3: Growing sweet sorghum on 100,000 acres not used for growing sugarcane. Sweet sorghum grown on the additional acreage would be converted to ethanol.

Our regional economic impact analysis in Hendry County will be focused on Scenario 3, growing 100,000 acres of sweet sorghum in addition to sugarcane and converting the crop to ethanol, which is the only viable option that can benefit the Hendry County economy.

Economic impacts of growing sweet sorghum on 100,000 acres in addition to sugarcane presently grown in South Florida was evaluated with regional economic models constructed with the *IMPLAN* software (version 3) and associated data for 2010 (MIG, Inc., 2011). In addition to the regional model for Florida, a regional model for Hendry–Palm Beach Counties was also constructed. Input-output models with social accounting matrices enable estimating the secondary impacts of industry activities in the local economy arising through input purchases from vendors, and through spending by employee households and governments, known as indirect and induced multiplier effects, respectively (Miller and Blair, 2009). The multiplier effects capture expenditures by households, local, state, and federal governments, and capital investment generated by new resources garnered by the new activity. Major economic impact measures include output, employment, value added, and indirect business taxes.

To estimate total economic impacts, economic multipliers were used for sugarcane farming in Hendry County, Florida (*IMPLAN* sector # 9), which was assumed to be similar for farming activities for sweet sorghum. Cost of production was taken as the direct output of one acre of sweet sorghum production in the area (Alvarez and Helsel, 2011). This analysis will cover regional economic impacts of growing, harvesting, and processing sweet sorghum to produce ethanol. The cost of processing and converting sweet sorghum to ethanol was estimated at $0.646 per gallon, based on a survey of 20 sugarcane mills producing ethanol in Brazil (APEC, 2010; Cargo et al., 2010). The conversion cost per gallon was applied to the estimated ethanol production on 100,000 acres of sweet sorghum in Hendry County in South Florida to get the direct output value. Regional economic impact multipliers for the processing and conversion of sweet sorghum to ethanol was estimated by the average of multipliers for *IMPLAN* industry sectors for Sugar cane mills and refining (sector 48) and Distilleries (sector 73). Table 20shows the total economic impact multipliers for output, employment, value added, and indirect business taxes for sugarcane farming and processing sectors.

Table 20: Total economic impact multipliers applied for sweet sorghum production and ethanol conversion processing in Hendry County, Florida

Sector	Total Output Multiplie r	Total Employment (Job)	Total Value Added ($/$ output)	Indirect Business Taxes ($/$ output)
Farming (Sugarcane)	1.661	26.071	0.832	0.071

Sugarcane mills and refining (Hendry Co.)	1.998	10.016	0.604	0.044
Distilleries (Florida)	3.159	22.397	2.271	0.702
Average of Sugarcane mills and refining + Distilleries	2.578	16.207	1.438	0.373

Source: *IMPLAN*, 2010 DATA, MIG, Inc.

No capital cost for plant construction was considered because reliable information could not be found. It is assumed that locally produced ethanol in Hendry County, Florida substitutes for imported products.

Results of the economic impact analysis show that production and harvesting of 100,000 acre of sweet sorghum in Hendry County, Florida would generate $269.1 million in output impacts, 4,223 jobs, $134.7 million in value added contributions to GDP and $11.5 million in indirect business taxes. Processing sweet sorghum to produce ethanol can generate an additional $83.3 million in output impacts, 523 jobs, $46.4 million in value added, and $12.0 million in indirect business taxes in Florida as summarized in Table 21.

Table 21: Economic impacts of growing 100,000 acres of sweet sorghum and conversion to ethanol biofuel in Florida

Economic Impacts	Output Impacts ($M.)	Employment Impacts (Jobs)	Value Added Impacts ($M.)	Indirect Business Taxes ($M.)
Production and harvesting	269.1	4,223	134.7	11.5
Processing to ethanol	83.3	523	46.4	12.0
Total	352.4	4,747	181.1	23.5

IMPLAN, 2010 DATA, MIG, Inc.

Total regional economic impacts of growing, harvesting, processing, and converting 100,000 acres of sweet sorghum to ethanol in Hendry County, Florida can generate a total of $352.4 million in output impacts; 4,747 jobs; $181.1 million in value added impacts; and $23.5 million in indirect business taxes. It is assumed that these results are for a biofuel project that will provide investment for growing sweet sorghum on 100,000 acres of land that presently is not in any other crop in South Florida.

The estimated regional economic impacts are based on a set of assumptions that construct the underlying output and other economic impact measures. Considering the high transportation cost of bulky sweet sorghum material to a processing facility, the production area should be in close proximity to the conversion plant. In addition, the availability and extent of funding to invest in the construction of a 50 MGY ethanol plant in South Florida will definitely be a challenging task.

Concern regarding allocating agricultural resources to produce ethanol instead of food makes the case for using agricultural resources to produce ethanol difficult to sell. It is assumed that any potential biofuel crop in South Florida would be produced on idle or available lands other than the lands presently in sugarcane due to the high opportunity cost of replacing sugarcane (i.e. the foregone earnings of replacing sugarcane for sugar with ethanol production). There are many reasons why replacing sugarcane is not a viable and economically feasible option. With the high price of sugar in the world market (27 cents/pound by mid–August 2011, www.bloomberg.com) there is no biofuel crop (sweet sorghum or switchgrass) that can compete with sugarcane on either muck or sandy soils in South Florida. Sugarcane for sugar production in South Florida is an established industry, with more than 1.54 million tons of sugar in 2009 (Roka et al., 2009).

Economic Analysis of Costs and Benefits of Water Treatment

Water storage and water treatment are two issues that are closely related because the stored water that comes from various sources may be contaminated with various nutrients and pollutants and must be treated for reuse. Water treatment efforts in South Florida to eliminate or reduce the content of phosphorus and nitrogen are mostly directed at drainage water flowing to lakes or storages facilities. While some reports by the South Florida Water Management District (SFWMD) address the amount of phosphorus and nitrogen reductions, there are no reports of the exact cost or benefit of these efforts. A study conducted by the University of Florida in 2005 compared the economics of two water treatment systems for phosphorus removal in Florida (Sano et al., 2005, 2008, and 2011). This study evaluated two types of water treatments for phosphorus removal: Stormwater Treatment Areas (STA), and the Proprietary Management Aquatic Plant Systems (MAPS). The MAPS showed significantly higher removal capacity per acre compared to STAs. The study estimated the costs and benefits of STAs in the Everglades Construction Project Basin, the Everglades Stormwater Program Basin, and the Lake Okeechobee Watershed Project Basin. The results showed the total capital costs range from $22.2 to $204.9 million in the Everglades Construction Project Basin, $20.9 to $88.9 million in the Everglades Stormwater Program Basin, and $6.7 to $140.4 million in the Lake Okeechobee Watershed. When operation and management costs are included, the total costs range from $27.7 to $352.1 million. Water storage/supply benefits show positive values only for the Everglades Stormwater Program Basin and Lake Okeechobee Watershed.

While there are cost data for both water storage and water treatment in South Florida, there are little data to support a realistic estimate of the benefits of water storage and treatments in monetary terms. Even the data on costs of water storage and water treatments estimated by SFWMD are within such a wide range that using those data for cost/benefit analysis can be challenged and are questionable. Recently, data were released by EPA on the cost of compliance with the numeric standards to cleanup state waters, but have been challenged by the agriculture community in Florida (Quin, 2012). To provide a reasonable cost/benefit analysis, a comprehensive study to estimate the monetary costs and benefits of water storage and water treatments in South Florida should be conducted.

A 2001 study assessed trade–offs from water retention in the Everglades Agricultural Area (EAA) (Aillery et al., 2001). The study was based on the premise that there is a trade–off when profitability of agricultural production in an area is compromised by the potential environmental benefits that may be achieved by restricting some of the crop production activities. The idea was to increase water retention on EAA lands through cropland acquisition for water storage. The study constructed a model with 500,000 acres of land in the EAA area where production activities included "sugarcane/dry fallow, sugarcane/flood fallow, sugarcane/rice, vegetable/dry fallow, vegetable/rice, continuous sod, and continuous pasture." Production costs and crop prices for each crop were taken into account to estimate the total returns to agricultural activities. Various scenarios of water-table restrictions, land acquisition (acres), and water-retention targets (acre-foot) were taken into account to estimate the agricultural income/loss in the area.

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TASK 8.0 [SUSTAINABLE FARMING SYSTEMS]

The Center will propose alternate farming systems for biomass production and work to create, refine, and demonstrate these new methods of feedstock production. Integral to these new farming systems should be the inclusion of explicit ecosystem services components serving the needs of the Florida Everglades, Lake Okeechobee, and coastal estuaries restoration priorities of south Florida. Few field or greenhouse studies have been conducted into the effects of bioenergy feedstock production on watershed quality for eco-regions where feedstocks could be sustainably produced. Without such research and the validation of model results, these deficiencies could pose major challenges to the design of biofuel production systems that actually are sustainable. An important element in these farming systems development efforts is linking research and potential modeling on water quantity and quality with information on soil processes and crop growth to more accurately predict the effects of biomass management options. The initial focus of the farming systems development work has been sugarcane and energy cane grown on both organic and mineral soils mentioned above. Another production system of interest is sweet sorghum.

Experiments at the Everglades Research and Education Center, Belle Glade, FL

The exploration of species selection with four biofuel crops and water table variations was conducted at the UF/IFAS Everglades Research and Education Center, Belle Glade, FL. in greenhouse conditions (Figure 19).
Elephantgrass, energycane, sugarcane, and giant reed was grown in lysimeters using 3 water table treatments (Fig.):

1. Constant 40 cm below the soil surface
2. Constant 16 cm below the soil surface
3. 2-week flood (water table at soil surface) – 2 week drain 40 cm below the soil surface.

Measurements of plant height, tiller number, stomatal conductance, SPAD, and chlorophyll fluorescence began on March 31, 2011. (See Section 6 for a presentation giving the details of the experiment to 20 participants). Three iterations of this experiment were completed to measure seasonal variations and temporal effects. When appropriate, a repeated measures analysis was completed. The initial planting

was followed by one ratoon. Then, a second planting was completed.

Figure 19: S. Jennewein, Agronomy M.S. candidate, examining biofuel crops in lysimeters at the Everglades Research and Education Center.

Harvest data for the plant crop, ratoon crop, and second plant crop were analyzed with SAS 9.2. Using Proc GLM, the data exhibited significant interactions with several attributes. Leaf dry weight, stalk fresh weight, stalk dry weight, total fresh biomass, total dry biomass, and total leaf area had significant ($P < 0.05$) genotype by water table interactions. There was not a significant genotype by water table interaction for pipe length, however, the abstract definition of aerenchyma applied to Arundo could be confounding the data. Additional analyses may confirm this effect.

The genotypes exhibited significant differences described with an LSD test. For leaf dry weight, all genotypes were in their own t grouping with Elephant grass exhibiting the highest fresh leaf harvest biomass followed by Energycane, Sugarcane and Arundo, respectively (MSE = 0.01). For stalk fresh weight, the same relationship was observed (MSE = 0.80). For stalk dry weight, the same order was observed, however, Arundo and sugarcane were not significantly different (MSE = 0.01). The relationship is supported again in total fresh biomass (Fig.) with all genotypes having unique t groupings ordered from heaviest to lightest as Elephant Grass, Energycane, Sugarcane, and Arundo (MSE = 1.50). Arundo has been observed in several journals to increase biomass production in subsequent ratoon crops and may exceed the other genotypes in production during the next trial.

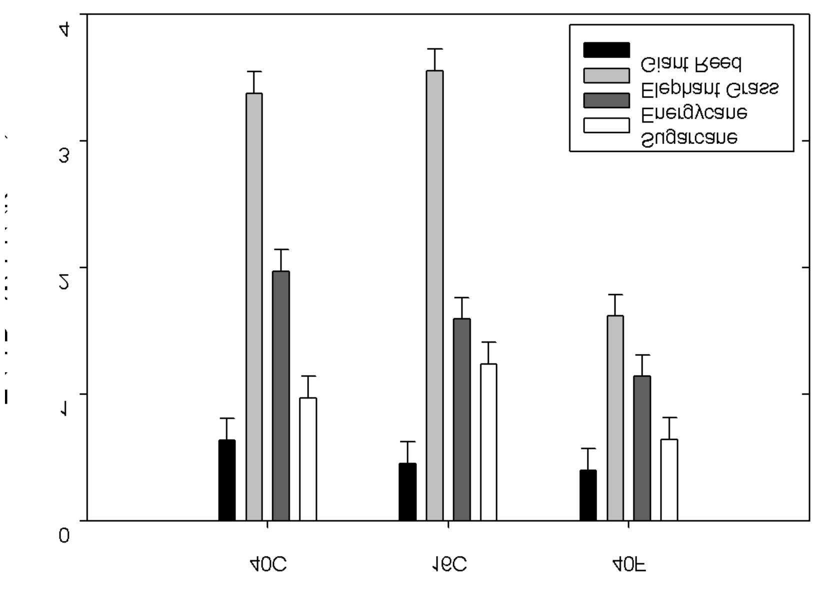


Figure 20: Total Dry weight of the four species by water table treatment interactions. 40C is

the constant -40 cm Water Table treatment; 16C is the constant -16 cm Water Table treatment, and 40F is the -40 cm Drained, Periodically Flood Water Table treatment.

This project at EREC will be presented as an MS thesis, which is being updated at this time. The researchers also expect to produce three journal articles, which are *in preparation*.

The primary findings of this work are:

1. There were yield reductions with the periodic flooding treatment (Figure 20)
    a) Yield reductions were reflected in decreasing SPAD and LAI measurements
    b) Effects of the timing and duration of any flooding event may not be reflected in the single flooding treatment selected in this experiment and using only single cultivars of each species. However, this experiment emphasizes the need for good water management for all three species.
2. The total dry weight yields (Figure 20) clearly show that yields for cellulosic biofuel feedstock production favor Elephant Grass and Energycane compared to Giant Reed or Sugarcane.
3. Aerenchyma production increased with high water tables.
4. This study suggested several management strategies to use for early growth with high water tables and are applicable to sugarcane for sugar, as well.
5. *Experiments at the Southwest Florida Research and Education Center, Immokalee, FL*

A second set of research field experiments in summer 2011 and fall 2012 was conducted at the Southwest Florida Research and Education Center (SWFREC) to evaluate the effect of high (HI) and low (LI) inputs on sweet sorghum (Sorghum bicolor (L.) Moench, cultivar: M81E) production in south Florida. Fertilizer additions were repeated for both fall 2011 and summer 2012 (Table 20). Summaries of cultural practices for both seasons are in Table 20 for fall 2011 and

Table 21 for summer 2012. The soil is Immokalee fine sand (sandy, siliceous, hyperthermic Arenic Haplaquods).

The experiment consisted of 6 plots separated by buried vertical plastic curtain walls to hydraulically isolate plots. Soil samples were collected before each season to determine the initial soil nutrient content before planting the crop. Each plot was equipped to monitor water applied (flow meter) and soil moisture content at several levels beneath the soil surface (10, 20, and 30 cm). Groundwater wells were installed to collect water samples for evaluating groundwater quality. Seven irrigation ditches were installed in each plot for seepage irrigation to provide sufficient moisture to the crops according to the assigned treatments. A seed drill was used to plant seeds on 30-in row spacing between irrigation ditches for each plot. Fertilizer (30 lbs. N and K20/acre) and water was applied to each plot for proper germination and establishment.

The experiment compared two production systems, high input (HI) and low input (LI) water and nutrient systems (Table 20 and Table 21). For HI, optimum soil moisture content was maintained while for LI irrigation was applied only for the crop establishment and thereafter based on the soil moisture content at the deeper soil depth.

After the establishment period, high input (HI) and low input (LI) treatments (3 reps each) were randomly applied to the six plots (). Water is applied to HI to maintain a specific water table depth (61 cm), while the water table in LI was allowed to fluctuate. Tensiometers were installed to determine if irrigation is required for LI. Biomass samples were collected from each plot.

Sweet sorghum biomass samples were collected 43 days after seeding by clipping 3 linear feet with a row in each plot. Biomass samples were divided into roots and biomass and oven-dried for 7 days at 65°C to obtain dry weight and plant tissue was analyzed for percent N, P, and K.

Total water use, water table depth, and groundwater N and P concentrations for the two systems were measured. Biomass sampling was conducted twice during each of the two growing seasons. To determine the nutrient uptake efficiency, nutrient plant uptake was measured at the time of each harvest.

Preliminary results from the first season were presented at the 2011 Fall Field Day (Figure 21) at SWFREC, UF/IFAS, Immokalee. The sorghum yields were lower than expected due to wet conditions and weed competition.

Table 22: Fertilizer application for the two production systems for summer 2011 and fall 2012 growing seasons.

Application	Days After Planting	N and K2O (lb/ac)	
		High Input	Low Input
1st	0	30	30
2nd	30-40	70	40
3rd	60-80	60	40
Total		160	110

Figure 21: Sweet sorghum planting at the Southwest Florida Research and Education Center, Fall 2011.

Table 23: Summary of cultural practices used for sweet sorghum grown with seepage irrigation in UF/SWFREC, Immokalee, FL. during fall 2011.

Field History				
Location	SWFREC, Immokalee, FL. (Field 1)			
Experimental design	RCBD (3 replications)			
Irrigation	Seepage			
Plot size (ft)	100 long/120 width total trial 1.65 acres			
Biomass harvest unit	3 ft			
Linear ft per acre	17,424			
Planting date	7/25/2011			
Treatments	Fertilizer Treatment	N	K_2O	Date
	High (160 lb/acre N and K)	30	30	7/25/2011
		70	70	9/7/2011
		60	60	10/11/2011
	Low (110 lb/acre N and K)	30	30	7/25/2011
		40	40	9/7/2011
		40	40	10/11/2011
Variety	M81E			
Plant spacing between rows	30 in			
Row run	North-South			

Table 24: Summary of cultural practices used for sweet sorghum grown with seepage irrigation in UF/SWFREC, Immokalee, FL. during summer 2012.

Field history				
Location	SWFREC, Immokalee, FL. (Field 1)			
Experimental design	RCBD (3 replications)			
Irrigation	Seepage			
Plot size (ft)	100 long/120 width total trial, 1.65 acres			
Biomass harvest unit	3 ft			
Linear ft per acre	17,424			
Planting date	17 May, 2012			
Treatments	Fertilizer Treatment	N	K_2O	Date
Fertilizer application	High (160 lb/acre N and K)	30	30	18 May, 2012
		70	70	19 June, 2012
		60	60	3 Aug. 2012
	Low (110 lb/acre N and K)	30	30	18 May, 2012
		40	40	19 June, 2012
		40	40	3 Aug. 2012
Variety	M81E main variety and Dale (in the middle of third replicate)			
Plant spacing between rows	30 inches			
Row run	North-South			

The root and shoot biomass was harvested in fall 2011 (Figure 22), and sampled on two dates. Three dates were sampled during the summer 2012 season (Figure 23)

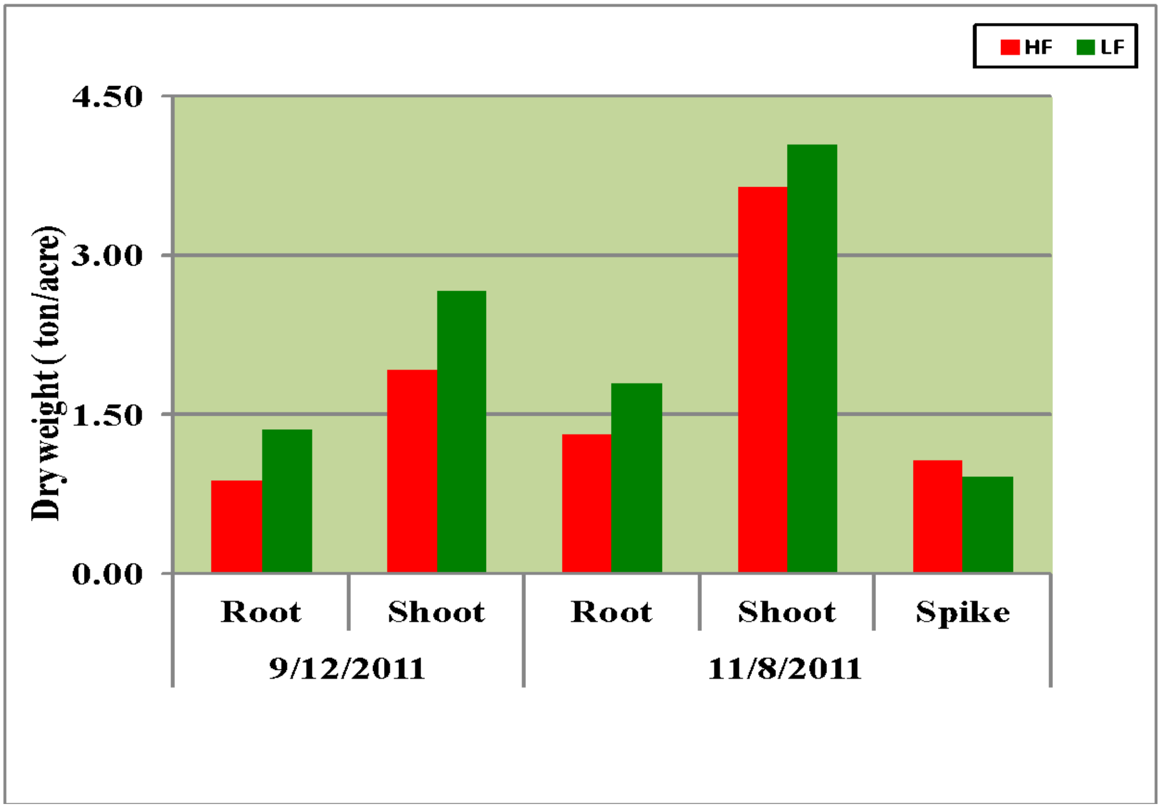


Figure 22: Effect of high (HF) and low (LF) fertilizer application treatments on biomass on sweet sorghum 'M81E' grown with seepage irrigation in UF/SWFREC, Immokalee, FL. during fall 2011.

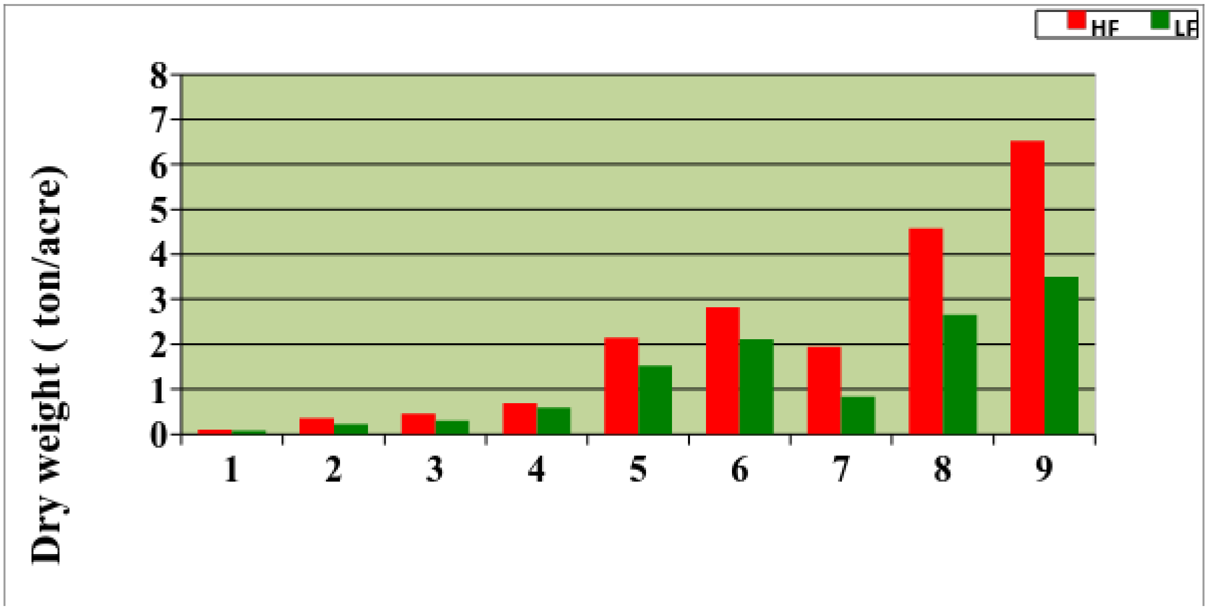


Figure 23: Effect of high (HF) and low (LF) fertilizer application treatments on biomass on sweet sorghum 'M81E' grown with seepage irrigation in UF/SWFREC, Immokalee, FL. during summer 2012.

Theoretical conversion of biomass to sugar ethanol using standard conversions is reported in Table 25 and Table 26. Both biomass and sugar ethanol decreased in 2012, compared to 2011, the amount of water increased due to the dry windy conditions during the 2012 growing season. The biomass production in both fall 2011 and summer 2012 was relatively low compared to other trials in more northern parts of Florida with the same cultivar. This comparison indicates that the subtropical climate of southwest Florida is at the limit of the cultivar used in this experiment.

Table 25: Biomass, sugar ethanol (excludes cellulosic ethanol), and irrigation volumes for the two production systems for the summer 2011 growing season.

Treatment	Biomass* (wet tons/acre)	Sugar Ethanol* (gal/acre)	Water Applied* (1000 gal)
High Input	7.2	105	719
Low Input	7.5	114	420

*Above data are for one cutting of sweet sorghum.

Table 26: Biomass, sugar ethanol (excludes cellulosic ethanol), and irrigation volumes for the two production systems for the summer 2012 growing season.

Treatment	Biomass* (wet tons/acre)	Sugar Ethanol*‡ (gal/acre)	Water Applied* (1000 gal)
High Input	6.4	36	1116
Low Input	3.3	17	951

*Data is for one cutting of sorghum. ‡Assume 14 lb of sugar = 1 gallon of ethanol

Data regarding plant tissue nutrient concentrations and biomass by plant part, as well as other information regarding water use, soil moisture, etc. that would be required for future modeling has been generated by this study. All of these data have been reported in tables and figures in the Quarterly reports (see Reports at http://swfrec.ifas.ufl.edu/soil_water/biofuels/hcsbc/).

INTELLIGENTSIA

Draft version of the "**Land Use Requirements for Production of Biofuels in Florida**" has been developed. It is currently being revised by the co-authors. The study establishes relationships between production of second generation secondary biofuels crops, associated biomass and bioethanol yields, land use requirements for these crops, biomass to biofuels conversion methods, and the overall fuel demands, particularly in Florida's transportation sector.

An important metric in evaluating the ability of various biofuel potential options to successfully address the above mentioned relationships is the quantity of fuel that can be produced from available agricultural land. Concerns are being raised regarding food production, available land, and water requirements, as well as other resources diverted by biofuels production. With the world having currently 4.89 billion hectares of agricultural land for its 7.1 billion inhabitants, there is on average 0.69 hectares of agricultural land available per person. Florida has even less available agricultural land per person (0.17 ha), but its favorable climatic conditions, advanced research, modern technologies, and a traditional leading role in agricultural production make Florida one of the nation's' forerunning regions for potential biofuels production. Florida has 18.9 million inhabitants, 14.3 million registered vehicles driving an average of 13,348 miles/vehicle/year with an average fuel consumption of 23.5 miles/gallon. If only bioethanol was used as a vehicular fuel, this fuel consumption translates to an average 647 gallons of bioethanol per year (assuming bioethanol having 66.7% energy content of petroleum-based gasoline per unit volume) per Floridian,. To generate this fuel from crop production within the state would require 0.24 ha/person using Energycane to 0.87 ha/person using Miscanthus. The economic feasibility of bioethanol crops requires further analysis. While the available farmland that would be required for producing only bioethanol crops does not compare favorably to the total of Florida's limited available land, there is still a tremendous potential to shift some of the Florida energy needs to biofuels.

The draft version is available at:
www.portlabelle.us/landuse/MF_paper/Paper_Fidler_121005.docx
A Community of Ecosystem Services (ACES) Conference (See other Tasks where presentations related to grant objectives were given at this important Conference)
An abstract was accepted and the following presentation was given.
Fidler, M., J. C. Capece, E. A. Hanlon, and K. Alsharif. 2012. Land Use Trade-offs between Fuel, Food and Ecosystem Services in Florida. ACES and Ecosystem Markets 2012 conference in Fort Lauderdale, FL, December, 2012.

TASK 9.0 [ECOSYSTEM SERVICES COMPENSATION]

The Center will contribute to the larger effort to create new compensation programs for the delivery of quantifiable ecosystem services by agricultural landowners. Estimating the cost to government of providing these services through alternate investments provides a starting point for assigning market values to these services and is a first step in creating private markets for their delivery. Structures and programs for implementing ecosystem services markets have to be designed with agricultural producers in mind. Where markets currently exist, farmers need assistance in accessing these markets.

BIOMASS FARMING SYSTEMS, ECOSYSTEM SERVICES, AND ANALYTICAL TOOLS

Abstract

Agricultural lands in Florida are being explored for increased water storage and delivery of other ecosystem services to aid in regional environmental restoration goals and to extend the economic life of farm land. A large part of the environmental

restoration, required by the Comprehensive Everglades Restoration Plan, calls for more water storage on lands south of Lake Okeechobee to restore the natural water flows of the Everglades Watershed. Modifying traditional farming systems to achieve ecosystem services can have a negative impact on agricultural production and profitability when viewed in terms of traditional farming business models. This research develops a model to assess economic costs of water storage in storage reservoirs versus increased water tables in agricultural fields in the Everglades Agricultural Area of Florida. The model calculates soil depth, depth to water table (DWT), subsidence rate, production, farm return, water storage and carbon loss. Economic costs of increased water tables in agricultural fields are determined by applying an ecosystem service valuation methodology for different scenarios. Results show that costs for water storage on farm land are very low in comparison to storage reservoirs. Furthermore, this study shows that more water storage on farm lands can significantly increase the economic life of farm land.

Agriculture is a vital part of the South Florida economy, however, it does not always agree with the restoration efforts of the region. A large part of the environmental restoration, required by the Comprehensive Everglades Restoration Plan, calls for more water storage on lands south of Lake Okeechobee to restore the natural water flows of the Everglades Watershed (CERP 2012). Agricultural lands in Florida are being explored for increased water storage and delivery of other ecosystem services to aid in regional environmental restoration goals and to extend the economic life of farm land. Raising water tables in the agricultural fields of the Everglades Agricultural Area (EAA) to achieve more water storage is an alternative approach. It is feasible due to the existence of crop irrigation and water control structures; the result of high water demands from EAA's primary crop, sugarcane. There is a concern that higher water tables in EAA may cause lower production yields. Planting sugarcane varieties that are more water-tolerant could alleviate this problem , and provide a payment for ecosystem services, known as a (PES) program. The benefits of expanded water storage to agriculture and the environment are difficult to quantify in traditional economical methods. By using an ecosystem services approach, this study gives economic value to the environmental trade-offs of growing water tolerant sugarcane with different water storage scenarios. This report develops an integrative model that measures soil depth, DWT, subsidence rate, production, farm return, water storage, and carbon loss. This is the first study that gives an ecosystem service assessment of water storage and the first to apply sugarcane yield data.

This study is the first step in assessing the feasibility of water storage on agricultural lands in the EAA and the possibility of a PES program. The study's research analyzes the cost of two different methods of water storage; water storage reservoirs and the raising the water tables on agricultural lands. This study aims to show that (1) increased water storage on agricultural fields is an economically viable option when compared to water storage in reservoirs; (2) by incorporating the valuations of the ecosystem services of water storage, a more sustainable farming system can be created that is ecologically and economically beneficial to farmers and to restoration efforts.

Methodology

<u>Model Framework</u>

An integrative model was developed to compare different sugarcane growing scenarios on a 5,000-acre model farm. The model calculates soil depth, DWT, subsidence rate, production, farm return, water storage, and carbon loss. The independent variables in the scenarios consist of 4 different soil depths, 3 different DWTs, and 2 different sugarcane yield equations for a total of 24 different scenarios. Starting at a baseline year of 2012, these scenarios are projected into the future to quantify sugarcane production, agricultural returns, soil subsidence, water storage, and carbon loss. The "life" of each model farm is equivalent to the years it takes the soil depth to reach ≤ 6 in (15 cm), which cannot support sugarcane farming (Aillery et al. 2001). Typically, farm life depends on this soil subsidence and whether a farmer can make a profit, but this study further investigates these scenarios regarding their relative environmental benefits. A 5,000-acre farm, as opposed to the typical 640-acre model farm, was chosen on the basis of reasons given in Roka et al. (2010). The rationale is: 1) a larger farm facilitates mechanical harvesting; 2) it is representative of scale of economic production; 3) it is closer to current land scenarios than a 640-acre farm; and 4) it improves accuracy of cost and return estimates.

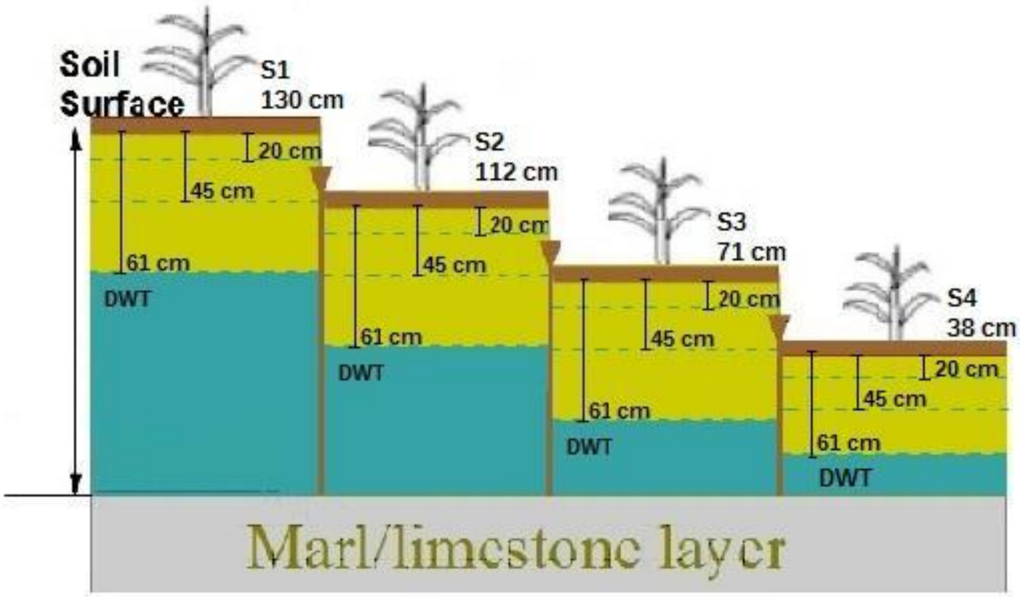


Figure 24: Illustration of different soil depths in relation to water table depths used in scenarios.

<u>Production</u>

Production is determined by two sugarcane yield equations (Model 1 and Model 2) taken from two different studies. The independent variable in both of the yield equations is DWT. This arrangement makes it possible to determine the effects of different water tables on sugarcane production and thus, economic production. Water table depths chosen for the scenarios are 61 cm (24 in), 45 cm (18 in) and 20 cm (9 in). The 61 cm water table is used since it is the recommended BMP water table depth (Wright and Hanlon, 2009). Forty-five cm and 20 cm water table depths are used because they were used in the Glaz (2010) study, from which one of the sugarcane cultivars for this research is taken. The equation for Model 1 is taken from Glaz (2006) and combines yields for CP 72-2086 and CP 80-1827 plant and first ratoon crop cane (Table 27). This equation was chosen because these two cultivars were two widely planted at the time of the study. The sugarcane yield equation is as follows:

$$Y= 23.8 + 0.16x \qquad (1)$$

where Y is yield (kg/m²), x is depth to the water table (DWT) (cm). The equation for Model 2 is calculated using yield data for CP 96-1252 (Glaz, 2010). This cultivar was chosen because it forms constitutive aerenchyma, making this cultivar a promising candidate for flood tolerance or high water tables. The yield averages for 45 cm DWT and 20 cm DWT for both plant and first ratoon cane were averaged (Table 3). The resulting yields produced the equation:

$$Y = 7.79 + 0.41x \qquad (2)$$

where Y is yield (kg/m²), x is depth to the water table (DWT) (cm). Figure 25 shows a comparison of the yield differences for Model 1 and Model 2.

Table 27: Yield results from Glaz (2010), their averages compared to the values for Model 1.

	Yield ($kg\ m^{-2}$)			
	Glaz (2010) results		Calculated avg.	Model 1 comparison
DWT (cm)	Plant Cane	1st Ratoon	CP 96-1252	CP 72-2086 & CP 80-1827
20	12.56	19.50	16.03	27
45	19.89	32.76	26.32	31

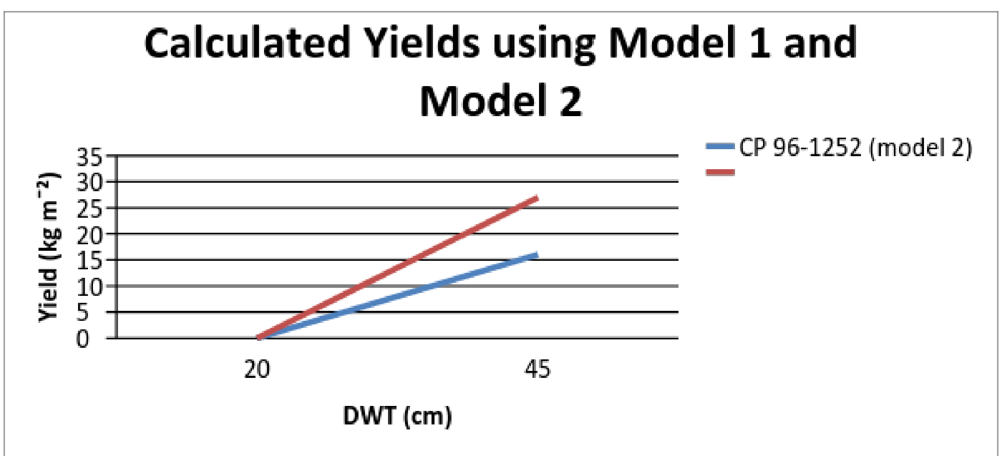


Figure 25: Calculated Yields using Model 1 and Model 2.

Yield results are converted to tons acre^{-1} then, divided by a conversion factor. This conversion factor is necessary because empirical yield results are extremely high compared to historical yield data for Palm Beach County, FL (Figure 26) (Southeast Climate Consortium 2010). The experimental conditions included plants grown in lysimeters spaced 10 feet apart. Given these conditions, factors that limit growth, such as competition for light, pests and diseases, are effectively removed and growth exceeds field grown yields. Also, the small size of the lysimeters allow for faster water table adjustments than field conditions (Personal communication with Barry Glaz). The conversion factor is calculated by setting the empirical yield results of Model 1 for a 61-cm water table (149.34 tons acre^{-1}) equal to the historical yield data from Palm Beach County (36.3 ton acre^{-1}) and dividing the empirical yield by the historical yield. The linear trend value for 2011 of 36.3 ton acre^{-1} was the latest value and used for the historical yield of Palm Beach County. This linear trend value reflects current production rather than the average for all production (Southeast Climate Consortium 2010).

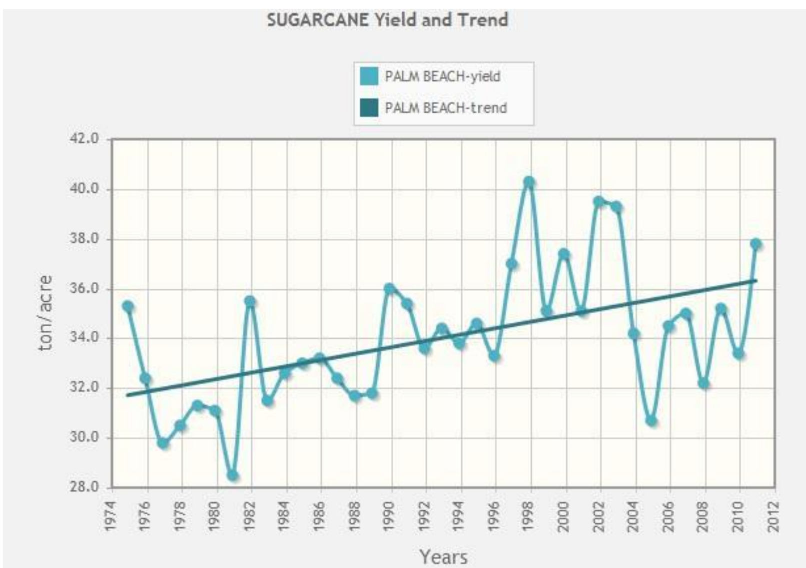


Figure 26: Graph of historical yield and trend for Palm Beach County sugarcane production (Southeast Climate Consortium 2010)

Production Returns

Production return is calculated using costs and returns reported by Roka et al. (2010). This includes sugarcane return ($24.50/ac) and molasses returns. Sugarcane also produces blackstrap molasses, which can be extracted and sold for the current market value. Roka et al. (2010) reports a historical average yield of seven gallons of molasses per ton of sugarcane at $0.2013 per gallon. Thus, the annual return per acre (ARA) is obtained by:

ARA = Y * $24.5 + [(7 gal * Y) * $0.2013/gal] (3)

where Y is sugarcane yield (tons/acre). The gross return (GR) is calculated to reflect production for the 5,000-acre model farm:

GR = ARA * 3,944 acres. (4)

Roka et al. (2010) estimates that a 5,000- acre farm annually harvests 3,944 acres or 79% of the total land. The remaining acreage is occupied by seed cane (156 acres), fallow land (650 acres), and infrastructure such as buildings, roads, canals, etc. (250 acres). The estimated total costs for production (Roka et al., 2010) are $3,194,380, and are included to give the net return (NR) of a 5,000-acre farm:

NR = GR - $3,194,380 (5)

The net return per acre (NRA) brings the price back to a price- per- acre for the model farm:

NRA = NR / 5,000 acres. (6)

The present value (PV) of NR and NRA are calculated at 2% interest rates as:

PV = CF * (1/(1+r)t) (7)

Where CF is current dollar value, r is the interest rate and t is the time factor or number of years into the future.

Soil and Subsidence

The four different soil depths chosen are 130 cm (S1), 112 cm (S2), 71 cm (S3), and 38 cm (S4) to represent the major soil types found in the EAA (Snyder 2004). Snyder (1978) states that the rate of soil subsidence is directly proportional to the depth to the water table. Based on this finding, the subsidence rate (SR) for each year is calculated by:

$$SR = (DWT / 100) * SR_i \quad (8)$$

where DWT is the target DWT for the given scenario and SR_i is the initial subsidence rate of 1.5 cm yr^{-1} (0.6 cm yr^{-1}). Soil depth for a given year in each scenario is calculated by subtracting the rate of subsidence for the previous year from the soil depth.

<u>Water Storage</u>

Water storage (WS) (acre-ft) is calculated based on the porosity (n) of the soil and the saturated thickness (ST) of the soil, using the equation:

$$WS = (ST*n) + ET \qquad (9)$$

where ST is saturated thickness of soil (ft) determined by the soil depth minus DWT and ET is the evapotranspiration rate. A soil porosity of 14% is used, based on the 1 inch of water per 7 in of soil ratio for the EAA (Aillery et al. 2002). Evapotranspiration (ET) is taken from Omary and Izuno (1995) at a rate of 93.2 cm/year (36.7 in/year).

The difference in water storage for all of the scenarios is calculated, as well as the difference in net return. The 61 cm (24 in) water table is used as the baseline and the differences for the other two water table depths are determined by the difference from the baseline. The economic value of water storage (WSC) can be determined by:

$$WSC = \Delta NR / \Delta WS \qquad (10)$$

where ΔNR is the difference in net return from the baseline and ΔWS is the difference in water storage from the baseline. To determine the most economical method of water storage, these volumes and costs for water storage were compared with the volumes and costs of a proposed storage area (Table 4) in the EAA, as required by CERP (2002) . The A-1 storage reservoir is the first of three storage areas envisioned by the CERP and is under construction. Estimated costs do not include the price of land purchases.

Table 28: Storage and costs for proposed EAA Storage Reservoir A-1 (Adapted from SFWMD 2006).

EAA Storage Resevoir A-1		
Storage	190,000 af	
Cost (no contingencies)	$401,000,000.00	$2,111 af[1]
Cost (w ith contingencies)	$483,000,000.00	$2,542 af[1]

<u>Carbon Loss</u>

The method to determine carbon loss employs the oxidation potential equation from Morris (2004):

$$Y=199.11+5.44x \qquad (11)$$

where Y is CO_2 (nmol kg^{-1} soil h^{-1}) and x is DWT (cm). The results are converted to CO_2 (g kg^{-1} soil yr^{-1}) using:

$$Z = ((Y / 1{,}000{,}000{,}000 \text{ mol}) / 44.01 \text{ g}) * 24 \text{ h} * 365 \text{ days} \qquad (12)$$

where Z is CO_2 (g kg^{-1} soil yr^{-1}) and Y is CO_2 (nmol kg^{-1} soil h^{-1}). To convert kg of soil into a volume, soil densities acquired from Hanlon (2007) (Table 29) were used. Densities of the Everglades Histosols vary by depth and soil type. A bulk density of 0.65 g cm^{-3} is used for yield belt 1 and a bulk density of 0.35 g cm^{-3} is used for the other three yield belts. There was no density found for soils equal to or less than 38 cm (15 in) so it is assumed to be 0.35 g cm^{-3}. The logic is that there are no data available for lower soil profiles. Izuno (1994) states that the bulk densities decrease as soil depth decreases, thus the bulk density cannot be greater.

Table 29: Bulk densities of Everglades histosols (adapted from Hanlon et al., 1997 and Snyder, 2004).

Soil Series	Bulk Density (g cm^{-3})	Thickness of Organic Layer in	cm
Torry	0.65	>51	>130
Pahokee	0.35	36-51	91-130
Lauderhill	0.35	20-36	51-91

Carbon loss (C) is converted to tonnes m^{-3} yr^{-1} by:

$$X = (1000g\ soil\text{-}1 * B) * Z * (1000/1000) \qquad (13)$$

where X is CO_2 (tonnes m^{-3}), B is the bulk density and Z is CO2 (g kg^{-1} soil yr^{-1}).

Results and Discussion

Overall, model farms with sugarcane yield in Model 1 experienced higher crop yields and consequently higher returns than model farms with yield in Model 2, which was not expected. This finding could be due to differences in experimental conditions. The Glaz and Gilbert (2006) study that produced Model 1 yields used foliar nitrogen treatment cycles while the Glaz and Morris (2010) study that produced Model 2 yield did not. Consistently, farms with deeper soil depth experienced longer years of production, water storage, and CO_2 loss than farms with shallower soils.

Results for sugarcane Model 1 yields are shown in Table 27. When DWT was 20 cm (9 in), none of the farms made a profit for any year, although, these farms experienced the longest farm lives (371 years), highest overall production (10,846 tons $acre^{-1}$) and water storage (11,077,909 acre-ft). Farms with a 61 cm DWT experienced the highest overall net returns ($23,272,973) and average crop yield (36.34 tons $acre^{-1}$). Farm life and years of water storage nearly tripled from a 61 cm DWT to a 20 cm DWT, going from 107 to 371 years and 76 to 376 years, respectively. The difference in the results between the 61cm DWT farms and the 45 cm DWT farms compared to the 45 cm DWT farms and 20 cm DWT farms is interesting. The differences are much greater going from a 45 cm DWT to a 20 cm DWT.

Results for sugarcane yield model 2 are shown in Table 28. In comparison to results from yield Model 1, farms with a DWT of 20 and farms with a DWT of 45 cm saw no positive years of returns. The differences in the results for farms with a DWT of 61 cm are not substantially different, as the water tables become shallower, the differences between the results for the two scenarios widen. In all of the scenarios that experience negative returns, the return is greater as the soil depth becomes shallower due to the reduced farm life. In both models, no water storage is achieved at a soil depth of 38 cm and DWT of 61 and 45. In all scenarios, water storage increases as the soil depths increase and the DWT decreases.

Water storage results are shown in Figure 27, Figure 28, Figure 29, and Figure 30. Result summaries are shown in Table 30 and Table 31. Results for Model 1 with a DWT of 45 cm actually achieved negative costs for S1 and S2 toward the end of the soil life, before reaching zero. Water storage costs, overall, are higher for yield Model 2 than yield Model 1, because yield Model 2 achieved less sugarcane production. The highest costs overall of \$165 $acre^{-1}$ for water storage occurs in Model 2 for soils 1, 2, and 3 and for both DWT. Similarly, the highest cost for water storage in Model 1 of \$64 $acre^{-1}$ occur in the same scenarios. In comparison to the EAA Storage Reservoir A-1 costs, these expenses are extremely low. Even the total costs for water storage are relatively low.

Table 30: Summary of results for sugarcane yield Model 1. * All model farms with DWT = 20 cm had no positive return for production.

DWT (cm)	Soil (cm)	Farm Life (years)	Yield (tonnes acre^{-1})	Avg Yield (tonnes acre^{-1})	PV NR	PV NR acre^{-1}	WS (ac-ft)	WS (ft acre^{-1})	Years WS	CO_2 (tonnes m^{-3})
61	130	107	3,888	36.34	$23,272,973	$4,655	1,866,526	373	76	7.35
	112	102	3,161	36.34	$21,728,351	$4,346	1,238,752	248	56	5.31
	71	42	1,526	36.34	$14,937,081	$2,987	181,446	36	11	3.65
	38	16	581	36.34	$7,183,029	$1,437	0	0	0	2.69
45	130	146	4,900	33.56	$11,340,060	$2,268	3,376,639	675	126	8.39
	112	120	4,028	33.56	$10,891,234	$2,178	2,425,640	485	100	3.71
	71	59	1,980	33.56	$8,273,978	$1,655	726,605	145	39	1.82
	38	16	537	33.56	$3,260,429	$652	0	0	0	0.49
20*	130	371	10,846	29.23	-$10,556,954	-$2,111	11,077,909	2,216	367	14.78
	112	311	9,092	29.23	-$10,541,420	-$2,108	8,505,350	1,701	283	12.39
	71	175	5,116	29.23	-$10,233,556	-$2,047	3,766,713	753	171	6.97
	38	65	1,900	29.23	-$7,647,630	-$1,530	1,066,299	213	161	2.59

Table 31: Summary of results for sugarcane yield Model 2.

DWT (cm)	Soil (cm)	Farm Life (years)	Yield (tonnes acre^{-1})	Avg Yield (tonnes acre^{-1})	PV NR	PV NR acre^{-1}	WS (ac-ft)	WS (ft acre^{-1})	Years WS	CO_2 (tonnes m^{-3})
61	130	107	3,813	35.64	$20,080,778	$4,016	1,866,526	373	76	7.35
	112	87	3,101	35.64	$18,748,022	$3,750	1,238,752	248	56	3.22
	71	42	1,497	35.64	$12,888,264	$2,578	181,446	36	11	1.55
	38	16	570	35.64	$6,197,782	$1,240	0	0	0	0.59
45*	130	146	4,161	28.50	-$13,574,680	-$2,715	3,376,639	675	126	8.39
	112	120	3,420	28.50	-$13,037,411	-$2,607	2,425,640	485	100	3.71
	71	59	1,682	28.50	-$9,904,410	-$1,981	726,605	145	39	1.82

	38	16	456	28.50	-$3,902,914	-$781	0	0	0	0.49
20*	130	371	6,437	17.35	-$72,444,329	-$14,489	11,077,909	2,216	367	14.78
	112	311	5,396	17.35	-$72,337,730	-$14,468	8,505,350	1,701	307	6.59
	71	175	3,036	17.35	-$70,225,091	-$14,045	3,766,713	753	171	3.75
	38	65	1,128	17.35	-$52,479,854	-$10,496	1,066,299	213	61	1.39

* These farms had no years of positive returns

Table 32: Summary statistics of water storage costs for yield Model 1.

		Model 1 WSC			
DWT	Soil	Total	Average	Maximum	Minimum
45	S1	$1,913.55	$15.19	$64.23	-$1.53
	S2	$1,769.93	$17.70	$64.23	-$2.43
	S3	$878.36	$22.52	$64.23	$8.84
-	S4	$0.00	$0.00	$0.00	$0.00
20	S1	$2,011.45	$5.48	$64.23	$0.01
	S2	$1,919.69	$6.25	$64.23	$0.03
	S3	$1,297.69	$7.59	$64.23	$0.48
	S4	$785.57	$12.88	$36.36	$4.21

Figure 27: Water storage costs for sugarcane yield Model 1 with a 45 cm DWT.

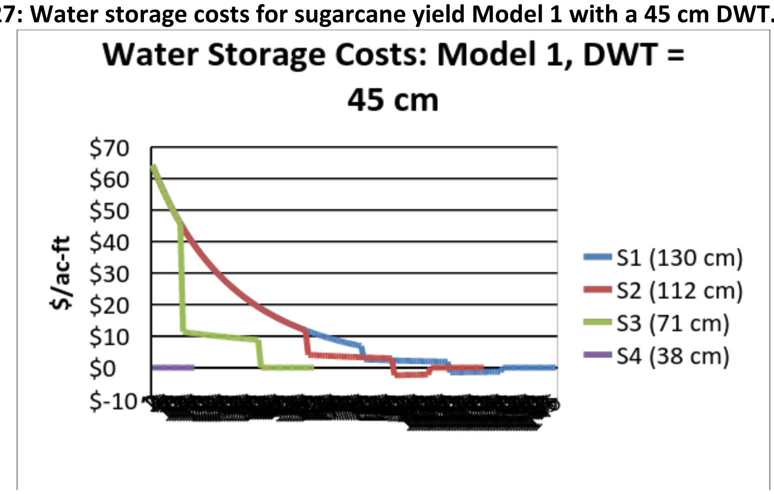


Figure 28: Water storage costs for sugarcane yield Model 1 with a 20 cm DWT.

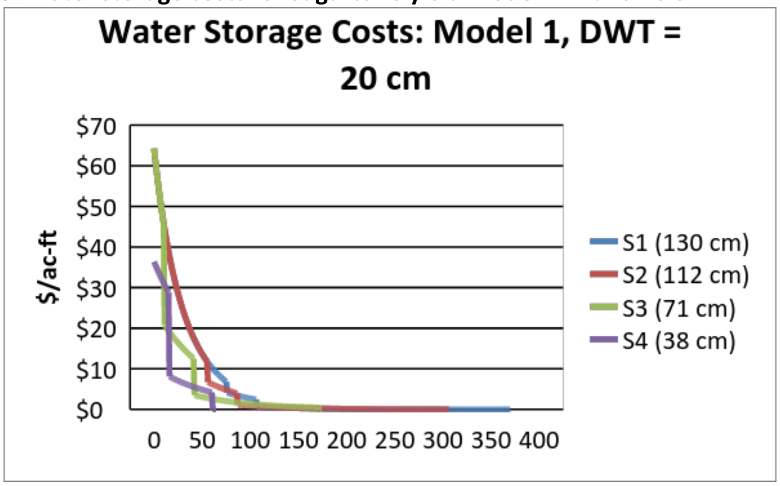


Table 9.

Table 33: Summary statistics of water storage costs for yield Model 2.

		Model 2 WSC			
DWT	Soil	Total	Average	Maximum	Minimum
45	S1	$5,028.39	$39.91	$165.40	$1.56
	S2	$4,670.96	$46.71	$165.40	$2.64
	S3	$2,261.77	$57.99	$165.40	$22.76
-	S4	$0.00	$0.00	$0.00	$0.00
20	S1	$5,349.21	$14.58	$165.40	$0.07
	S2	$5,221.32	$17.01	$165.40	$0.22
	S3	$4,168.38	$48.47	$165.40	$3.27
	S4	$3,165.75	$51.90	$93.63	$28.88

Figure 29: Water storage costs for sugarcane yield Model 2 with a 45 cm DWT.

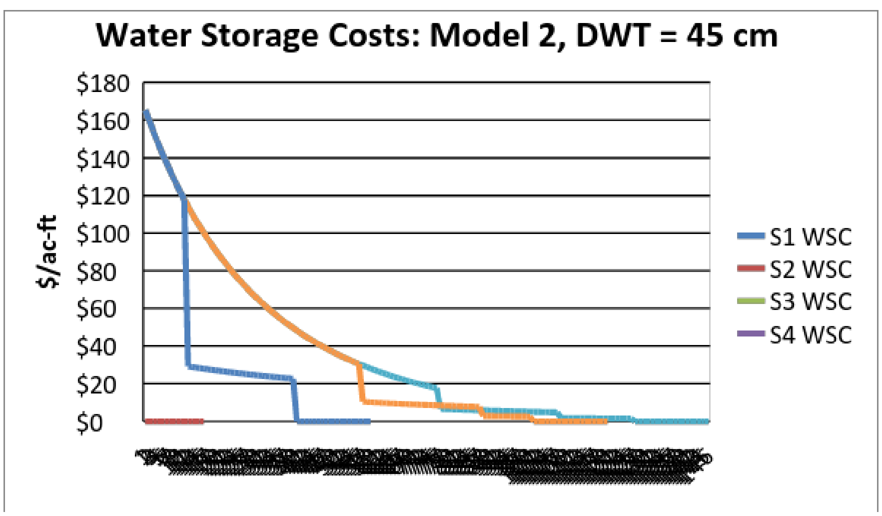
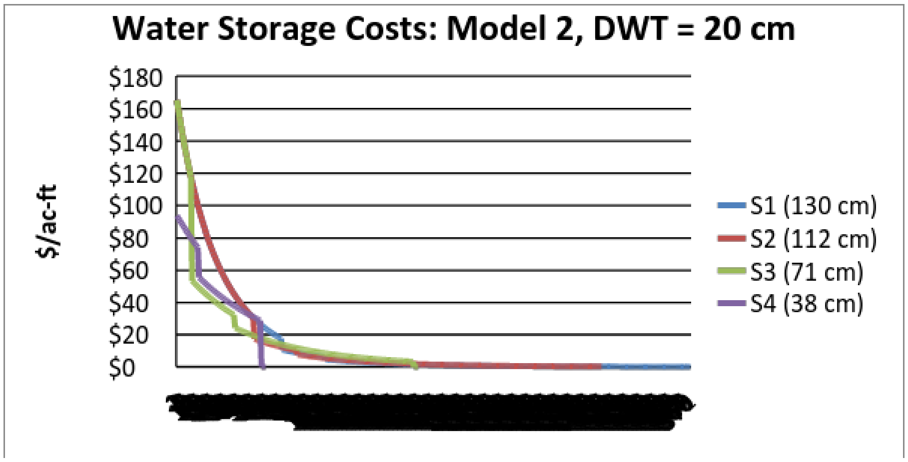


Figure 30: Water storage costs for sugarcane yield Model 2 with a 20 cm DWT.



Farm income lost to water storage is may be replaced by developing a payment for ecosystem services (PES) program, where the farmers would be compensated for income lost when providing the needed service of water storage. Stakeholders, like local government agencies, such as the South Florida Water Management District (SFWMD), could provide the payment, since they would not have to pay for reservoir construction. A PES program would help to diversify farmers' incomes, which further increase the economic sustainability of farming in the EAA. However for such a program to be successful in this area, farmers would have to prove that they are not merely back-pumping this stored water into Lake Okeechobee. Strict regulations have been set for back-pumping water into Lake Okeechobee to decrease phosphorus levels. Eutrophication of Lake Okeechobee is a high priority environmental issue for South Florida and one of the issues that CERP aims to alleviate (Perry 2008).

Results also show that it would be necessary for multiple farms in the EAA to participate, to store enough water to reach water storage goals of 190,000 acre-ft yr^{-1}. Farms that would be best suited for increased water storage would be located on deeper soils. These results illustrate that farms with soils of 38 cm or less may not benefit from increased water storage on lands. Farmers could also face an issue with maintaining higher water tables while adjacent farms or fields have lower water tables. Differential water tables would create a hydraulic head that would drive water to shallower water tables. It is possible that increased pumping would be necessary to maintain higher water tables, which would be an added expense to farmers and would slightly raise the cost of water storage in fields.

Even though the sugarcane variety CP 96-1252 did not achieve the expected results of being more productive in higher water tables, this finding does not mean that there are no water-tolerant varieties of sugarcane available. Experimental results are difficult to scale up to farm production but more studies are being done on water-tolerant varieties and energycane (personal communication with Barry Glaz). The USDA Agricultural Research Service in Canal Point, FL, diligently develops new sugarcane cultivars with various tolerances; one being high water tables. The success of the breeding program is evident, when data for historic averages of sugarcane yield in Palm Beach County, Florida is taken into consideration. These data show a steadily increasing linear trend (Figure 26) (Southeast Climate Consortium, 2010). In addition to the fact that subsidence seems to have decreased in recent years (Wright and Hanlon, 2009), it seems that there is hope that sugarcane farming will remain viable in the EAA.

Conclusion

The results of this study demonstrate that models similar to the one used for this research can help in assessing water storage options. Improvements to the model, such as including flood scenarios and showing more statistics for results, such as the maximum and minimum values rather than just the averages, should be considered in the future. These results, however, do not necessarily prove that increased water storage on farm land in the EAA is the best option. The purpose of this study is to develop a methodology to assign a cost for water storage on farm land to economically compare this option to other methods of water storage. The results show that increased water storage on agricultural fields is an economically viable option, when compared to water storage in reservoirs. Farms with increased water storage experienced a longer production life, thus resulting in a more sustainable farming system.

Results from this analysis also show that increased water storage on farms lands would be a relatively short-term solution, compared to building water storage areas. Water storage on farm lands could be a more favorable option, if funds for storage reservoirs and land purchases were not available. Pushing back the construction of reservoirs for some years could allow for the use of better technology and innovations for water storage that become available. Political and economic situations could change, that bring about new land uses for the EAA.

Florida is in a unique position to serve as a model for ecosystem service valuations and programs in order to preserve valuable and unique natural resources. Economic profitability should not be the driving force in decision-making, although it is unrealistic to not consider costs. The goal of this study is to provide an outline for future water storage valuations for the EAA to make more sustainable decisions regarding the natural resources of the region. If the history of South Florida has taught us anything, it should be that inflexible solutions are not appropriate for maintaining a dynamic and complex natural environment.

TASK 10.0 [CURRICULUM DEVELOPMENT]

The Center staff will create a set of curricula for regional secondary and postsecondary institutions to prepare students to pursue integrated agricultural, environmental, and biofuels-related professions. At the high school level, curriculum development this will take the form of a new Career Academy for Agriscience. Career academies are a State of Florida program to enhance academic achievement among students and to award students with an Industry Certification/Credential in preparation for jobs.

Curriculum Development Objectives:

1. Identify competencies in sustainable biofuels for high school curricula to be utilized by career academies in Hendry County Public School Agriscience Programs. http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/Secondary Biofuels Results_27Feb13.pdf.
2. Identify competencies in sustainable biofuels for post-secondary schools, specifically in Hendry County (http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/Post-Secondary%20Delphi%20Results_27Feb13.pdf).
3. Develop course outline and matrix for secondary career academy to be used in Hendry County Public School Agriscience (http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/Secondary Biofuels Results_27Feb13.pdf).
4. Develop course outlines and matrix for post-secondary schools in Hendry County that articulates with a four year degree program centralized in sustainable biofuels (http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/poster_Biofuels_Ed_Continuum_

Poster.pdf and http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/Edison State College Course Development_27Feb13.pdf).

These objectives were met through conduction of Delphi panels. Panel experts were determined based on community leaders in education and industry (http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/poster_Biofuels_Ed_Continuum_Poster.pdf) then educational researchers incorporated the expert panel results into formative documents for local educational practices (http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/poster_A_True_Delphi_Approach.pdf).

Middle and Secondary School Educational Curriculum Development

Once panel participants were selected the Delphi panel was conducted. The Delphi began with a lead question that was constructed in collaboration with an educational expert with experience in the Delphi approach. The Delphi panel was conducted by a trained discussion leader and a recorder to transcribe all concepts presented by the panel. A faculty investigator provided an introduction to panel participants and oversaw the process.

The Delphi consisted of three rounds, and was guided by the question, "If you were to hire a high school graduate with training/education in agricultural and environmental practices, what are the knowledge, skills, and competencies you would want the student to have?" Panelists were asked to respond to the question based upon their expertise. At the conclusion of round one, all ideas were added into a tabulation document. Panelists were then asked to rate the knowledge, skills, and competencies in the tabulation document. During round two, further discussion on the topic was also accepted. During round three, members clarified, combined, and further discussed items presented in the previous two rounds. At the conclusion of the third round, the panelists were again asked to rate the items on a scale of 1 to 5 (1= Not Needed; 2 = Optional; 3 = Somewhat Important; 4 = Very Important; 5 = Essential). It was determined *a priori* that a characteristic scoring "4" or higher would be included in the final recommendation of knowledge, skills, and competencies necessary for the sustainable biofuels and agriculture curriculum.

During the secondary school Delphi panel, Round 1 of the panel yielded 100 items, and Round 2 yielded an additional 22 items. Overall, panelists emphasized the importance of six main items, which they all scored essential ("5") on the tabulation sheet. Those items were: “work ethic,” “responsibility,” “teamwork and cooperation with others,” “follows instruction,” “accountability to own work,” and “required internship experiences.” Additionally, all 10 panelists scored 31 items as either “essential” or “very important.” For a complete list of items, please see the article, which has been submitted for publication (Burleson, S. E., Thoron, A. C., & Hanlon, E. A. (In review). Knowledge, skills, and competencies needed by students with training in agricultural and environmental practices as perceived by local leaders: A Delphi study. Manuscript submitted for publication in the Journal of Agricultural Education). Of the responses, the items could be categorized into three main areas: 1) life and leadership skills, 2) core subject area knowledge, and 3) competence in production agriculture knowledge/practices (http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/List_of_skills_competencies.pdf).

Following the completion of the Delphi panel, results from the secondary school panel were compiled to cross-reference with existing standards for Florida agriculture courses. The courses that were used for cross-referencing were: Agriscience Foundations, Agritechnology 1, Agritechnology 2, Agricultural Biotechnology 2, Environmental Resources 3, and Environmental Resources 4. Each item presented by the Delphi panel was referenced to one or more of these courses. The result was a document that consisted of each item presented by the panel correlated with all standards from any of the courses that covered the same topic.

The purpose of this document was to identify existing courses that were offered within Florida that could be used to teach the material necessary to prepare students for work in sustainable agriculture and biofuels. This information was utilized to make decisions about courses offered at secondary schools within Hendry County. Knowledge and skills gained from instruction in this area should prepare students for a multitude of options upon graduation of high school. First, students may choose to take a job in Hendry County working in agriculture and biofuels. Second students may choose to obtain an Associate’s degree at Edison State College, where they can continue their instruction in sustainable agriculture and biofuels. At this point, the student may enter the workforce in Hendry County, or chose to pursue a Bachelor’s degree from the University of Florida in a sustainable agriculture and biofuels area. Regardless of the student’s education decisions, the goal is to prepare educated students for careers that are available in their home community (http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/poster_Biofuels_Ed_Continuum_Poster.pdf).

Post-Secondary Educational Curriculum Development

The Delphi panel process was implemented in the same manner as described for Middle and Secondary School Educational Curriculum Development and shall not be repeated herein.

Following round one of the Delphi, each panelist was asked to rank each of the 172 knowledge, skills, and competencies. During round two, the panelists added, removed, and combined the knowledge, skills, and competencies from round one. At the end of round two, the panelists combined and removed 40 knowledge, skills, and competencies. During round three, further discussion was accepted and the panelists were administered an instrument to respond to the remaining 132 knowledge, skills, and competencies with the same 1 to 5 Likert scale. Following the second round, only one item reached conscious (Water Management, M = 5.00) by the group (http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/List_of_skills_competencies.pdf).

Once the Delphi panel was conducted, the researchers obtained current course syllabi for courses taught in science, mathematics, English/literature, history, and the humanities at Edison State College and the University of Florida. The courses were examined by the researchers for inclusion in an Associate of Arts Degree in sustainable agriculture and biofuels at Edison State College and a Bachelor of Science Degree at the University of Florida. The researchers aimed to create an articulation agreement between both institutions for students that were interested in majoring in sustainable agriculture and biofuels (http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/poster_Biofuels_Ed_Continuum_Poster.pdf).

Once the course syllabi were collected, the results were further analyzed. The research team had established an *a priori* mean score of 3.4 for a knowledge, skill, and competency to be included in the post-secondary curriculum in sustainable agriculture and biofuels. The 75 knowledge, skills, and competencies that were retained were examined for inclusion in pre-existing courses taught at Edison State College and at the University of Florida. Each item was cross-referenced with the course syllabi to determine if the course should be included in the sustainable agriculture and biofuels degree program

(http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/Edison%20State%20Curriculum%20Outline.pdf)
(http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/UF%20Curriculum%20Outline.pdf).

Each knowledge, skill, and competency was assigned to at least one of the 55 selected pre-existing courses. Following the analysis, 30 pre-existing courses from Edison State College and 25 pre existing courses were selected from the University of Florida as courses for inclusion in a degree program focused on sustainable agriculture and biofuels.

The completed document was then utilized to identify the deficient knowledge, skills, and competencies, which were not adequately covered in the pre-existing courses. The deficient knowledge, skills, and competencies were then separated between two newly developed courses that would be taught at both the University of Florida and Edison State College. One of the courses focused on an introduction to agriculture, environmental, and natural resource science, while the second course focused on a specific introduction to biofuels and sustainable agriculture. These two courses were presented to Edison State College for acceptance and creation.

The educational expert has met with administration and faculty at both Edison State College and the University of Florida to further discuss the creation of a major in sustainable agriculture and biofuels. The focus of this major would be to prepare students for careers in biofuels and sustainable agriculture, while encouraging these students to return to rural communities to advance the industry. Specifically, students will be encouraged to return to their home rural communities to accept jobs in sustainable agriculture and biofuels.

Final presentations of findings will be shared with professional education community at a May, 2013, conference in Columbus, OH to disseminate the knowledge of findings to outside audiences in the educational community. Further, formal peer-reviewed journal articles have been submitted for publication.

Rubenstein, E.D., & Thoron, A.C. (*In review*). The Creation of a Biofuels and Sustainable Agriculture Post-Secondary Curriculum: A True-Delphi Study. Manuscript submitted for publication in the Journal of Career and Technical Education.

Burleson, S.E., & Thoron, A.C. (*In review*). Knowledge, skills, and competencies needed by students with training in agricultural and environmental practices as perceived by local leaders: A Delphi study. Manuscript submitted for publication in the Journal of Agricultural Education.

TASK 11.0 [YOUTH DEVELOPMENT]

Both the high school career academy program and the college level studies program include opportunities for mentorship and internships with more senior students and professionals. Equally important is showing students of all levels the real-world agribusiness and ecological aspects of field and factory operations. The UF-IFAS Extension Service crop specialists and 4-H staff are ideal for helping deliver these types of extra-curricular learning programs through field tours and other practical learning experiences.

Objective K. 1.

Conduct background research to identify age groups of students in K-12 program leading up to the college level. Conduct background research on topics of interest in the field of Agriscience and Biofuels. Incorporate into internship or mentorship programs rigorous inquiry-based learning and analytical thinking. Hands-on experience with mentors will help students be more comfortable with the field and the industry.

<u>Accomplishments</u>

Initially, the targeted schools for the Youth Development Project were: LaBelle High School, a comprehensive high school with grades nine through twelve with an emerging Agricultural Academy; LaBelle Middle School with grades six through eight; and West Glades, a combination school including grades kindergarten through grade eight. Meetings with local school principals and the director of Edison State College provided an initial list of perceived needs for both the K-12 and postsecondary schools. The list of needs and possible areas of collaboration were further refined by the participation in the Delphi Process. The Delphi Process is a structured interview technique and survey tool that was used on more than 30 professionals including participants from the agricultural industry, agricultural research, K-12 education, postsecondary education, and the local environmental community. In addition, networking during the CIC (Community Involvement Committee) meetings provided important information on local and regional initiatives in biofuels. After the extensive collection of interviews with school principals, agricultural extension experts, agricultural researchers/scientists, environmental groups, and local agribusiness leaders, the targeted group was expanded to include grades three through five from the following schools: LaBelle Elementary, Country Oaks Elementary, Upthegrove Elementary, and West Glades. The other factor influencing this decision was the work of Page Keeley a nationally recognized speaker and author. Keeley's work on "Conceptual Change" and "Common Misconceptions in Science" makes two important points:

1. Students learn best and master complex concepts more thoroughly by constructing their own meaning with the assistance and facilitation of a trained teacher.
2. Many common scientific concepts are misconceived by the public. These misconceptions have a negative impact on the public's ability to make scientifically based decisions. These misconceptions begin at an early age and are based upon the students' observations and experiences. One of the most commonly misconceived collection of concepts in science deals with the understanding of energy. What is energy? How is energy transformed from one form to another? In what forms can energy be stored and later used? Are there processes that produce more energy than what existed before?

Because these misconceptions start at such an early age the Youth Development Project included elementary school students, grades three through five.

LaBelle Middle School did not participate throughout the entire task. The school had received a low grade on the state's accountability report, and the principal was unable/unwilling to justify the value of further participation.

In addition to the meetings, surveys, and interviews, a literature search provided additional topics and grade-appropriate scientific concepts for students.

Objective K.2

Establish an intermediate connection of peer review, peer help and collaboration between high school and college level students. Students will learn presentation skills to present to their peers, both senior and junior. Identify interesting mentorship and internship activities for students in the program in order to learn more about the job market and the job field.

<u>Accomplishments</u>

The connection with students included the following structured activities:

1. A series of presentations for all students grades three through four from all participating schools, were delivered during Earth Week, along with three follow-up presentations with selected fifth-grade classrooms at LaBelle Elementary. These presentations served more than 1000 local elementary school students from both Hendry and Glades counties. The presentations/demonstrations included the following concepts based upon the Project's previous research:
   a) **Examples of human mechanical energy**. In this section, students used a hand crank flashlight to make the connection between work (mechanical energy) and light energy.
   b) **Examples of energy conversion/transformation**. In this section, students were able to observe a solar car operating with batteries and in another example the car used a solar panel. Students were able to articulate that stored chemical energy in the battery was converted to electrical energy and the electrical energy was converted to mechanical energy or work. Students were also able to articulate the conversion of solar energy to electrical energy and finally to the mechanical energy used to move the car.
   c) **Examples of solar energy and food/fuel production**. In this section, students observed and participated in a number of demonstrations including the conversion of stored energy in sugarcane, to sugarcane juice, to raw sugar, and finally to ethanol; and then, peanuts, to peanut oil through peanut oil extraction. In both examples, students were able to observe the combustion of ethanol, peanut oil, and peanut husk. Students were able to articulate the conversion from stored chemical energy to the release of light and heat through combustion. Through a series of probing questions, students were able to realize that the source of the released heat and light energy in combustion was solar energy. Solar energy converted to stored energy in the process of photosynthesis. In addition, students were able to articulate the reduction in available energy after each successive conversion/transformation.
   d) Finally students were asked an open ended question, "Should we grow plants for food, or for fuel, or can we do both?" Students were allowed to offer differing points of view, but they were consistently asked to justify their opinion based upon concepts learned during the presentation.

e) These concepts were mastered at an 80% proficiency level. This percentage is an approximation of mastery based upon an informal assessment provided by the presenter's questions, student answers, as well as participation rates and levels of student engagement. After the presentation, a more formal assessment of student proficiency was attempted using classroom teachers. Classroom teachers were hard-pressed to move on to other educational goals, and participation in this formal assessment was inconsistent and incomplete.

2. A series of teacher/student consulting, coaching, and mentoring for science fair participation/competition was initiated by the Youth Development Project. Participation in the science fair process included school fairs at West Glades and Bonita Springs Middle Schools. In addition, there was participation in the Glades County District Fair and the Heartland Regional Fair representing six local counties. The Youth Development Project participated in judging for all of these fairs. Before our involvement, there were no projects based upon biofuels or sustainable agriculture. After our involvement, 3 to 5 projects were included in all of the aforementioned fairs. One Regional project based upon the conversion of bovine animal waste to methane was recommended to advance to the State Fair.

Objective K.3

Research and formulate mentorship programs. Establish collaboration with professionals, administrators, educators, and students. Generate general interest in students on mentioned topics and explain facilities on entering the field as a professional.

Accomplishments

The Youth Development Project participated in two primary mentorship programs. These programs were:

A. **Biofuels in Sustainable Agriculture Teacher Summer Workshop**: Targeted participants included secondary teachers grades five through eleven from LaBelle High School and West Glades in the disciplines of science, agriculture, and social studies. The workshop contained the following elements:

A three day summer workshop and model lesson planning: The first goal of the three day workshop was to provide background knowledge on both biofuels and sustainable agriculture, and to justify the inclusion of this content into the secondary curriculum. In addition to content specific information, teachers were exposed to the alignment of this content with Next-Generation Sunshine State Standards; STEM, Science Technology Engineering and Mathematics goals and objectives, and the newly adopted Common Core Standards provided through the United States Department of Education's Race to the Top initiative. The culminating product was a teacher-designed lesson plan incorporating age-appropriate, standards-aligned biofuels and/or sustainable agriculture content and the incorporation of teaching strategies appropriate for maximum student engagement and content mastery. These teaching strategies included techniques often associated with inquiry learning, Socratic questioning, argumentation, and evaluative thinking. These strategies are also often associated with the newly adopted Common Core Standards and are considered best practice by most professional educators.

Each teacher/participant had an additional two days of scheduled consultation, coaching, and mentoring to modify, resource, and plan delivery of their lesson plan.

Each teacher/participant had a minimum one-day observation and feedback during the delivery of their lesson.

As an incentive, teachers were provided classroom resources, a District-provided stipend, and in-service points necessary for recertification within the state of Florida.

Teachers were also required to participate in the Fall Farm Tour of local farms, agribusiness facilities, and government facilities used for the treatment of agricultural wastewater as part of the federal and state Everglades Restoration Act. The purpose of this activity was to provide information and potential networking for these teachers with local/regional agricultural concerns.

Workshop Outcomes:

Seven teachers participated in the three-day summer workshop. These teachers included: one high school agriculture teacher, two high school social studies teachers (one teacher General Ed and one teacher AP, Advanced Placement), two high school science teachers (one teacher Environmental Ed and one teacher AP, Advanced Placement biology), and two middle/elementary school General Ed science teachers.

All seven teachers designed lesson plans with acceptable content, appropriate alignment to standards, and employed pedagogy for maximum student engagement and content mastery.

Six of the seven original teachers successfully delivered their lesson plans in at least one class during a multi-day presentation.

Five of the seven original teachers successfully completed the farm tour and have incorporated some of their experiences in at least one subsequent lesson.

In an informal survey following the conclusion of the program, all participants admitted that they were skeptical about the inclusion of biofuels as a content appropriate for their discipline. All the participants agreed that they would include this topic in the future. Two teachers have planned for extended activities in biofuels for the upcoming term.

B. A presentation at the annual FAST, **Florida Association of Science Teachers Convention**: The target participants included members and nonmembers of FAST representing K-12 science teachers, K-12 district science supervisors, and post secondary professors associated with science education from state Colleges of Education.

1. The goals of this presentation were:
   a) Present and network with Florida educators.
   b) Attend other presentations with the topics of energy, biofuels, and sustainability.
      i) Attend the presentation by Page Keeley, a nationally recognized speaker and author. Keeley's work on "Conceptual Change" and "Common Misconceptions In Science" emphasizes the use of probing questions to uncover a student's metacognition and potential misconceptions of scientific concepts. A portion of her presentation was dedicated to the common misconceptions about energy. The Youth Development Project was able to incorporate some of her strategies in the follow-up sessions for the teacher summer workshop.
      ii) The Youth Development Project presentation included the script, materials and activities from the Earth Week presentation. The presentation provided justification for using biofuels and sustainable agriculture as a content

anchor for the teaching of energy, for the incorporation of Common Core Standards in science education, and the inclusion of more inquiry-based instruction.

c) Presentation Outcomes:
   i) All participants remained for the entire 8:00 AM presentation on Saturday morning including the question/answer and feedback session.
   ii) In the informal survey following the presentation, some participants identified themselves as more likely to include biofuels and/or sustainable agriculture as a content or content anchor in their science teaching.
   iii) None of the participants identified themselves as teachers and or supervisors that had considered using biofuels and/or sustainable agriculture as a content or content anchor in their science teaching.

Objective K.4

Write final report on internship topics.

<u>Accomplishments</u>

The five multi-day lessons designed and delivered as part of the Biofuels and Sustainable Agriculture Summer Teacher Workshop are:

1. "Soda Can Calorimeter"
   a) The primary objective of this lesson plan was for eighth grade students to predict and then measure the caloric content of different primary agricultural products and secondary agricultural waste materials.
   b) Student questions using evaluative thinking skills were:
      i) Do you think any of these forms of agricultural products or bio-waste materials could be used as a biofuel?
      ii) Which of these agricultural products or bio-waste materials could be used successfully as a biofuel and why? How do we measure success?
      iii) How would you persuade a congressman to support/fund further research into producing biofuels from one or more of these materials?
   c) Pre-Post test results:
      i) Pre-Test: Average Correct 42.8%, Standard Deviation 1.4

   - ii) Post-Test: Average Correct 80%, Standard Deviation 1.2

2. " Bio-assay Following the Enzymatic Digestion of Different Biomass Materials"
   - a) The primary objective of this lesson plan was for high school students in AP, Advanced Placement, biology to identify and quantify the importance of an enzymatic catalyst in the conversion of biomass to usable biofuel.
   - b) Student questions using critical or evaluative thinking skills were:
     - i) Identify and list some of the variables that should be considered in analyzing the efficiency of biofuels.
     - ii) Identify and list some of the variables that increase/decrease the efficiency of the enzymatic catalyst.
     - iii) Compare/contrast the advantages/disadvantages of different biofuels using what you've learned.
     - iv) What are the advantages of using an enzyme/catalyst in the production a biofuels from biomass products?
   - c) Pre-Post test results:
     - i) Pre-Test: Average Correct 95%, Standard Deviation 8.4%
     - ii) Post-Test: Average Correct 100%, Standard Deviation 0.0%
3. "A Debate/Forum for Special Interest Groups Debating/Discussing the Efficacy of Biofuels"
   - a) The primary objective of this lesson plan was for high school students in an AP, Advanced Placement, human geography class to use evidence-based argumentation to convince the teacher and a group of their peers about the efficacy and the governmental investment in biofuels ,as a driver of economic development in our community from the point of view of a specific interest group.
   - b) Background knowledge was provided by the teacher in a number of presentations and a group of speakers representing local agribusiness, economic development, and government leaders.
   - c) Student questions using critical or evaluative thinking skills were:
     - i) What biases or predispositions does your special interest group have?

   ii) What arguments support your position, and identify the evidence that supports these arguments.
   iii) What local or regional variables exist that impact the efficacy of this biofuel's investment?
   iv) How do you evaluate the persuasiveness of each of these arguments based upon the evidence provided?
 d) Pre-Post test results:
   i) Pre-Test: Average Correct 46.9%, Standard Deviation 21.3%
   ii) Post-Test: Average Correct 87.5%, Standard Deviation 12.4%

4. "Using Targeted Reading Strategies for a Variety of Biofuels Articles"
 a) The primary objective of this lesson plan was for high school students in a General Ed Environmental Science class to identify the appropriate main ideas and supporting details from journal articles about biofuels. The secondary objective was for students to identify questions (what else do I want to know?) about biofuels.
 b) Student questions using critical or evaluative thinking skills were:
   i) Identify and list a series of potential biofuel resources. Further, which of these resources could be locally a regionally available?
   ii) What variables must be considered in evaluating the pros and cons of different biofuels?
   iii) Design/construct a cost-benefit analysis of a biofuels facility located locally or regionally.
 c) Pre-Post test results:
   i) Pre-Test: Average Correct 32.7%, Standard Deviation 12.4%
   ii) Post-Test: Average Correct 59.3%, Standard Deviation 10.6%

5. "Fermentation of Sugarcane Juice and the Use of Ethanol as a Biofuel"
 a) The primary objective of this lesson plan was for two classrooms of General Ed middle/elementary school science and one class of high school entry level agriculture to successfully trace the energy conversion/transformation from the

sun (solar energy), to sugar produced in plant photosynthesis, to ethanol produced in anaerobic fermentation and finally to a usable/combustible fuel.

b) Students observed the seven-day fermentation of sugarcane juice and observed physical as well as chemical changes. The culminating day-eight activity was the distillation of the fermentation product and its testing as a potential combustible fuel.

c) Student questions using critical or evaluative thinking skills were:
   i) How much available energy is in the ethanol produced in fermentation compared to the sugar produced in photosynthesis, or the original solar energy used in plant photosynthesis?
   ii) In the process of making ethanol as a biofuel, why use additional energy and resources in the conversion from one form to another (solar, sugar, ethanol, heat/light)?
   iii) What observations can you identify that indicated physical/chemical changes within the fermentation vessel? What tests are used to confirm the observed physical/chemical changes?

d) Pre-Post test results for Middle/Elementary School Grade Eight Science:
   i) Pre-Test: Average Correct 42.5%, Standard Deviation 16.1%
   ii) Post-Test: Average Correct 51.9%, Standard Deviation 21%

e) Pre-Post test results for Middle/Elementary Grade Five School Science:
   i) Pre-Test: Average Correct 42.8%, Standard Deviation 12.3%
   ii) Post-Test: Average Correct 55.6%, Standard Deviation 18.5%

f) Pre-Post test results for High School Agriculture:
   i) Pre-Test: Average Correct 35.9%, Standard Deviation 36%
   ii) Post-Test: Average Correct 72.7%, Standard Deviation 72.7%

K.5 Write a summary of facts regarding Internship and Mentorship program activities

<u>Earth Week Presentations</u>

Activity: A celebration of Earth Day hosting in excess of 1,000 elementary school students.

Dates: April 23-25, 2012

Participants: 1,000+ Elementary students in grades three through four (follow-up presentations with selected fifth-grade students), 48 Elementary school teachers. This represented four schools in two Districts.

Impact: Introduced important concepts of energy and biofuels, and provided follow-up activities for more than 48 elementary teachers.

<u>Summer Teacher Workshops</u>

Activity: Three day workshop, two day follow-up and coaching/mentoring, one day lesson delivery and feedback and Fall Farm Tour.

Dates: Workshop; June 13-15, 2012, coaching/mentoring; scheduled during September-October, 2012, Fall Farm Tour; October 20, 2012.

Participants: Seven High School/Middle School teachers representing two schools in two Districts.

Impact: The workshop produced 5 model lessons with biofuels in the content, alignment to the new common core standards and instructional strategies designed for maximum student engagement and mastery. One hundred fifteen students in grades ranging from grades 5-11 participated in the model lesson presentations. During the verbal feedback sessions, both teachers and students encouraged more inclusion of biofuels in the curriculum, and the use of evidence-based argumentation as an instructional strategy to deal with scientific/social/economic/political dilemmas. Also based upon the verbal feedback sessions, teachers identified the Fall Farm Tour as an important opportunity to raise their awareness and appreciation of the depth and breadth of the region's agribusiness industry and its supporting institutions.

Science Fairs

Activity: West Glades School Science Fair-2012; West Glades School Science Fair-2013; Glades County/District Science Fair-2012; Glades County/District Science Fair-2013, Bonita Springs Middle School Science Fair and the Heartland Six County Regional Science Fair.

Dates: School Fairs in January 2012 and January 2013; District/County Fairs in February 2012 and February 2013; Regional Science Fair in February 2013 and the Bonita Springs Middle School Science Fair in November 2012.

Participants: Student participation ranged from a low of 55 to a high of 100 in each of the Science Fairs (Figure 31). Teacher/Chaperone participation ranged from a low of five to a high of sixteen. Science Fair judges included educators from both K-12 and postsecondary, pre-service teachers from FGCU, agency staff from government agencies, such as FWCC, Fish and Wildlife Service; IFAS, Institute of Food and Agricultural Sciences, and the USDA, United States Department of Agriculture, and Business leaders and entrepreneurs from science-based industries such as agriculture, medicine, mining, and materials processing.

Impact: These activities promoted networking and provided an opportunity to promote biofuels and sustainable agriculture as a potential scientific problem/question for inclusion in future Science Fairs projects.

FAST, Florida Association of Science Teachers Convention

Activity: The annual FAST, Florida Association of Science Teachers Convention provides an opportunity for K-12 and post secondary science educators from all sixty-seven Florida districts to meet and to exchange ideas about the K-12 science curriculum and effective instructional strategies.

Dates: October 25-27, 2012.

Participants: More than 1500 participants attended the three-day convention and concurrent sessions. Participants included K-12 teachers and science curriculum specialists; post secondary educators; staff members from the Florida Department of Education; staff members from the NSTA, National Association of Science Teachers, and vendors in science equipment/supply/publishing businesses.

Impact: This activity further promoted networking within the educational community and provided an opportunity to present examples of some of the presentations produced by the Youth Development Project of the Biofuels and Sustainable Agriculture Grant. After-presentation feedback sessions identified a lack of awareness of the emerging biofuels industry. Information gathered from these sessions also indicated an initial reluctance/ resistance to include what many consider yet another set of isolated information to the growing body of K-12 science curriculum. A few participants agreed that the biofuels information was topical, interesting, and lent itself to some of the goals in the newly adopted common core standards. Also, some participants appreciated the use of open-ended and higher order questions/problems that could employ a evaluative thinking and evidence-based argumentation.

K.6 Write a summary of facts regarding Professional Personnel collaboration structure

The following fact sheet includes function/setting, institutions, and personnel intimately involved in the Youth Development Project:

1. Meetings/Collaboration with School Principals, Teachers, Support Staff and Students included
2. LaBelle High School, LaBelle Middle School, LaBelle Elementary School, Country Oaks Elementary School, Upthegrove Elementary, West Glades School and Bonita Middle.

3. Meetings/Collaboration with District Administrators included Superintendents, Assistant Superintendents, and curriculum specialists from Hendry County Schools and Glades County Schools.
4. Collaboration and participation with University of Florida, Edison State College, Florida Gulf Coast University, and South Florida State College included professors, support staff, and curriculum specialists.
5. Meetings/Collaboration with Heartland Educational Consortium included the Director of the Heartland Educational Consortium and Consortium Support Staff for the Six District/County Regional Science Fair.
6. Delphi Process, a Structured Interview/Survey Process included K-12 Administration, K-12 Instructional Staff, High School Agriculture Teacher, K-12 Agriculture Students (Future Farmers of America), Post Secondary Administration, Post Secondary Professors, Post Secondary Curriculum Specialists, Environmental Activists, Doctoral Interns in Agriculture, Agribusiness Entrepreneurs, Agriculture Extension Agents and Agricultural Research Scientists.
7. Collaboration and networking within the CIC, (Community Involvement Committee) Meetings included Post Secondary Professors, Post Secondary Curriculum Specialists, Environmental Activists, Doctoral Interns in Agriculture, Agribusiness Entrepreneurs, Biofuels Entrepreneurs, Agricultural Extension Agents and Agricultural Research Scientists.
8. Presentation and collaboration for local teachers in the Fall Farm Tour included High School General Ed Biology Teacher, High School AP, Advanced Placement Biology Teacher, High School General Ed Social Studies Teacher, High School AP Advance Placement Social Studies Teacher, High School Agriculture Teacher, Middle School General Ed Science Teacher, Elementary School General Ed Science Teacher, Agriculture Extension Agents, Post Secondary Professors of Agriculture, Agribusiness Entrepreneurs and Environmental Activists.
9. References used in creation of lesson plans and teacher training:

Bio-Energy Feedstock Information System https://bioenergy.ornl.gov/

Biofuel Revolution A quiet revolution is fomenting, with its epicenter here in Southwest Florida, where a handful of entrepreneurial pioneers are on a quest to develop renewable biofuels as alternatives to fossil fuels. It is a revolution that could create tens of thousands of jobs, have a profound impact on the national economy, change the way Americans fuel their cars and move the nation further down the path toward the elusive goal of energy independence. http://video.wgcu.org/video/2253775690

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TASK 12.0 [ECONOMIC DEVELOPMENT]

The Sustainable Biofuels Center will assist in regional economic development by creating a process for evaluating biofuels project proposals as to their natural resources costs and benefits. Center staff will provide this analytical service to private companies and to government. Proposal assessments will be followed by assistance in modifying designs of biofuels production and conversion systems. Employment and Ad valorem tax revenue will be enhanced for the region by the Center helping develop the most sustainable biofuels industry possible. Biofuels projects constructed without proper attention to sustainability aspects will be vulnerable to future carbon taxes or cap and trade economics.

1ST QUARTER

A discussion with the CoPI and the new economic development officer for Hendry County was helpful in linking the Biofuels Center to this county office.

2ND QUARTER

No action this quarter.

3RD QUARTER

Plan for Next Quarter

The development of the Implan economic information for Hendry County and related LCA/economic components associated with other Tasks above should allow this Task to be advanced, especially with the involvement of the Stakeholder Framing Committee.

4TH QUARTER

Achievements

Only background work on a number of related topics have been achieved, but were advanced more rapidly in Q4 than in Q3.

Plan for Next Quarter

The continued development of the Implan economic information for Hendry County and related LCA/economic components associated with other Tasks above will be enhanced with full staffing that took place in Q4. This Task will be advanced, especially with the involvement of the Framing and Community Involvement Committee.

5TH QUARTER

Achievements

Introduction

Based on the most recent estimates by USDA, producers in the sugarcane growing region of South Florida expect to harvest 405,000 acres of sugarcane for the 2011-2012 production season (AGFAX.COM, August 12, 2011). In south Florida, sugarcane is grown mostly on muck soils, which are rich in nutrients and highly suitable. To develop a biofuels industry in this region, it is assumed that, in addition to sugarcane, there will be other crops that can serve as a year-round source for producing biofuel feedstocks, to fully utilize processing plant infrastructure. Among several crops receiving consideration, sweet sorghum and switchgrass are those with some potential to be grown in the area. Due to environmental concerns crops such as elephantgrass is considered a potentially invasive plant and currently listed as “do not plant” for South Florida (Woodard & Sollenberger, 2011).

In this report, costs and returns are presented for sugarcane, sweet sorghum, and switchgrass as biofuel crops in South Florida. For each crop the most feasible scenarios for conversion to energy are taken into account. Sugarcane and sweet sorghum can be converted to ethanol using conventional saccharide fermentation technology. Since cellulosic conversion technology has yet to be commercially applied at scale, switchgrass can't be considered as a biofuel crop for ethanol at the present time, however, switchgrass may be converted to electricity, using combustion technologies. In this report, switchgrass has been treated as a bio-energy feedstock rather than biofuel.

Sugarcane has been grown commercially in South Florida and converted to sugar for many years. Sweet sorghum and switchgrass will be new crops in the area and therefore there are no commercial data on these crops in the region. Data on costs and returns for sweet sorghum and switchgrass are taken from research studies and semi-commercial results on these crops in other states. Since there is no conversion facility for sugarcane to ethanol in the region, data for conversion of sugarcane to ethanol are also taken from other sources.

Methodology

Costs and returns per acre are estimated for conversion of sugarcane and sweet sorghum to ethanol, and conversion of switchgrass to electricity using most recent data available. Construction costs of relevant conversion facilities to produce ethanol and electricity accounts for a major investment undertaking and is a major cost for the final products. The cost of an economic capacity conversion facility for producing ethanol, and for production of electricity will be major components of the costs and returns estimates for the proposed biofuels industry in South Florida. In absence of commercial data in south Florida for any of the conversion facilities, data from other sources places will be applied. According to available information, an ethanol conversion facility of at least 50 million gallons ethanol per year is considered as the economic capacity (BB International) and 50 MW is the commercial scale for a biomass-fueled electric generation plant (Rahmani and Hodges, 2009). Based on the conversion ratio of sugarcane and sweet sorghum to ethanol and switchgrass to electricity, the total amount of feedstock necessary for a 50 million gallons ethanol plant and 50 MW electricity plant are estimated (BB International, 2001, Rahmani, 2009). Based on yield per acre of any of the crops in the biofuels industry mix, the total acreages required to produce each of the crops are assessed, and then the total costs and returns for each option are estimated and compared. Costs and returns to the existing sugar industry are used as a baseline for the opportunity cost of the proposed biofuels industry development in the sugarcane growing region of South Florida.

Sugarcane

Sugarcane is a commercially grown crop in South Florida where soil and climatic conditions are highly favorable. Sugarcane is one of the Florida's major crops, grown on nearly 400,000 acres, with total production of 14.4 million tons in 2009-10 production season (USDA-NASS, 2010). Average sugarcane yield per acre was estimated at 36.7 tons by USDA, however yield ranges from 32 to 38 tons per acre based on soil type, crop year, harvesting, and other agricultural practices. Overall, the weighted average yield for sugarcane grown on muck soils was estimated at 40.8 gross tons per acre, and for sugarcane grown on mineral soils 32.1 gross tons per acre. Based on data for costs and returns of sugarcane production in South Florida (Roka, et al., 2009, 2010), the total costs of producing sugarcane on muck soil was stated at $32.2 per net ton and on mineral soil at $47.81 per net ton, not including the value of land. Alvarez, et al. (2011), estimated the cost of sugarcane grown on mineral soil at of $33.16 per ton including land charge and taxes and assessments for 32 tons yield per acre. This study assumed the conversion rate of 19.5 gallons of ethanol per ton of sugarcane. Rahmani and Hodges (2006) estimated the total cost of sugarcane at $30 and $35 per ton, depending on agricultural practices and soil types, and a conversion factor of 17 and 20 gallons of ethanol per ton of sugarcane depending on sucrose content. Sugarcane with higher sucrose content can yield more ethanol and vice versa. Tables 1 and 2 show alternative cost estimates of sugarcane per ton, conversion rate to ethanol and estimated cost of ethanol per gallon.

Table 1. Cost of sugarcane production, ethanol yield and cost of ethanol from sugarcane[1]

Total Cost of Sugarcane Production	Ethanol Yield	Feedstock Cost	Total Cost of Ethanol from Sugarcane*
(dollars/ton)	(gallons/ton)	(dollars/gallon)	(dollars/gallon)
$30.25 (36 tons /acre)	19.5	$1.55	$2.05

$33.16 (32 tons /acre)	19.5	$1.70	$2.20
$36.89 (28 tons /acre)	19.5	$1.89	$2.39

[1] Alvarez and Helsel, 2011

*The cost of sugarcane conversion to ethanol was estimated at $0.50 per gallon.

Table 2. Alternative estimate of cost of sugarcane production, ethanol yield and cost of ethanol from sugarcane[1]

Total Cost of Sugarcane Production	Ethanol Yield	Feedstock Cost	Total Cost of Ethanol from Sugarcane*
(dollars/ton)	(gallons/ton)	(dollars/gallon)	(dollars/gallon)
$30	20	$1.50	$2.00
$30	17	$1.77	$2.27
$35	20	$1.75	$2.25
$35	17	$2.06	$2.56

[1] Rahmani and Hodges, 2006

*In absence of any conversion plant in the area, the cost of sugarcane conversion to ethanol was estimated at $0.50 per gallon.

In Florida, sugarcane is produced for conversion to sugar, and growing sugarcane as a feedstock for ethanol production will be considered a new use. Presently, there is no conversion facility for conversion of sugarcane to ethanol and in order to consider the new use for sugarcane, the cost of the facility that converts sugarcane juice to ethanol should be considered as part of the cost for the proposed biofuels industry in south Florida.

Sweet Sorghum

In the proposed biofuels industry for south Florida, sweet sorghum is considered an alternative crop to sugarcane as saccharide feedstock for conversion to ethanol. From an agronomic point of view, south Florida has favorable conditions for growing sweet sorghum, however, there has been no experience on a commercial scale for growing sweet sorghum in the region and converting it to ethanol. A 1995 demonstration project funded by the National Renewable Energy Laboratory looked into the possibility of using sweet sorghum (among other crops) for conversion to ethanol in central Florida. The results did not provide any clear indication of feasibility for growing sweet sorghum for ethanol using conventional technology. Since the study was performed on reclaimed phosphate-mined lands, some technical issues appeared to hinder the cultural practices during the rainy season. Both sweet and forage sorghum have a high risk for lodging that can result in loss of some yield from either the initial or ratoon crop (Sticker, revised 2009).

There are several studies on sweet sorghum as a biofuel crop in other states (Oklahoma, Texas, and Tennessee), or other parts of the world particularly in China and India. In 2008, the Florida Department of Agriculture and Consumer Services awarded a $7 million grant to U.S. EnviroFuels to develop an ethanol plant in Florida that would utilize sweet sorghum (Neal, 2008). There is no result of their work available yet. A recent study on sweet sorghum in South Florida (Helsel and Alvarez, 2011) provides the most relevant data for growing sweet sorghum in the area and compares its ethanol yield to that for sugarcane. Results indicate that sugarcane is a preferred feedstock compared to sweet sorghum in South Florida because it has a higher sugar percentage, does not to be planted each year, and the harvest and transport costs are lower. It was concluded that new varieties of sweet sorghum with higher sucrose content would need to be developed for ethanol from sweet sorghum to be competitive with sugarcane in south Florida. Helsel and Alvarez (2011) estimated the total production cost of one acre sweet sorghum at $1,620, and an average yield of 22.5 tons per acre.

Tables 3 indicates the range in costs of ethanol per gallon for sweet sorghum grown in south Florida. Ethanol yield per acre is estimated between 400 and 600 gallons (Vermerris, et al., 2007).

Table 3. Cost of sweet sorghum production, ethanol yield and cost of ethanol from sweet sorghum

Cost of Sorghum Production[1]	Ethanol Yield[2]	Feedstock Cost	Total Cost of Ethanol from Sorghum*
(dollars/acre)	(gallons/acre)	(dollars/gallon)	(dollars/gallon)
$1,620	600	$2.70	$3.31
$1,620	500	$3.24	$3.65

[1] (Helsel and Alvarez, 2011)

[2] (Vermerris, et al., 2007)

*The cost of sweet sorghum conversion to ethanol was estimated at $0.61 per gallon (Frosh, et al., 2008).

Switchgrass

Experience with switchgrass as a biofuel crop goes back more than two decades. It is a crop that is grown in several parts of the United States and used for conversion to electricity by direct combustion. Switchgrass can also be converted to ethanol through cellulosic technology, however, this technology is still in experimental stages, and has not been implemented at commercial scale. This report considers only conversion of switchgrass to electricity by combustion.

Experience in Florida growing switchgrass is limited (Newman et al., 2011). The yield potential in Florida is estimated at 2 to 4 tons per acre. While the crop has potential as a biofuel crop in Florida, it has significant production challenges. Rust can be a serious problem with switchgrass in southern Florida during the wet, humid season. Moisture content and field drying conditions for this crop in Florida is another challenge.

Presently, there is no cost estimate for growing switchgrass in Florida. The total production cost of switchgrass in Iowa is estimated at $236 per acre, with a yield of 4 tons per acre (Duffy and Nanhou, 2002). A recent revised study estimated the total cost of switchgrass production including land rent at $50 per ton with energy content of 7,500 BTUs per pound (Burden, 2011). An earlier study in Iowa estimated production cost of $82.23 per ton of switchgrass. Adding other costs such as storage and transportation, the total cost was estimated at $113.66 per ton (Duffy, 2007, 2008). The results of a 5-year study of switchgrass production in Nebraska showed annualized switchgrass yields throughout a 5 year rotation between 3.8 to 6.0 Mg per hectare (1.69 to 2.68 tons per acre), and annualized cost of production of $59.95 to $88.25 per Mg dry matter ($54.5 to $80 per ton) (Perria at al., 2008). Table 4 shows cost of switchgrass production, its heating value for electricity production, and the cost of switchgrass feedstock for producing electricity. Note that this electricity cost estimates is based on results of studies in other states. Costs may be higher or lower in Florida. It is also assumed that the cost is on a dry-weight basis (oven dried).

Table 4. Switchgrass cost of production, heating value, conversion ratio, and cost of electricity.

Cost of Switchgrass Production (dollars/ton)	Gross Heating value[3] (Btu/ton)	Efficiency[3]	Net Heating value (Btu/ton)	kWh equivalent (3,413 Btu = 1 kWh)	Cost of Switchgrass feedstock for 1 kWh of electricity (dollars/kWh)	Cost of 1 kWh electricity production (including conversion costs)[4]
$113.66[1]	15,500,000	80%	12,400,000	3,633	$0.0313	$0.0773 to $0.0853
$111.65[2]	15,500,000	80%	12,400,000	3,633	$0.0307	$0.0767 to $0.0847

[1]Source: Duffy (2007, 2008); includes transportation and storage costs.

[2]Source: Perria et al. (2008); transportation and storage costs added to the production estimates of $80 per ton.

[3] TechLine, Fuel Value Calculator, Forest Products Laboratory, USDA, 2004

[4] Cost of woody material conversion to electricity is based on a 50 MW plant capital cost and yearly operating costs of $.46 to $.54 per kWh (Rahmani and Hodges, 2008).

Economic Analysis

It is assumed that any potential biofuel crop competitive for south Florida would be produced on idle or available lands other than the lands presently producing sugarcane, because of the high opportunity cost of replacing sugarcane, i.e. the foregone earnings of replacing sugarcane for sugar with ethanol production. There are many reasons why replacing sugarcane is not a viable and economically feasible option. With the high price of sugar in the world market (more than 27 cents per pound by mid August 2011, www.bloomberg.com) there is no biofuel crop (sweet sorghum or switchgrass) that can compete with sugarcane on either muck or sandy soils in South Florida. Sugarcane to sugar in south Florida is an established industry with production of more than 1.54 million tons of sugar in 2009 (Roka et al., 2009). To destroy an industry that has been in the area for many decades and idle all sugar plants as well as all the equipment, manpower, and expertise that were developed throughout the past many years, there needs to be much more deliberation.

For biofuel crops to become a reality there must be enough marginal lands available to provide low cost feedstocks for a 50 million gallon per year ethanol plant or a 50 MW electricity plant in the area as the minimum economic capacity. Also, because of high AGFAX.COM. Florida: Cotton and Peanut Acres Near 2010, Sugarcane up, August 12, 2011.

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Duffy, Michael D., and Virginie Nanhou. Cost of Producing Switchgrass for Biomass transportation costs for bulky feedstock materials for conversion to ethanol or electricity, construction of the conversion facilities should be in the area close to crop production fields. To provide enough sugarcane or sweet sorghum feedstock for a 50 million gallon per year ethanol plant, there should be nearly 100,000 acres devoted to the production of these crops every year, based on an average yield of 500 gallons of ethanol per acre per year. To keep a 50 MW electric power plant running for 1 year, the power plant needs enough feedstock to generate 438,000 of megawatt hours (50 MW). One ton of switchgrass can produce 3,633 kWh and one acre of switchgrass can produce 3 tons dry matter, therefore one acre of switchgrass can provide feedstock to generate nearly 10,000 kWh. So, there need to be 45,000 to 50,000 acres of switchgrass to provide enough feedstock for a 50 MW power plant. In addition to allocating nearly 150,000 acres of land for the proposed biofuel industry in South Florida, the availability and extent of funding to invest in construction of a biomass to ethanol conversion plant and a biomass to electricity conversion plant in South Florida will definitely be a challenging task.

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Plan for Next Quarter

The continued development of the Implan economic information for Hendry County and related LCA/economic components associated with other Tasks above will be enhanced with full staffing that took place in Q4. This Task will be advanced, especially with the involvement of the Framing and Community Involvement Committee.

6TH QUARTER

Achievements

Please see Task 7.0 Cost-Benefit Analysis.

Plan for Next Quarter

The continued development of the Implan economic information for Hendry County and related LCA/economic components associated with other Tasks above shall continue.

7TH QUARTER

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Plan for Next Quarter

The continued development of the Implan economic information for Hendry County and related LCA/economic components associated with other Tasks above shall continue.

8TH QUARTER

Achievements

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Plan for Next Quarter

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9TH QUARTER

Achievements

Please see Task 7.0 Cost-Benefit Analysis.

Plan for Next Quarter

The continued development of the Implan economic information for Hendry County and related LCA/economic components associated with other Tasks above shall continue.

6. IDENTIFY PRODUCTS DEVELOPED UNDER THE AWARD AND TECHNOLOGY TRANSFER ACTIVITIES, SUCH AS:

a. Publications (list journal name, volume, issue), conference papers, or other public releases of results. If not provided previously, attach or send copies of any public releases to the DOE Project Officer identified in Block 11 of the Notice of Financial Assistance Award;

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Cost of Switchgrass Production (dollars/ton)	Gross Heating value[3] (Btu/ton)	Efficiency[3]	Net Heating value (Btu/ton)	kWh equivalent (3,413 Btu = 1 kWh)	Cost of Switchgrass feedstock for 1 kWh of electricity (dollars/kWh)	Cost of 1 kWh electricity production (including conversion costs)[4]
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[1]Source: Duffy (2007, 2008); includes transportation and storage costs.

[2]Source: Perria et al. (2008); transportation and storage costs added to the production estimates of $80 per ton.

[3] TechLine, Fuel Value Calculator, Forest Products Laboratory, USDA, 2004

[4] Cost of woody material conversion to electricity is based on a 50 MW plant capital cost and yearly operating costs of $.46 to $.54 per kWh (Rahmani and Hodges, 2008).

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6TH QUARTER

Achievements

Please see Task 7.0 Cost-Benefit Analysis.

Plan for Next Quarter

The continued development of the Implan economic information for Hendry County and related LCA/economic components associated with other Tasks above shall continue.

7TH QUARTER

Please see Task 7.0 Cost-Benefit Analysis.

Plan for Next Quarter

The continued development of the Implan economic information for Hendry County and related LCA/economic components associated with other Tasks above shall continue.

8TH QUARTER

Achievements

Please see Task 7.0 Cost-Benefit Analysis.

Plan for Next Quarter

The continued development of the Implan economic information for Hendry County and related LCA/economic components associated with other Tasks above shall continue.

9TH QUARTER

Achievements

Please see Task 7.0 Cost-Benefit Analysis.

Plan for Next Quarter

The continued development of the Implan economic information for Hendry County and related LCA/economic components associated with other Tasks above shall continue.

6. IDENTIFY PRODUCTS DEVELOPED UNDER THE AWARD AND TECHNOLOGY TRANSFER ACTIVITIES, SUCH AS:

a. Publications (list journal name, volume, issue), conference papers, or other public releases of results. If not provided previously, attach or send copies of any public releases to the DOE Project Officer identified in Block 11 of the Notice of Financial Assistance Award;

Amponsah, N.Y. 2010. An Emergy Approach to Evaluate Impacts of Soil Subsidence on Biofuels Production Sustainability in South Florida. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/SWCposter_Nana_120827.pdf.

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Borisova, T. 2009. Experiences with Trading Water Quality Credits. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/hcsbc_pres_0009.pdf.

Burleson, S.E., E.D. Rubenstein, A.C. Thoron, and E.A. Hanlon. 2012. The Development of an Educational Continuum to Meet Agricultural Workforce Needs. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/poster_Biofuels_Ed_Continuum_Poster.pdf.

Capece, J.C., and E.A. Hanlon. 2011. A Systems Analysis Approach to Ecosystems Services and Sustainable Farming Practices Development. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/hcsbc_pres_0001.pdf.

Hodges, A.W., and M. Rahmani. 2012. Regional Economic Impact Analysis of Biofuel Production in South-Central. m: 1–7. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/bib_121212.pdf

CRCA. Caloosahatchee River Citizens Association. 2011. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/poster_crca_100104.pdf.

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Hanlon, E.A., and J.C. Capece. 2011. A New Farming Systems Development Initiative. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/hcsbc_pres_0000.pdf.

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Jennewein, S., R.A. Gilbert, A.L. Wright, and B. Glaz. 2011. Effect of Water Table Management on Biofuel Species Growth. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/hcsbc_pres_0007.pdf.

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Rubenstein, E.D., and A.C. Thoron. 2012. The Creation of a Biofuels and Sustainable Agriculture Post-Secondary Curriculum- A True-Delphi Study.

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Southwestern Datastream Inc. 2009. Estimating the Value of Ecosystem Services from Government Project Costs. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/hcsbc_pres_0008.pdf.

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Thoron, A.C., and E.A. Hanlon. 2013. UF Curriculum. 73–74. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/UF Curriculum Outline.pdf.

Thoron, A.C., E.D. Rubenstein, and S.E. Burleson. 2013a. Delphi Panel Results- Post Secondary Level. Available at: http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/Post-Secondary%20Delphi%20Results_27Feb13.pdf

Thoron, A.C., E.D. Rubenstein, and S.E. Burleson. 2013b. Edison State College Course Development. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/Edison State College Course Development_27Feb13.pdf.

Thoron, A.C., E.D. Rubenstein, and S.E. Burleson. 2013c. Delphi Panel Results - Secondary Level. 28–30. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/Secondary Biofuels Results_27Feb13.pdf.

Tropical Research and Education Center (TREC). 2011. Water Quality Regulations And Policy Development. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/hcsbc_pres_0017.pdf.

Hendry County Sustainable Biofuels Center Public Private Partnership. 2009. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/hcsbc_pres_0012.pdf.

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Williams, D.L., and A.E. Dollisso. 1998. Rationale For Research On Including Sustainable Agriculture In The High School Agricultural Education Curriculum. Journal of Agricultural Education 39(3): 51–56Available at http://www.jae-online.org/back-issues/51-volume-39-number-3-1998/499-rationale-for-research-on-including-sustainavle-agriculture-in-the-high-school-agricultural-education-curriculum-.html (verified 26 February 2013).

6b. Web site or other Internet sites that reflect the results of this project;

http://swfrec.ifas.ufl.edu/soil_water/biofuels/hcsbc/default.aspx

c. Networks or collaborations fostered;

Hanlon, E.A., N.Y. Amponsah, J.L. Izursa, and J.C. Capece. 2013. Energy Valuation Methods for Biofuels in South Florida : Introduction to Life Cycle Assessment and Emergy. : 1–5. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/IntroLCA_Emergy_EDIS_2Mar13.pdf.

Hanlon, E.A., and J. Capece. 2010. Overview of Hendry County Sustainable Biofuels Center: ARRA, 6 Jan 10, 30 participants

Hanlon, E.A., and J. Capece. 2010. Innovative Water Management and Valuation of Eco-services. Hendry County Sustainable Biofuels Center. Cooperative Conservation Blueprint, Pilot Project Advisory Group, Okeechobee, 15Nov10. 12 participants, Polycom with DACS/DEP/FFWC.

Hanlon, E.A. 2009. Farming in the Future – Reaping Ecosystem Services. SWFREC. Co-organizer with Dr. F. Roka. Six other speakers. 107 participants.

Hanlon, E.A. 2010. Transforming Agricultural Water Management in Support of Ecosystem Restoration. American Water Resources Association. Ft. Myers, FL. 20Nov09. 97 participants.

Hanlon, E.A., and J. Capece. 2010. Future Farms & Fuel/Hendry County Sustainable Biofuels Center. Collier County Rotary Club. Naples, FL. 10Feb10. 23 participants. *Invited* by County Commissioner Coletta.

Hanlon, E.A., and J. Capece. 2010. Transforming Agricultural Systems on Public Lands within the EAA to Support Everglades Restoration. Everglades Coalition, West Palm Beach, FL. Jan10. Poster. ~300 participants.

Hanlon, E. A., J. Capece, A. Hodges, L. Racevskis, T. Borisova, and J. Owens. 2010. Hendry County Sustainable Biofuels Center. Everglades Coalition, West Palm Beach, FL. Jan10. Poster. ~300 participants (see poster above).

Hanlon, E.A., and J. Capece. 2010. A New Farming Systems Development Initiative. Everglades Coalition, West Palm Beach, FL. Jan10. Presentation. Co-organizer of Break-out Session with 4 other speakers. 43 participants.

Hanlon, E.A., and J. Capece. 2010. New Farming Systems Initiative: Humans and the Environment. Presentation to Environmental undergraduate course, FGCU. Instructor: Dr. M.K. Cassani. 19 students.

Hanlon, E.A., and J. Capece. 2010. Hendry County Sustainable Biofuels Center New Farming Systems Initiative: Humans and the Environment. Lee County Extension Faculty, Ft. Myers, FL. 6 participants.

Hazel, J. 2012. Community Involvement Committee Visioning Report. Available at http://swfrec.ifas.ufl.edu/docs/pdf/soils/biofuels/CIC VisioningSummaryRpt_Apr12.pdf.

Gomes, E., J. Capece, and E.A. Hanlon. 2010. New Sugarcane Farming Systems to Protect Florida Estuaries. Poster. Intern from Brazil. 20 participants at seminar.

These presentations reached a considerable number (as indicated on each citation) of clients receiving information concerning selected aspects of biofuels, agriculturally-based ecosystem services, and alternative farming practices, including developing markets for these services.

Hanlon, E.A. 2011. Setting boundaries for biofuels development in Southwest Florida: The Stakeholder Framing Committee Concept. Natural Resource Committee of the Southwest Florida Watershed Council. 7 participants.

Hanlon, E.A. 2011. The Stakeholder Framing Committee Concept. Southwest Florida Resource Conservation and Development Committee. 15 participants.

Hanlon, E.A., and J. Capece. 2011. Mutual Interests of the Everglades Foundation and the Hendry County Sustainable Biofuels Center. 6 Participants.

Gene McAvoy:

An article by local writer Cathy Chestnut, *Reinventing Life in SW Florida - Cleaner Caloosahatchee*, was published in the WGCU Public Media Expressions Magazine (pg 9). CoPI Gene McAvoy explained the concept of ecosystem services and agriculture, which is one of the components of this grant. Readership in Southwest Florida exceeds 30,000.

One presentation to the LaBelle Rotary Club (25 participants) about agriculture in general and our project in particular and how it could be a win-win for growers and the environment

Presentations to six busloads of participants in the Big O Bird Festival, Clewiston (approximately 200 participants) explaining alternative farming systems concepts and agriculturally based ecosystem services

A presentation to the Hendry-Glades Youth Leadership class of 2011.

Hanlon, E.A., E.J. McAvoy, and L. Baucum. 2011. Overview of Hendry County Sustainable Biofuels Center. in Biofuels Extension Specialists and County Faculty Meeting: Southern Florida. 27 participants. Gene McAvoy and Les Baucum also gave overviews of their work with biofuels in Hendry County in addition to explaining their involvement in this grant.

McAvoy, E.J. Florida Gulf Coast University Undergraduate Colloquium. Instructor: Dr. N. Demers. Bus tour: 1.5 hr. Biofuels and southwest Florida agriculture related to environmental services as a part of biofuels production. 20 students.

McAvoy, E.J. LaBelle Rotary Club on IFAS Extension Activities including bio-fuel. 19 participants.

Presentations addressing selected aspects of biofuels and this grant were made to:
LaBelle Rotary, 27 participants

Hendry Co Administrator Dept. Directors Meeting, 18 participants Lehigh Leadership Group, 9 participants

Labelle Business Networking Breakfast, 15 participants

Florida Gulf Coast University Interdisciplinary Studies Class, 21 participants and

Florida Energy Summit (attended/participated) – 10/26-28/2011 – 500 participants

<u>Les Baucum:</u>

- Discussed agricultural/environmental interactions as well as current and future best management practices and water quality issues in Lake Okeechobee, the Everglades Agricultural Area, the Everglades and the Caloosahatchee at the National Association of County Agricultural Agents SARE Fellows Tour – 4/14/2011 – 20 participants
- Led a group of County Agents from around the country (touring with the SARE Fellows group) on a tour of the south Florida sugarcane industry. Discussions centered on current and future sustainability issues, including water quality and quantity issues and ecosystem service opportunities.
- Best Management Training – Everglades Research and Education Center – 4/28/2011 – 88 participants
- Led discussion on water quality best management current and future practices including ecosystem restoration and ecosystem service opportunities.
- Okaloacoochee Slough Land Management Review – 5/4,5/2011 – 10 participants, made up of FCS, Forest service and members of private ecological groups.
- Discussed land management options as they relate to water quality and quantity issues and possible relationships with state land forests and land management areas.
- AGR6932 – UF Graduate Student summer course on agricultural sustainability issues in Florida (Bennett and Hochmuth) – 5/18,19/2011 - 11 participants.
- Setup tour of south Florida agricultural and ecosystem for group and led discussion on sustainability and ecosystem issues, including ecosystem service opportunities.
- West Side Elementary, 4th Grade Field Day – 5/26/2011 – 49 participants
- Organized and led three 4th grade classes from Westside Elementary School on a field day outlining south Florida's ecosystem/agricultural interrelationship and discussed water quality and water quantity issues and soil/fertility issues. Assisted classes in collecting samples and discussed sample results.

- ➢ Sugarcane Sand Land Variety Field Day – 5/31/2011 – 42 participants
- ➢ Discussed potential new sugarcane varieties including discussions on selection criteria that have aided in growing sugarcane under higher water tables than in the past.
- ➢ SFWMD – C139 Basin Growers Meeting – 6/28/2011 – 18 participants
- ➢ Participated in meeting between SFWMD and C139 Basin Growers; discussions included successfully meeting water quality standards, P baseline calculations, water control structures within the C139 Basin, water flow and past SFWMD reports.

Florida Energy Summit (attended/participated) – 10/26-28/2011 – 500 participants. A great venue to meet others working in this subject area. I talked to several different groups.

UF Graduate Student (With Gene) – 10/25/2011 - 6 participants. Setup tour of south Florida agricultural and ecosystem for group and led discussion on sustainability and ecosystem issues, including ecosystem service opportunities.

North Florida Sugarcane Field Day – 11/7/2011 – 79 participants. Discussed agronomic requirements for sugarcane and energy cane in Florida.

Onion Growers Tour – 12/1/2011 – 82 participants. Discussed south Florida agriculture and ecosystem as well as potential for ethanol production and water storage challenges.

Hendry County Farm City Tour – 12/3/2011 – 100 participants. Discussed south Florida agriculture and ecosystem as well as Hendry County's possible role in ethanol production.

Palm Beach County Science Fair – 12/7/2011 – 400 participants. Discussed/mentored students working on agricultural or water based projects.

Discussed south Florida agriculture and ecosystem as well as Hendry County's possible role in ethanol production in the Everglades Agriculture Area tour for farming flyers.

On 2/4/2012 organized Hendry County Farm City Tour, which included 100 participants.

At South Florida Ag Expo, held on 2/17/2012 had with attendees, Les and Gene McAvoy held a Feedstock/Ethanol based Learning Sessions. The Expo was a great venue to meet different parties and collaborate about projects; which was discussed with several different groups.

On 2/21/2012 met with Jessica Cattelino (UCLA) to deliberate on setting up a tour of south Florida agricultural and ecosystem for group. He also led a discussion on sustainability and ecosystem issues, including ecosystem service opportunities.

Attended Biofuels Community Involvement Meeting was held on 3/5/2012 and had 40 partakers.

Twenty-two participants attended Leadership Glades; Environment & water Management meeting on 3/21/2012, where issues, related to South Florida agriculture and ecosystem as well as potential for ethanol production and water storage challenges, were discussed.

At FFVA Spring Regulatory Tour, on 3/21/2012 (34 participants), agricultural or water based projects were discussed.

<u>J. Capece, Intelligentsia, Intl.</u>

Presentation on sustainability considerations for biofuels industry to Hendry Glades Leadership Course, 16Nov11, 25 participants. The Leadership Course is an 8-month regional issues orientation program. The lecture focused on water issues of the Caloosahatchee Basin. As part of the presentation, Dr. Capece explained many of the basic issues being considered by the sustainable biofuels project and its relationship to regional water management.

d. Technologies/Techniques;

Nana Amponsah participated in series of Life Cycle Analysis (LCA) 'GaBi' software training and modeling sessions. This training resulted in an almost complete LCA model for Mineral soil sugarcane farming system in 'GaBi'.

Processed data for the emergy calculations for sugarcane, energycane, and sweet sorghum.

e. Inventions/Patent Applications, licensing agreements; and

f. Other products, such as data or databases, physical collections, audio or video, software or netware, models, educational aid or curricula, instruments or equipment.

7. For projects involving computer modeling, provide the following information with the final report: N/A

a. Model description, key assumptions, version, source and intended use;

b. Performance criteria for the model related to the intended use;

c. Test results to demonstrate the model performance criteria were met (e.g., code verification/validation, sensitivity analysis, history matching with lab or field data, as appropriate);

d. Theory behind the model, expressed in non-mathematical terms;

e. Mathematics to be used, including formulas and calculation methods;

f. Whether or not the theory and mathematical algorithms were peer reviewed, and, if so, include a summary of theoretical strengths and weaknesses;

g. Hardware requirements; and

h. Documentation (e.g., user's guide, model code).

8. Ensure the report does not contain any Protected PII. Protected PII is defined as an individual's first name or first initial and last name in combination with any one or more of types of information, including, but not limited to, social security number, passport number, credit card numbers, clearances, bank numbers, biometrics, date and place of birth, mother's maiden name, criminal, medical and financial records, educational transcripts, etc.