Final Technical Report

FCEB Project #19

Assessing Land Intensification and Grazing Impacts on Soil Greenhouse Gas Fluxes in Florida Subtropical Grasslands

Project Director: Jiangxiao Qiu, Associate Professor, University of Florida
Sponsoring Agency: Florida Cattle Enhancement Board
Award ID: AWD15777
Project ID: P0324507
Project Duration: 30 Oct 2023 – 31 Jul 2024
Date of Final Report: 15 August 2024

FINAL REPORT

1. Project Overview

Grasslands (e.g., pastures and grazing lands) occupy ~70% of agricultural production area and are the most dominant agroecosystems that support a wide array of ecosystem services. Besides forage and livestock production, one other important ecosystem service from grasslands is greenhouse gas (GHG) regulation – defined as the capacity to regulate and prevent emission and foster update of GHGs. Yet the extent to which grasslands can regulate GHG can also be affected by changing climate and grassland management practices, which remain less well understood. Yet such information and knowledge can be critically important for informing sustainable management practices in grasslands for environmental stewardship, ranch livelihoods, and rural prosperity. In this project sponsored by the Florida Cattle Enhancement Board and leveraged by an existing long-term experimental infrastructure at the Buck Island Ranch in central Florida, USA, we aim to address two research objectives: (1) Determine how land intensification and alternative grazing regimes interact to affect three soil GHG fluxes (CO_2, CH_4 and N_2O); and (2) Investigate the underlying mechanisms on these responses through linking aboveground and belowground biotic and abiotic trait measurements. Our research findings have been presented to different stakeholder groups, including ranchers, producers, tribal communities, general public, and state and federal agencies, and are disseminated through a range of outreach and extension avenues, including field days, educational tours, extension workshops, media coverage, and outreach and extension publications. All these efforts contribute to informing best management practices (BMPs) to increase agricultural productivity while improving GHG mitigation and climate adaptation in Florida subtropical grasslands. Our project contributes directly to several program area priorities of Florida Cattleman's Association, including *Ecosystem Services of Grazing lands* (e.g., GHG mitigation, BMP programs, economic valuation of ecosystem services), *Pasture and Forage Management* (e.g., optimizing management, systems approach), and *Societal Benefits of Ranching* (e.g., promote land stewardship).

2. Project Accomplishments

Since the start of the project, we have successfully maintained functionality of our experimental field infrastructure with full treatment of grassland intensification (i.e., improved vs. semi-native pastures) and cattle grazing intensity (i.e., low vs. high). We have constructed closed chamber systems with installed collars and soil moisture and temperature sensors for gas sampling, and developed detailed protocols for synchronized field sampling where soil gas fluxes were collected at the same window of time (i.e., 9-11 am) (**Fig. 1**). Monthly *in situ* soil GHG flux measurements have been performed from October 2023 to August 2024. For each sampling

event, a total of eight staffs and students have participated so that all gas samples were taken at the same time in synchrony, which allows for the GHG measurements to be comparable. Implementing such synchronized sampling scheme is challenging but fundamental to our research goals due to high intra-daily variability in soil GHG fluxes. Although extremely labor intensive, this scheme can also ensure that our results are valid and have sufficient statistical power and lowest measurement error to detect treatment effects.

All gas samples (i.e., a total of 320 gases from each sampling event) from field collection were brought to the lab and run through gas chromatography to determine concentration and thus flux rate of three GHG (including CO_2, CH_4 and N_2O). Besides GHG flux measurements, we have also completed post-treatment measurements for above-belowground responses across all plots in both dry and wet seasons. This includes plant community, forage productivity and quality, plant diversity, soil nutrients, and biophysical characteristics (e.g., soil compactness, pH, soil moisture, temperature). Dominant plant species have been also collected for measuring plant functional traits. Soil samples were also collected for microbial functions (e.g., microbial growth, N denitrification and net N nitrification). Certain measurements (soil moisture) were monitored continuously using soil sensors. Below we highlight major findings on responses thus far, with 2 manuscripts that are completed for submission to scientific journals (see *Product* section below).

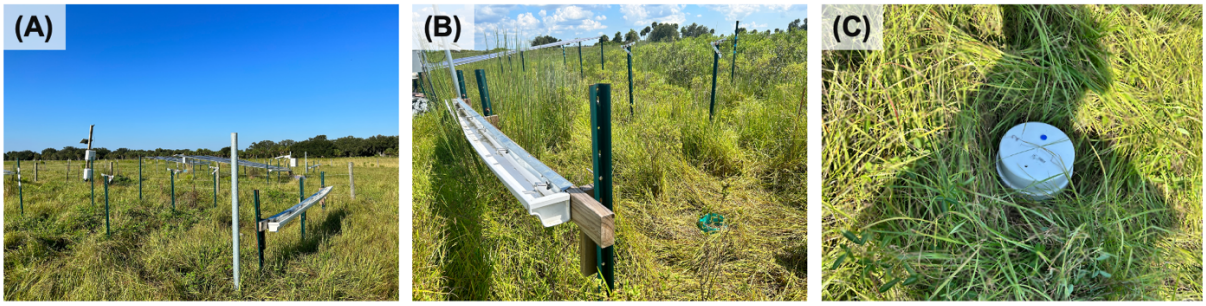


Fig. 1 (A) Setup of the experimental plots at the Buck Island Ranch, where our greenhouse gas (GHG) measurements were taken. **(B)** Close-up view of the soil collar (*green color*) that were inserted into the ground for measuring GHG fluxes. **(C)** Close-up view of closed chamber (white color cap, sitting on top of the soil collar) during the sampling event, where gas samples were taken every 15 mins using specialized syringe and needle through the blue-colored seal on top of the cap.

(1) Soil GHG flux. Preliminary analyses showed that, consistently for each month, land management showed as the most significant factor influencing CO_2 fluxes (all $P<0.001$) (**Fig. 2**), where greater CO_2 flux rates were found in improved than semi-native pastures. *However, it is important to note that these flux measurements are monthly soil gas fluxes, where CO_2 uptake by vegetation and plant growth has not been accounted for due to the nature of how static chamber operates and the high temporal frequency of sampling*

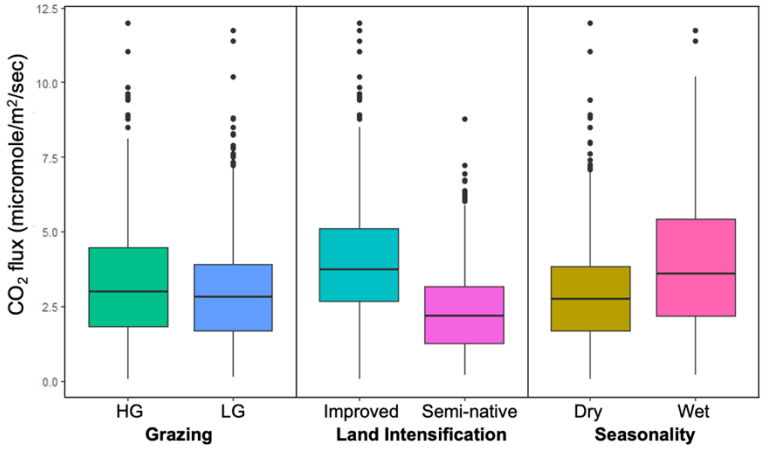


Fig. 2. Responses of soil CO_2 fluxes to land intensification and grazing intensity treatments (*HG* – high grazing; *LG* – low grazing) and variations between dry and wet seasons.

scheme. It is very likely that increased CO_2 uptake in improved pastures due to their greater forage productivity (as shown by our data below) could offset the amount of soil CO_2 fluxes, which could ultimately shift annual carbon balance and strength of sink capacity of improved pastures that warrants future investigations. Grazing intensity, on the other hand, did not show significant individual effects on soil CO_2 fluxes (**Fig. 3**). These results suggest that at least for the duration of our sampling, high-intensity grazing practice did not lead to significant differences in soil CO_2 fluxes as compared to low-intensity grazing practice. Nevertheless, for certain month (e.g., December 2023), we also found moderate evidence of interactive effects between land intensification (i.e., pasture type) and grazing intensity (i.e. $P = 0.06$).

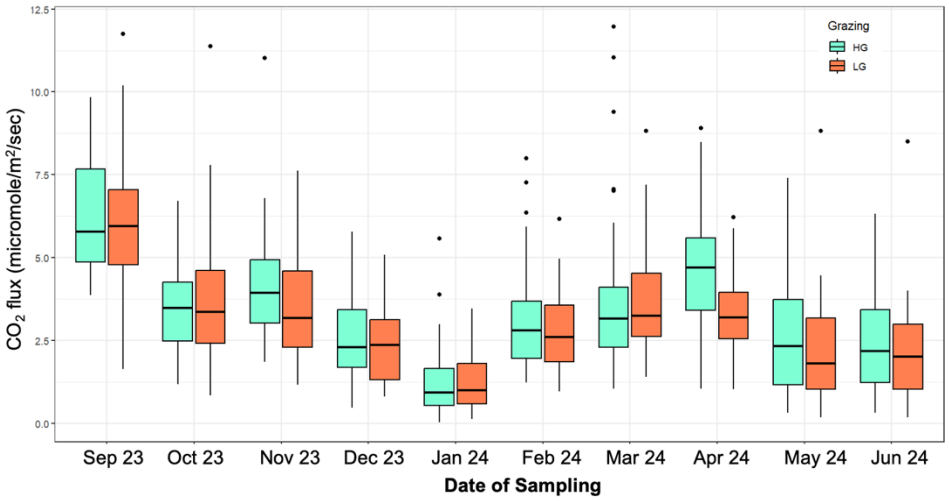


Fig. 3. Monthly responses of soil CO_2 flux to grazing intensity treatments (*HG* – high grazing; *LG* – low grazing) over the project duration.

For soil CH_4 flux, given its process of anaerobic digestion of organic matter in the absence of O_2, it can only be produced and thus detected under certain field conditions, rather than all year around. Hence, over our sampling period, consistent soil CH_4 fluxes have been detected for certain months of our project duration, and here we selected for months to report where soil CH_4 flux measurements were robust (**Fig. 4**). Overall, our results showed consistent significant effects of land intensification, where greater soil CH_4 flux rates were found in improved than semi-native pastures (all $P<0.001$). Grazing intensity effects were more variable, where our results showed no significant effects in October 2023, but significant effects in March 2024. *It is very important to note that the magnitude of soil CH_4 flux was much lower in March 2024 as compared to October 2023* (**Fig. 4**). In other words, for the months where grazing intensity has indeed exerted significant impacts, the differences in soil CH_4 flux due to grazing practices were likely to be minimal. All these results alluded that over a long period, grazing intensity practices may not significantly alter soil CH_4 fluxes. *However, it is key to acknowledge that these CH_4 flux measurements were soil fluxes and thus did not include the direct digestion effects of livestock on CH_4 production, which could be another important component in the CH_4 budget.*

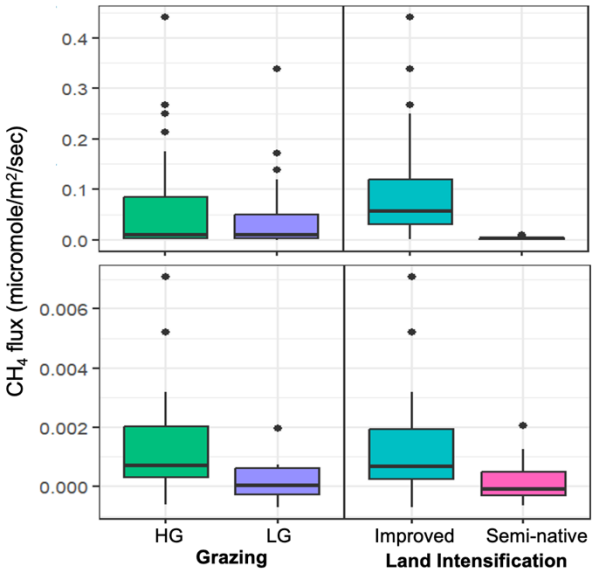


Fig. 4. Monthly responses of soil CH_4 flux in Oct 2023 (upper panel) and Mar 2024 (lower panel) to land intensification and grazing intensity treatments (*HG* – high grazing; *LG* – low grazing).

For soil N_2O fluxes, no substantial fluxes were measured so far, suggesting that N_2O production from these pasture systems is likely to be minimal. Such results could be due to the overall low fertility and nitrogen content of these subtropical grassland soils.

(2) Plant and soil nutrient stocks. Plant and soil nutrient stocks is a key set of biophysical traits altering soil GHG fluxes. Our results showed that land intensification (i.e., pasture type) exerted significant individual or interactive effects on stocks of C, N, and P in aboveground plant biomass, 0-5 cm soil, and 5-15 cm soil. Specifically: (1) Improved pastures led to greater C, N, and P stocks in aboveground plant biomass, 5-15 cm soil layer, and combined all three pools, while only increasing P stocks in 0-5 cm soil. However, high-intensity grazing resulted in lower N and P stocks in aboveground plant biomass compared to low-intensity grazing. (2) Stocks of C, N, and P in aboveground plant biomass were positively affected by soil pH and organic matter (OM) content. While stocks of C and nutrients in the two soil layers were positively influenced by soil moisture and OM content, the magnitudes of effects of soil pH on soil C and nutrient stocks varied across elements. (3) Land intensification (i.e., pasture type) altered sensitivity of C and nutrient stocks to edaphic properties. In aboveground plant biomass, sensitivity of C and nutrient stocks to soil pH and OM content was higher in improved than semi-native pastures, and similar patterns were observed in 5-15 cm soil. Yet in 0-5 cm soil, semi-native pastures exhibited greater sensitivity of C, N, and P stocks to soil moisture and OM content compared to improved pastures. (4) Higher values of dissolved organic carbon (DOC), total dissolved nitrogen (TDN), exchangeable Ca and Mg, free Fe oxides, and organically complexed Fe and Al contents were observed in improved than in semi-native pastures.

(3) Plant productivity, composition, and forage quality. Vegetation responses are also associated with soil GHG fluxes that are significantly influenced by our treatment. Specifically, semi-native pastures had significantly lower aboveground net primary productivity (ANPP) than improved pastures ($P<0.001$), and there was moderately greater ANPP in treatments with low- than high-intensity grazing ($p=0.05$). In vitro organic matter digestibility (IVOMD) was significantly greater in improved than semi-native pastures ($p<0.001$). PERMANOVA analysis showed that land intensification (i.e., pasture type) was the only treatment affecting species composition ($p=0.01$). For plant species richness or Shannon diversity, our results showed that only land intensification showed significant effects. Dominant plant species functional traits measurements are still underway for determining community-weighted functional responses.

(4) Microbial response. Microbial responses and functions provide mechanistic understanding of how and why soil GHG fluxes respond to our treatment. Specifically, our results indicated that land intensification (i.e., pasture type) and grazing intensity exerted significant individual effects on soil microbial carbon metabolism. Specifically, improved pasture led to a 56.0% rise in microbial growth rate while high-intensity grazing resulted in a 23.5% reduction in microbial respiration rate. Our result did not show significant effects of land intensification and grazing on potential N denitrification and net N nitrification, likely due to the overall small pool of inorganic N in the soils. Hence, microbial carbon metabolism and associated drivers could play an important role in explaining the variations in soil GHG fluxes resulting from effects of land intensity and grazing practices.

3. Project Products

(1) Journal Articles. Overall, two scientific publications are derived from this project in collaborations with other project collaborators, with details provided below. Full drafts of these manuscripts are completed and have been shared with coauthors for input, which will be submitted within the next 1-2 months.

- Emmi, A.L., Martens-Habbena, W.M., Dugan, P., Boughton, E.H., Guo, Y., **Qiu, J.** Responses of soil greenhouse gas fluxes to land intensification and cattle grazing in Florida subtropical grasslands. Target journal: *Agriculture, Ecosystems, and Environment.*
- Guo, Y., Boughton, E.H., Bhadha, J.H., Silvia, M., **Qiu, J.** Soil chemical properties influencing mineral protection effects on soil organic carbon stabilization. Target journal: *Soil Biology and Biochemistry.*

Additional publication from this project to be submitted within six months:

- Guo, Y., Boughton, E.H., Bhadha, J.H., Martens-Habbena, W.M., **Qiu, J.** (In preparation) Effects of linked above-belowground traits on responses of soil greenhouse gas fluxes to land intensification and cattle grazing in subtropical grasslands. Target journal: *Global Change Biology.*

(2) Conference Papers and Presentations. We have also presented or are scheduled to present our results and data at professional conferences in collaborations with other project collaborators, with details shown below.

- Emmi, A.L., Martens-Habbena, W.M., Dugan, P., Boughton, E.H., Guo, Y., **Qiu, J.** Responses of greenhouse gas fluxes to altered precipitation, land intensification, and cattle grazing. *2024 Ecological Society of American Annual Meeting (Poster presentation), 5-8 August 2024, Long Beach, CA, USA*
- Cha, J.Y., Emmi, A.L., Guo, Y., Boughton, E.H., Martens-Habbena, W., **Qiu, J.** Microbial responses to altered precipitation, land management, and cattle grazing in a subtropical grassland. *2024 American Geophysical Union Fall Meeting (Oral presentation), 9-13 December 2024, Washington, D.C., USA*
- **Qiu, J.** Multifunctionality of spatially connected grassland-wetland mosaic in an era of global changes. *The 9th Landscape Sustainability Science Forum (Oral presentation)*, Nanjing, Jiangsu, China (Invited keynote speaker), *May 2024.*
- Gonzales, S., Emmi, A.L., **Qiu, J.** Influence of land management and grazing intensity on soil moisture and organic matter content. *Miami-Dade College Research Symposium (Poster presentation), Miami, August 2024.*
- Research intern seminar *(Oral presentation)*, "Investigating soil biogeochemistry and microbial dynamics as key factors in CO_2, N_2O, and CH_4 soil emissions from subtropical grazing ecosystems", Jackie Valiente, *14 December 2023.*
- Presentation at Archbold Research Symposium *(Oral presentation)*, "Do altered precipitation regimes interact with grazing intensity and pasture type to affect plant productivity and vegetation composition in subtropical humid grazing lands?", Boughton, E.H., Anderson, E., Landau, L., Li, H., Saha, A., Sonnier, G., **Qiu, J.,** *30 January 2024.*

(3) Data and Research Materials. Below is the list of major data and research materials derived from this project. Upon publication of our planned papers, we will make our data publicly available and deposit our data into public repository (e.g., LTAR, FCA, AmeriFlux) to foster Open Science and large-scale synthetic research.

- Monthly greenhouse gas field sampling and lab measurements (CO_2, CH_4, and N_2O)
- Dry season soil nutrient data (including total C, N, inorganic N, organic matter, pH, available P, etc.)
- Wet season soil nutrient data (including total C, N, inorganic N, organic matter, pH, available P, etc.)
- Soil microbial biomass, microbial growth and respiration rate measurements
- Soil potential N denitrification and N nitrification lab incubation measurements
- Dry season aboveground net primary productivity
- Wet season aboveground net primary productivity
- Forage quality data (including crude protein, phosphorus, and digestibility) in plant tissue
- Plant species composition, diversity, and functional traits of dominant species
- Grazing heights data collected for wet and dry season post planned grazing events
- Soil moisture and temperature data (continuous measurements at 15-min interval)
- Animal use days and grazing intensity data

4. Broader Impacts

(1) Student and postdoc training. With leveraged support from other resources and institutions, this project has provided valuable internship and career training opportunities for three undergraduate students (through University of Florida, Archbold Biological Station, and interns from Miami-Dade College), two graduate students, two research staffs, and one postdoc. By working on this research project, graduate and undergraduate students have built general skills (e.g., communication, team science, leadership) and research-based skillsets (e.g., experimental design, hypothesis formulation, data analysis, oral and poster presentation) that are vital for their future career. Undergraduate students who worked on this project have enriched their research experience, and have either admitted to their desired graduate schools, led to paths for inspired interests in research endeavors, or entered the industry that aligned with their career choice. Research staffs have accumulated vital field and laboratory skillsets (e.g., gas sampling, lab soil nutrients and gas analyses, microbial analyses, field logistics) that have advanced their career in other universities and organizations. In addition, the postdoc has gained important skills and experience in student mentoring, paper publication, and leading and coordinating large and complex research project, further preparing for the career in academia and research institutions.

(2) Outreach and Extension. Besides scientific products, findings from this project have been presented to a range of stakeholders (e.g., ranchers, land managers, extension agents, scientists, NGOs) who are working on grazing lands through social media platforms, newsletters, and field tours. Please find below the specific list of activities conducted over the duration of this project, with leveraged support and in collaborations with other project collaborators:

- 16 November 2023, Environmental Stewardship Field Day. This was a full day event with stakeholders from industry, state and federal agencies and ranchers to provide

information from research at Archbold's Buck Island Ranch. This project was a key part of the program.

- 30 November 2023, USDA LTAR Network tour. This is a science tour with USDA ARS scientists on the varied research projects at the Buck Island ranch, including this project on soil greenhouse gas fluxes in response to subtropical grassland management (20 head).
- 19 December 2023, Tour for Seminole Tribe Council members, featured this research project at the Buck Island Ranch (10 head).
- 24 January 2024, Tour for Biomemakers, featured this research project at the Buck Island Ranch (10 head).
- 29 January 2024, Tour for Australian Cattle Producers, featured this research project at the Buck Island Ranch (8 head).
- 5-6 February 2024, Tours for National Cattlemens Beef Association and TNC, Alltech, Australian Cattle tours, featured this research project at the Buck Island Ranch (8 head).
- 21 February 2024, Tour for group of German Farmers, featured this research project at the Buck Island Ranch (29 head)
- 13 March 2024, Tour for Florida Environmental Film Festival on sustainable ranching practices that are related to this project (18 head)
- 16 March 24, Tour for Florida International University agroecology students (10 head)
- 31 July 2024, Tour for University of Florida and Barry University (10 head)

5. Next Steps

Our next steps are to complete the submission of two planned manuscripts to peer-reviewed scientific journals, as well as finish the analyses, writing and submission of a third 'bonus' manuscript. We will continue to achieve all other deliverables beyond the funded project period. Specifically, after publication of scientific papers, we will then develop extension publications (e.g., EDIS – a public extension database) and organize in-service training for continuing to inform agricultural decisions, facilitating public discourse, and providing training to diverse audiences and extension agents. In addition, after the scientific papers are published online, we will work with reporters (e.g., communication and public relation specialist at University of Florida) to disseminate our findings to the general public (e.g., through press releases) and through interviews with the traditional media, as well as contribute to educational articles for the Florida Cattlemen's Magazine. Based on our past experience, all these additional outreach and extension products are most effective and efficient to be incorporated into BMPs and inform agricultural decision-making when the associated scientific data have been peer-reviewed and published so that all translated knowledge are data-driven and evidence-based.

Since many agroecological responses will take a long time to be detected, many agricultural management practices can have long-term consequences, and the initial upfront experimental cost is very high, we will seek for additional funding to continue to maintain the experimental infrastructures and treatments to better and mechanistically understand the long-term GHG dynamics to pasture type and grazing intensity in subtropical grasslands that remain much less well understood and under-represented in the literature. Our ultimate goal is to produce actionable science to foster grassland resilience and long-term sustainability.

UF | UNIVERSITY of FLORIDA

PLEASE REMIT TO:
UNIVERSITY OF FLORIDA BOARD OF TRUSTEES
Contracts & Grants
PO Box 931297
Atlanta, GA 31193-1297

SPONSOR:
FL CATTLE ENHANCEMENT BOARD
P.O. Box 421929
Kissimmee FL 34742-1929
United States

Invoice Date:	08/08/2024
Invoice Period:	03/01/2024 - 07/31/2024
Principal Investigator:	Qiu,Jiangxiao
Award Begin Date:	10/30/2023
Award End Date:	07/31/2024
UF FEIN:	59-6002052

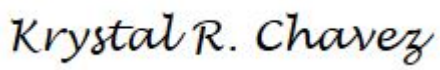
Sponsor Award ID:	19
Award Title:	Assessing Land Intensification and Grazing Impacts on Soil Greenhouse Gas Fluxes in Florida Subtropical Grasslands
Award Amount:	$50,020.00

Invoice #	I000130150
UF Award #	AWD15777
Primary Project #	P0324507
Primary Department:	60850000
Current Invoice Amount:	$18,446.51

Description	Current	Cumulative
Personnel - Salary	$12,052.76	$32,693.44
Personnel - Fringe Benefits	$1,623.79	$4,059.31
Materials and Supplies	$1,259.63	$2,801.30
Contractual Services	$1,268.00	$1,268.00
Other Expenses	$5.78	$248.59
Domestic Travel	$76.99	$3,406.94
Direct Cost	$16,286.95	$44,477.58
Facilities and Administrative Costs	$2,159.56	$5,542.42
Total	$18,446.51	$50,020.00

For billing questions, please call 352.392.1235
Chavez,Krystal R kchavez41@ufl.edu
Please reference the UF Award Number and Invoice Number in all correspondence

By signing this report, I certify to the best of my knowledge and belief that the report is true, complete, and accurate, and the expenditures, disbursements and cash receipts are for the purposes and objectives set forth in the terms and conditions of the federal award. I am aware that any false, fictitious, or fraudulent information, or the omission of any material fact, may subject me to criminal, civil, or administrative penalties for fraud, false statements, false claims or otherwise. (U.S Code Title 18, Section 1001 and Title 31, Sections 3729-3730 and 3801-3812).



Certifying Official

Payment History	
Cumulative Invoices:	$50,020.00
Payments Received:	$31,573.49
Outstanding Balance:	$18,446.51
Note: Outstanding balance includes current invoice amount	

FOR UF USE ONLY Additional Projects: N

Project ID	Deptid	Department Name	Current	Cumulative
P0324507	60850000	AG-FLREC-FT LAUDERDALE	$18,446.51	$50,020.00