CRITICAL INFRASTRUCTURE AND LAND USE CLIMATE VULNERABILITY ANALYSIS

TASK 3 – AGRICULTURAL RISK ASSESSMENT REPORT

Alachua County | October 2023

CRITICAL INFRASTRUCTURE AND
LAND USE CLIMATE VULNERABILITY ANALYSIS

TASK 3 – AGRICULTURAL RISK ASSESSMENT REPORT

Prepared for:

Alachua County

Environmental Protection

408 W University Avenue

Gainesville, Florida 32601

Prepared by:

Agsilico LLC

184 Tropical Ave

West Palm Beach, FL 33415

and

Jones Edmunds & Associates, Inc.

730 NE Waldo Road

Gainesville, Florida 32641

Jones Edmunds Project No.: 01560-157-01

October 2023

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

ac	Acre
bu	Bushel
cm	Centimeter
CMIP6	Coupled Model Intercomparison Project 6
CO_2	Carbon Dioxide
°C	Degrees Celsius
DSSAT	Decision Support System for Agrotechnology Transfer
DUL	Drained Upper Limit
ET	Evapotranspiration
FDACS	Florida Department of Agriculture and Consumer Services
g cm^{-3}	Grams per Cubic Centimeter
GFDL-ESM4	Geophysical Fluid Dynamics Laboratory Earth System Model
IPCC	Intergovernmental Panel on Climate Change
ISIMIP	Inter-Sectoral Impact Model Intercomparison Project
K	Potassium
kg ha^{-1}	Kilograms per Hectare
kg K ha^{-1}	Kilograms of Potassium per Hectare
kg N ha^{-1}	Kilograms of Nitrogen per Hectare
kg P ha^{-1}	Kilograms of Phosphorus per Hectare
lb N ac^{-1}	Pounds of N per Acre
LL	Lower Limit
mm	Millimeter
m^2	Square Meter
N	Nitrogen
NASS	National Agricultural Statistics Service
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
P	Phosphorus
ppm	Parts per Million
SAT	Saturation of Soil
SSP585	Shared Socioeconomic Pathway 5 to 8.5 W m^{-2}
UF IFAS	University of Florida Institute of Food and Agricultural Sciences
USDA	United States Department of Agriculture
W m^{-2}	Watts per Square Meter

EXECUTIVE SUMMARY

This assessment examines the agricultural impact of future climate change in Alachua County for four future climate scenarios (2026 to 2035, 2036 to 2045, 2066 to 2075, and 2091 to 2100) compared to a baseline climate scenario (2005 to 2014). The future climate projection was based on the SSP585 climate change scenario, which projects the highest radiative forcing (resulting in the highest CO_2 concentration and temperature) of the Shared Socioeconomic Pathway (SSP) scenarios. Three crop models were used to simulate a field (maize/corn), forage (bahiagrass), and vegetable (snap bean) crop in the County under four different management practices: 1) Rainfed (non-irrigated) and non-fertilized, 2) rainfed and well-fertilized, 3) well-irrigated and non-fertilized, and 4) well-irrigated and well-fertilized. Watermelon and blueberries are common crops in the county, however, suitable crop models for production of those crops were not available. Table ES-1 summarizes the future yield, irrigation, and nitrogen (N) uptake changes of each crop between the future climate scenarios and the baseline scenario. The detailed results of all management practices for each crop are described in the main text.

Overall, significant reductions in maize production, moderate reductions in snap bean production, and moderate increases in bahiagrass production are projected for the County by the end of the century under the SSP585 climate change scenario. Maize production in the County is projected to decline in each period simulated under the SSP585 climate change scenario when compared to the baseline scenario. These losses are driven by the combined interaction of heat and water deficit stress and the accelerated phenological development (growth) due to the warmer temperatures (i.e., reduced time from planting to harvest). The variable yield response in snap bean production is because the simulated growth benefits from the increased CO_2 fertilization effect (i.e., increased CO_2 promoting photosynthesis) in the near-term decades, but the warming temperatures will eventually mitigate these minimal gains by the end of century. Bahiagrass production is projected to increase in each period simulated because of the higher CO_2 fertilization effect and the resiliency of the perennial vegetative growth stages to heat and water deficit stress.

The irrigated treatments resulted in lower production losses (or higher production gains for bahiagrass) than the rainfed treatments for all three crops, indicating that irrigation will become increasingly imperative to mitigate the projected increase in future water deficit stress caused by changing rainfall patterns and increased temperatures. For maize, the projected decrease in nitrogen uptake is because the reduced growth limited nitrogen demand, indicating that higher amounts of nitrogen fertilization will not be needed to achieve the simulated future production. For snap bean, the increased nitrogen uptake suggests that increased nitrogen fertilization or improved nitrogen use efficiency of the crop will be necessary to achieve the simulated future production. For bahiagrass, increased irrigation and nitrogen fertilization could maximize production under higher CO_2 concentrations later in the century, but future production is projected to still increase under rainfed and non-fertilized management so additional management inputs may not be needed.

Overall, these results suggest that current maize and snap bean producers within the County may soon face fundamental challenges to maintain large and profitable production in a changing climate. Bahiagrass producers may not face these same production challenges;

however, bahiagrass is primarily used for forage instead of for human consumption because of its low nutritive value, and it is not as profitable as maize or snap bean. The strong projected decreasing trends in the major field and vegetable production within the County under SSP585 suggest the need for targeted agricultural production adaptation strategies and improved risk management in the coming decades. These strategies should aim to sustainably achieve the potential increased irrigation and fertilizer demand, which may be needed to maintain yields and to mitigate negative impact on groundwater and surface water quality in the County.

Table ES-1 Summary of Average Precent Change in Crop Production, Irrigation, and N Uptake Changes for the Future Climate Periods

	2026 to 2035			2036 to 2045			2066 to 2075			2091 to 2100		
	Percent Change			Percent Change			Percent Change			Percent Change		
Crop and Treatment	Yield	Irrigation	N Uptake	Yield	Irrigation	N Uptake	Yield	Irrigation	N Uptake	Yield	Irrigation	N Uptake
Maize Irrig; WF	**-11.9**	**12.6**	**-1.6**	**-23.6**	**16.4**	**-3.7**	**-39.5**	**17.5**	**-9.5**	**-63.5**	**29.5**	**-28.2**
Maize Irrig; NF	-14.9	10.2	-4.1	-20.3	13.6	5.0	-28.0	14.5	13.2	-52.1	26.3	12.8
Maize Rain; WF	-37.2	---	-39.3	-40.8	---	-37.2	-55.7	---	-37.6	-75.9	---	-80.8
Maize Rain; NF	-39.0	---	-19.0	-23.8	---	-6.9	-50.6	---	-3.2	-74.1	---	-32.5
Snap bean Irrig; WF	**-2.9**	**5.7**	**2.4**	**2.5**	**11.2**	**12.4**	**-0.8**	**7.0**	**19.1**	**-23.1**	**8.9**	**24.6**
Snap bean Irrig; NF	3.4	5.7	0.6	9.3	11.1	12.5	12.2	6.8	24.3	-7.1	9.0	32.9
Snap bean Rain; WF	-24.0	---	-14.3	-20.7	---	-5.1	4.9	---	16.0	-26.5	---	13.7
Snap Bean Rain; NF	-31.9	---	-24.1	-19.8	---	-5.3	0.4	---	11.2	-24.0	---	3.9
Bahiagrass Irrig; WF	5.1	3.1	1.3	7.1	6.8	2.8	19.4	1.2	7.8	23.9	12.7	11.7
Bahiagrass Irrig; NF	5.0	2.3	0.3	10.2	4.6	6.7	31.5	-3.7	22.5	48.1	4.5	37.3
Bahiagrass Rain; WF	2.6	---	1.1	-3.3	---	0.5	3.7	---	7.0	1.3	---	4.1
Bahiagrass Rain; NF	**1.3**	**---**	**0.4**	**1.7**	**---**	**-0.2**	**15.1**	**---**	**11.3**	**11.2**	**---**	**10.6**

Notes: Irrig = irrigated; Rain = rainfed; WF = well-fertilized; NF = non-fertilized. The results for the most common management practice for each crop are in bold. The percent change is between the SSP585 future climate scenario and the corresponding baseline (2005 to 2014) climate scenario.

1 INTRODUCTION

As proposed in Task 1, Agsilico used crop simulation models to simulate the impact of future climatic conditions on the agricultural production for the main field, forage, and vegetable crops within Alachua County, i.e., maize (corn), bahiagrass, and snap bean, respectively. Field maize production is important in Florida and the County since it is used for grain and silage and is widely used in the dairy and livestock industries (Wright et al., 2022). Bahiagrass is the most common warm-season perennial grass grown in Florida and the County and is mainly used for livestock feed due to its adaptation to low soil fertility and low input management (Wallau et al., 2019). Florida ranks first nationally in the production of snap beans (United States Department of Agriculture [USDA] National Agricultural Statistics Service [NASS], 2022). Snap bean production is an essential part of agriculture in the County since it is the second most produced vegetable behind watermelons (Frey et al., 2022; USDA NASS, 2022). A suitable crop model for watermelon production was not available. Future climate change projections suggest that agricultural production in tropical and subtropical regions such as the humid subtropical climate of the County will be impacted by an increased frequency of droughts and extreme temperatures driven by the increasing global temperature and atmospheric carbon dioxide (CO_2) concentrations (Intergovernmental Panel on Climate Change [IPCC], 2021).

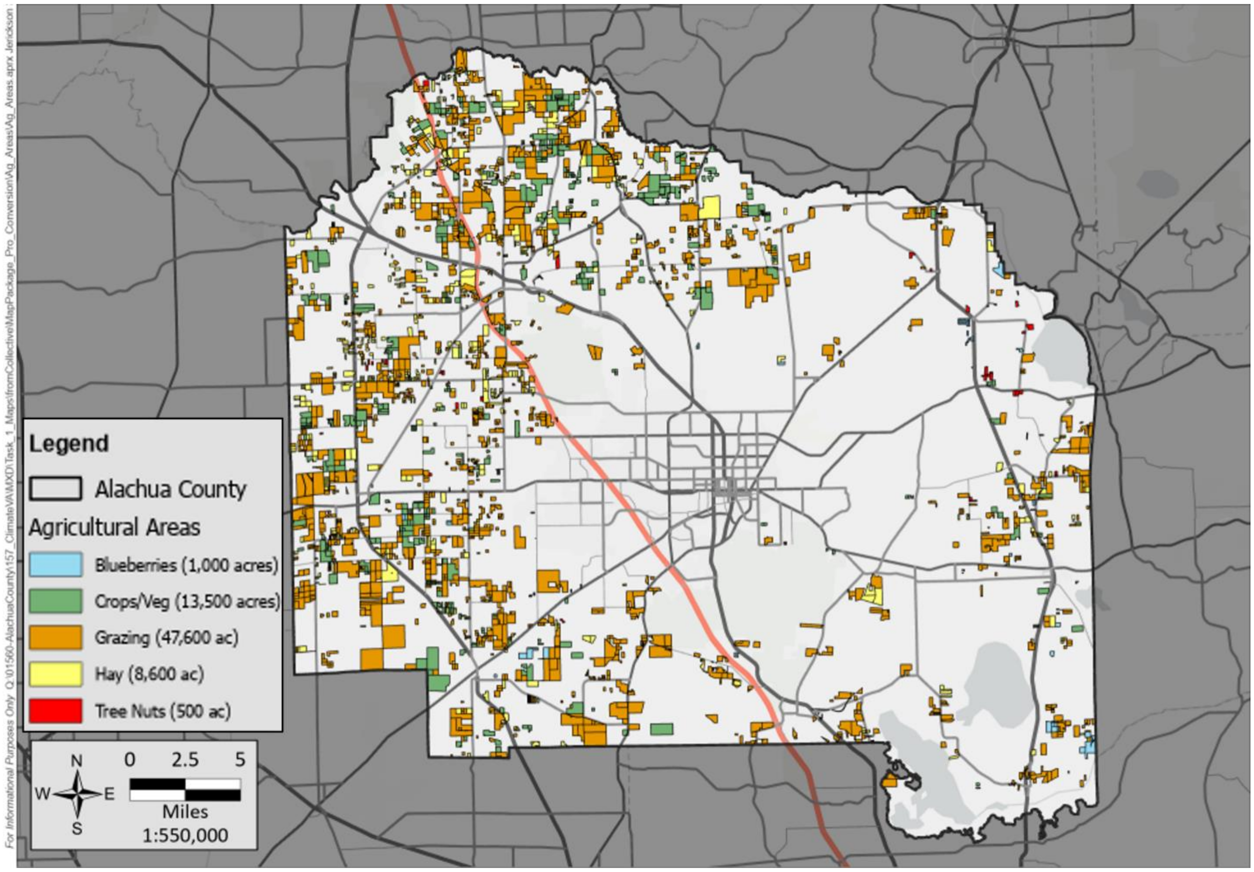
This assessment examines the impact of future climate change in the County for each of the three crops under four different management practices:

- Rainfed (non-irrigated) and non-fertilized.
- Rainfed and well-fertilized.
- Well-irrigated and non-fertilized.
- Well-irrigated and well-fertilized.

These management practices encompass the range of high and low water and Nitrogen (N) interactions that affect crop growth throughout the season within the County. Maize and snap bean production in Florida is often irrigated and well-fertilized because this is essential to maximize yields and profit. Bahiagrass is often grown with minimal irrigation and fertilizer applications because it is more tolerable to abiotic stresses and used mainly for forage. These management practices were simulated for the baseline climate scenario ranging from 2005 to 2014 and the future climate scenario ranging from 2025 to 2100. The same management practices were assumed for the baseline and future scenario simulations to provide a proper comparison to assess the impacts of future climate change on potential crop management of the County. Figure 1 provides a map of agricultural properties within Alachua County based on the Alachua County 2022 property appraiser data.

Understanding future irrigation demands is important as water for irrigation in Alachua County comes from the Upper Floridan Aquifer, the same sources used for domestic potable water and for maintaining spring flows as set by the state’s Minimum Flow and Level program. Water availability is a concern in the face of population growth in the County. Similarly, understanding potential changes in agricultural nitrogen application is important as nitrogen from agriculture fertilization is a major source of nutrients to both surface and groundwater systems in the County. Some of these systems are considered impaired due to nutrients. Potential changes in nitrogen application could further impact impaired waterbodies in the County.

Figure 1 Map of Agricultural Properties in Alachua County (2022 Property Appraiser Data)



2 METHODOLOGY

As described in Task 1, three crop simulation models from the well-known Decision Support System for Agrotechnology Transfer (DSSAT) platform (Hoogenboom et al., 2019) were used to simulate maize, bahiagrass, and snap bean production within the County. The crop models used were the DSSAT v.4.8.0.020 CERES-Maize, CROPGRO-Bahiagrass, and CROPGRO-Green bean models.

2.1 Crop Model Environmental Input

The experiment was set in Alachua County, Florida (29.650° N, 82.317° W, elevation 50 meters or 164 feet). The weather input consisted of the total daily solar radiation, maximum and minimum temperature, rainfall, wind speed, relative humidity, and atmospheric CO_2 concentrations for the baseline scenario (2005 to 2014) and the future climate scenario (2025 to 2100). The downscaled daily weather data were obtained from the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) database for the National Oceanic and Atmospheric Administration (NOAA) Geophysical Fluid Dynamics Laboratory Earth System global climate model (GFDL-ESM4). The future climate scenario used was the Coupled Model Intercomparison Project 6 (CMIP6) Shared Socioeconomic Pathway 5-8.5 watts per square meter ($W\ m^{-2}$) (SSP585) forcing scenario, which assumes global intensified fossil-fueled development with an additional radiative forcing of 8.5 $W\ m^{-2}$ by 2100. The SSP585 scenario has the highest projected global CO_2 concentration and temperature increases by the end of the century compared to other SSP scenarios, which allowed the crop models to simulate agricultural production in the County for the *worst-case* climate scenario that was represented in CMIP6 .

The dominant soil profile of the agricultural area within the County was selected using the Natural Resources Conservation Service (NRCS) Web Soil Survey database (NRCS, 2021). The dominant soil was Arredondo fine sand (loamy, siliceous, semiactive, hyperthermic Grossarenic Paleudult, 0- to 5-percent slopes), a well-drained soil consisting of rapidly permeable fine sand in the surface and subsurface layers (0 to 60 inches), and moderately permeable loamy fine sand in the subsoil layers (60+ inches). The same soil profile was used for the baseline and future scenario simulations (Table 1).

Table 1 Soil Profile for Arredondo Fine Sand Used as Input for the Crop Models

Depth (cm)	Depth (inches)	Soil Horizon	LL	DUL	SAT	Bulk Density ($g\ cm^{-3}$)	Clay (%)	Silt (%)	Sand (%)
5	1.97	Ap	0.042	0.110	0.379	1.57	3.7	6.1	90.2
10	3.94	Ap	0.042	0.110	0.379	1.57	3.7	6.1	90.2
20	7.87	E1	0.042	0.110	0.379	1.57	3.7	6.1	90.2
30	11.81	E1	0.028	0.092	0.381	1.58	3.3	1.5	95.2
40	15.75	E1	0.028	0.092	0.381	1.58	3.3	1.5	95.2
50	19.69	E2	0.028	0.092	0.381	1.58	3.3	1.5	95.2
60	23.62	E2	0.028	0.092	0.381	1.58	3.3	1.5	95.2
70	27.56	E2	0.028	0.092	0.381	1.58	3.3	1.5	95.2
90	35.43	E2	0.028	0.092	0.381	1.58	3.3	1.5	95.2

Depth (cm)	Depth (inches)	Soil Horizon	LL	DUL	SAT	Bulk Density (g cm^{-3})	Clay (%)	Silt (%)	Sand (%)
110	43.31	E2	0.028	0.092	0.381	1.58	3.3	1.5	95.2
130	51.18	EB	0.028	0.092	0.381	1.58	3.3	1.5	95.2
150	59.06	EB	0.028	0.092	0.381	1.58	3.3	1.5	95.2
170	66.93	Bt1	0.075	0.160	0.363	1.63	9.6	1.2	89.2
190	74.80	Bt2	0.192	0.280	0.353	1.66	30.8	0.9	68.3
210	82.68	Bt2	0.223	0.308	0.353	1.66	36.7	0.9	62.4

Source: NRCS, 2021.

Notes: The soil pH = 5.3; g cm^{-3} = grams per cubic centimeter; LL = lower limit; DUL = drained upper limit; SAT= saturation of soil water content.

2.2 Crop Model Initial Conditions and Experimental Setup

The model simulations were initialized on the day of planting for maize and snap bean and on the first day of the year for bahiagrass since it is a perennial crop. The sowing date for maize was set on March 21 of each year based on the Florida Department of Agriculture and Consumer Services (FDACS) *Agriculture by the Numbers 2020 handbook* (FDACS, 2021). Snap bean is harvested biannually in North Florida, so the sowing dates were set on March 21 and August 21 of each year based on the University of Florida Institute of Food and Agricultural Sciences (UF IFAS) *2022-2023 Vegetable Production Handbook of Florida* (Frey et al., 2022). Since bahiagrass is a perennial forage crop, the simulation began on the first day of the year with scheduled harvests every 30 days, beginning on April 30 and ending on November 26 of each year, based on the guidelines from Wallau et al. (2019). To reproduce the slower growth and dormancy in bahiagrass during the winter season, the photosynthetic growth rate was reduced between October 29 and March 30 as is standard for forage crop simulations. Maize and snap bean were automatically harvested when the model reached simulated physiological maturity.

The initial soil water profile was set to 100 percent because of the well-draining nature of Arredondo fine sand, and the initial soil mineral N was set to 80 kilograms of N per hectare (kg N ha^{-1}) (71.4 pounds of N per acre [lb N ac^{-1}]) at the beginning of each year. Maize was planted in rows at a depth of 3 centimeters (cm) (1.2 inches) using dry seed with seven plants per square meter (m^{-2}) (28,329 plants per acre [ac^{-1}]) and a row spacing of 80 cm (31.5 inches) based on the UF IFAS *Field Corn Production Guide* (Wright et al., 2022). Snap bean was planted in rows at a depth of 3 cm (1.2 inches) using dry seed with 35 plants per m^{-2} (141,645 plants per ac^{-1}) and a row spacing of 60 cm (23.6 inches) (Frey et al., 2022). To ensure that bahiagrass was established by the first harvest each year, the model assumed a transplant of the maximum available plant population, 999 plants per m^{-2}, which was then set to a standard stubble height of 7.6 cm (3 inches) on March 1 allowing for growth before the first scheduled harvest (Johnson et al., 2001).

For the maize well-fertilized treatment, fertilizer was applied broadcast, not incorporated into the soil, on the day of sowing and at 40, 60, and 80 days after sowing at a depth of 5 cm (2 inches). Each application consisted of starter fertilizer consisting of ammonium poly-phosphate 60-20-20, or 60 kg N ha^{-1}, 20 kilograms of Phosphorus (P) per hectare (kg P ha^{-1}), and 20 kilograms of Potassium (K) per hectare (kg K ha^{-1}) (53.5 lb N ac^{-1}, 17.8 lb P ha^{-1}, and 17.8 lb K ac^{-1}) (Wright et al., 2022). Instead of a non-fertilized treatment for maize, a low-fertilized treatment consisting of a single ammonium poly-phosphate 60-20-20 application was applied on the day of sowing, which is common for maize production. For the snap bean well-fertilized treatment, ammonium poly-phosphate 60-20-20 was applied broadcast, not incorporated into the soil, on the day of sowing and at 20, 40, and 60 days after sowing at a depth of 5 cm (2 inches) (Hochmuth and Hanlon, 2020). For the bahiagrass well-fertilized treatment, ammonium poly-phosphate 60-20-20 was applied broadcast, not incorporated into the soil, at a depth of 5 cm (2 inches) on March 1 and again with every scheduled harvest (Mylavarapu et al., 2019). No fertilizer was applied for the non-fertilized snap bean and bahiagrass treatments.

The DSSAT model calculates the daily N uptake of the crop for each of the simulated scenarios. The N uptake consists of the initial soil mineral N available that is set at the start of the simulation (described above), and the N that is applied through the fertilization schedule described above. The well-fertilized scenario was developed so that N is not a limiting factor in the crop growth. The average N uptake is presented in this report for each of the simulated scenarios as an indicator of how potential N demand may change in the future since fertilizer application is of interest to the County. It is unclear how agricultural producers will respond to this change in demand as fertilizer application is often correlated to the cost-benefit analysis of field management inputs (not considered in this assessment), although it may be reasonable to assume that fertilizer application rates will increase proportionally.

The irrigated treatments used the *automatic irrigation* feature of the crop models, where irrigation applications of 10 millimeters (mm) were applied via sprinkler if the available soil water within the first 30 cm (11.8 inches) of the soil profile dropped below a set threshold. Irrigation was then applied until the available water within the first 30 cm (11.8 inches) of the soil profile reached 100 percent. The threshold was set at 80 percent of the maximum water available for maize and bahiagrass, to mitigate the risk of water deficit stress affecting the crop. A threshold of 90 percent of the maximum water available was used for snap bean because of a higher simulated water demand than the other two crops. The rainfed treatments did not receive any supplemental irrigation.

Genetic variation in cultivars affects growth and development of crops (e.g., phenological development, grain number, grain weight, harvest index, and many other traits); therefore, calibrating the model cultivar parameters with measured field experiment data is ideal. However, conducting detailed field experiments is a time-consuming and challenging process and was outside the scope of this study. Therefore, regional cultivars with genotypic parameters calibrated from previous modeling studies conducted in North Florida were used for each specified crop. The cultivars used were McCurdy84aa (maize) (Bennett et al., 1989), Pensacola (bahiagrass) (Johnson et al., 2001), and Bronco (snap bean) (Djidonou, 2008).

3 RESULTS AND DISCUSSION

3.1 BASELINE ASSESSMENT (2005 TO 2014)

This agricultural assessment focuses on the production change between the future climate scenario and the baseline scenario; therefore, ensuring that the simulated baseline results for each crop are within an acceptable range and representative of the County production is important. To check this, the baseline scenario results were compared to the USDA NASS data for Alachua County and previous field experiments conducted in Florida reported in the literature. Maize production in Florida is usually well fertilized with average growing seasons of approximately 120 days resulting in rainfed yields of 6,300 ± 1,300 kilograms per hectare (kg ha^{-1}) (100 ± 21 bushels per acre [bu ac^{-1}], 1 bu maize ac^{-1} = approximately 62.77 kg ha^{-1}) and irrigated yields of 11,500 ± 1,000 kg ha^{-1} (183 ± 16 bu ac^{-1}) (Wright et al., 2022). From 2005 to 2014, average yield in the County was 6,800 ± 2,800 kg ha^{-1} (110 ± 45 bu ac^{-1}) (USDA NASS, 2022). The average simulated growing season for the baseline rainfed and well-fertilized treatment was 119 days with an average yield of 6,200 ± 2,400 kg ha^{-1} (99 ± 38 bu ac^{-1}) and 115 days with an average yield of 9,900 ± 1,200 kg ha^{-1} (160 ± 19 bu ac^{-1}) for the baseline irrigated and well-fertilized treatment, respectively. The simulated growing season length and yield of these treatments correspond well with the USDA NASS data and the data from the literature.

Snap bean production in Florida is usually irrigated and well fertilized with average growing seasons of approximately 60 days and yields of 6,000 kg ha^{-1} (180 thirty-pound bu ac^{-1}) (Frey et al., 2022; Snodgrass et al., 2011). From 2005 to 2014, the County average-reported yield was 7,600 kg ha^{-1} ± 1700 kg ha^{-1} (226 ± 50 thirty-pound bu ac^{-1}) (USDA NASS, 2022). The average simulated growing season for the baseline irrigated and well-fertilized treatment was 69 days with a yield of 6,000 ± 400 kg ha^{-1} (180 ± 12 thirty-pound bu ac^{-1}). The simulated growing season length and yield of the irrigated and well-fertilized treatment correspond well with the data from the literature; and although the simulated yield is lower than the USDA NASS data, it is still within the reported variation.

Bahiagrass production in Florida is used for hay/haylage and grazing so it usually has minimal irrigation or fertilizer applications with annual herbage (i.e., yield) between 3,300 kg ha^{-1} (3,000 lb ac^{-1}) to 11,200 kg ha^{-1} (10,000 lb ac^{-1}), and up to 15,700 kg ha^{-1} (14,000 lb ac^{-1}) under high fertilization (Wallau et al., 2019). From 2005 to 2014, the County average-reported yield was 7,500 kg ha^{-1} ± 1,300 kg ha^{-1} (6,700 ± 1,200 lb ac^{-1}), but only 2 years of data were available during this period (USDA NASS, 2022). The average simulated yields were 11,400 ± 800 kg ha^{-1} (10,200 ± 700 lb ac^{-1}) for the baseline rainfed and non-fertilized treatment and 15,000 ± 850 kg ha^{-1} (13,400 ± 760 lb ac^{-1}) for the baseline irrigated and well-fertilized treatment, respectively. This corresponds well with the non-fertilized and fertilized yield from the literature, but the yield is higher than the reported USDA NASS data. This may be because the USDA NASS data only had 2 years of data available for this baseline period resulting in uncertainty within the reported results.

In summary, the crop models simulated the baseline scenario results within the reported range of observations for all three crops in the County. Therefore, the simulated future scenario results can be used as an estimate of the future agricultural production in the County.

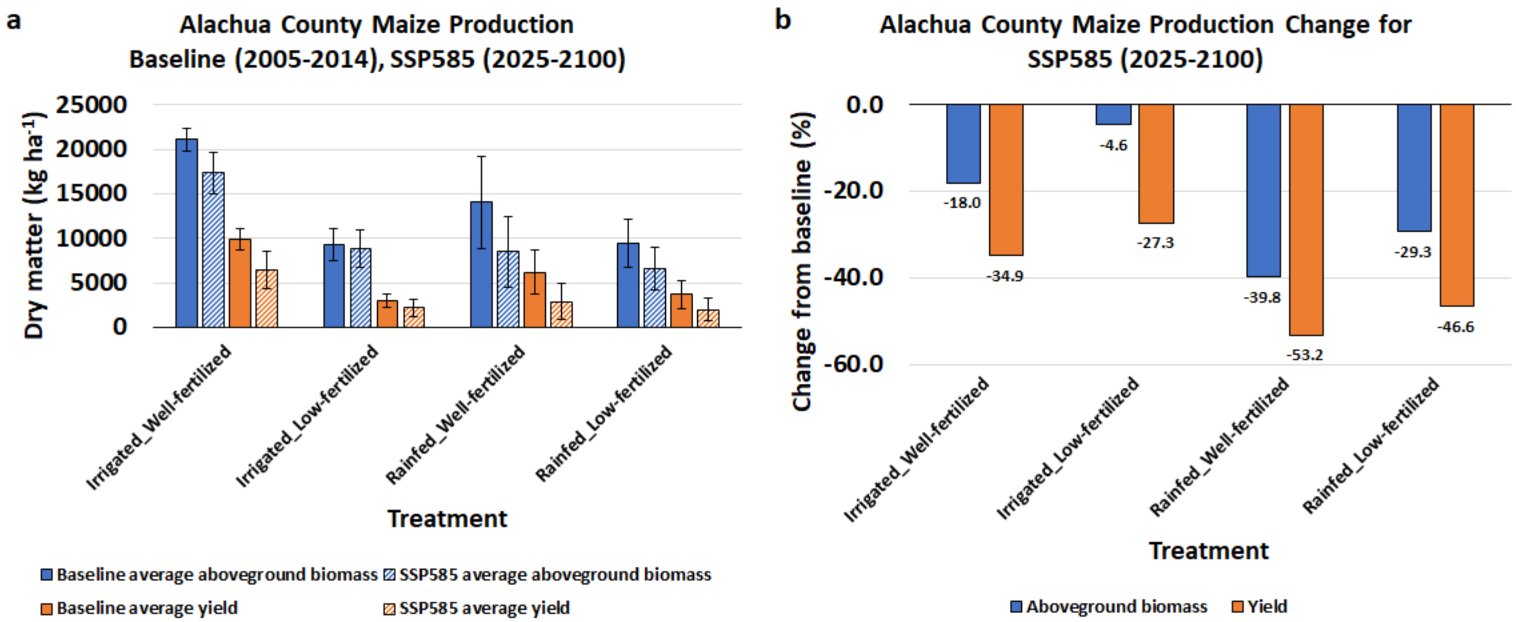
3.2 Climate Change Assessment for the Full Period (2025 to 2100)

This assessment examined the full future period from 2025 to 2100. The more extreme trends are not as prominent across this full period when compared to the warmer end of century.

Figure 2 shows the Alachua County a) average simulated maize production, and b) future maize production change. Table 2 summarizes the average simulated growing season, seasonal maximum air temperature, minimum air temperature, atmospheric CO_2 concentration, and precipitation for maize under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2025 to 2100) for the four management treatments. Table 3 summarizes the average simulated cumulative seasonal irrigation, evapotranspiration (ET), and N uptake for maize under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2025 to 2100) for the four management treatments.

Aboveground biomass refers to all crop dry matter accumulated from planting to harvest (e.g., stems, leaves, sheaths, husks, and pods). Figure 2b shows future projected maize yield losses due to the higher projected future seasonal temperatures leading to increased heat stress and faster phenological development (i.e., reduced growing seasons across all treatments by 9 to 12 days) and the reduced seasonal rainfall resulting in increased water deficit stress in the rainfed treatments (Table 2). Simulated yield losses are higher than the simulated aboveground biomass losses because the reproductive growth stage (i.e., grain filling or seed formation stage) is more sensitive to abiotic stresses than the vegetative growth stages and requires a higher demand of resources for seed development. To mitigate water deficit stress from the projected decrease in seasonal rainfall, simulated irrigation increased 22 and 18 percent in the well-fertilized and low-fertilized treatments, respectively (Table 3). The decrease in future N uptake is driven by the lower N demand from decreased crop growth. The increase in N uptake for the irrigated and low-fertilized treatment is not significant because of the low overall uptake (i.e., 73 lb N ac^{-1} vs 80 lb N ac^{-1}) and focus should be on the well-fertilized treatments.

Figure 2 Simulated Average Maize Production and Future (2025 to 2100) Production Change



Note: The average simulated aboveground biomass (blue bars) and average simulated yield (orange bars) are shown for the four management treatments under the baseline climate scenario from 2005 to 2014 (solid bars) and the SSP585 future climate scenario from 2025 to 2100 (dashed bars). Error bars show the standard deviation of the simulated aboveground biomass and yield. The production change was calculated as the percent change between the SSP585 future climate scenario and the baseline climate scenario for the average simulated aboveground biomass and yield of each of the four management treatments (labeled).

Table 2 Simulated Maize Seasonal Climate Variables for the Baseline (2005 to 2014) and SSP585 Future (2025 to 2100) Climate Scenarios

Treatment	Growing Season (days)	Maximum Temperature (°C)	Minimum Temperature (°C)	CO_2 (ppm)	Precipitation (mm)	Precipitation (inches)
Baseline_Irrigated_Well-fertilized	115	30.9	18.2	388.4	493.2	19.4
Baseline_Irrigated_Low-fertilized	115	30.9	18.2	388.4	493.2	19.4
Baseline_Rainfed_Well-fertilized	119	31.0	18.3	388.4	516.9	20.3
Baseline_Rainfed_Low-fertilized	119	31.0	18.3	388.4	516.9	20.3
SSP585_Irrigated_Well-fertilized	106	33.1	19.7	712.8	381.2	15.0
SSP585_Irrigated_Low-fertilized	106	33.1	19.7	712.8	381.2	15.0
SSP585_Rainfed_Well-fertilized	107	33.1	19.7	712.8	389.0	15.3
SSP585_Rainfed_Low-fertilized	107	33.1	19.7	712.8	389.0	15.3

Notes: °C = degrees Celsius; ppm = parts per million.

Table 3 Simulated Cumulative Maize Irrigation, ET, and N Uptake for the Baseline (2005 to 2014) and SSP585 Future (2025 to 2100) Climate Scenarios

Treatment	Irrigation (mm)	Irrigation (inches)	% Change	ET (mm)	ET (inches)	% Change	N Uptake (kg N ha^{-1})	N Uptake (lb N ac^{-1})	% Change
Baseline_Irrigated_Well-fertilized	222	8.7		499	19.7		253	226	
Baseline_Irrigated_Low-fertilized	232	9.1		479	18.9		82	73	
Baseline_Rainfed_Well-fertilized	0	0.0		372	14.7		188	168	
Baseline_Rainfed_Low-fertilized	0	0.0		367	14.4		93	83	
SSP585_Irrigated_Well-fertilized	270	10.6	21.8	488	19.2	-2.2	230	205	-9.0
SSP585_Irrigated_Low-fertilized	274	10.8	17.9	472	18.6	-1.4	90	80	9.2
SSP585_Rainfed_Well-fertilized	0	0.0		287	11.3	-23.0	127	113	-32.3
SSP585_Rainfed_Low-fertilized	0	0.0		285	11.2	-22.4	82	73	-11.8

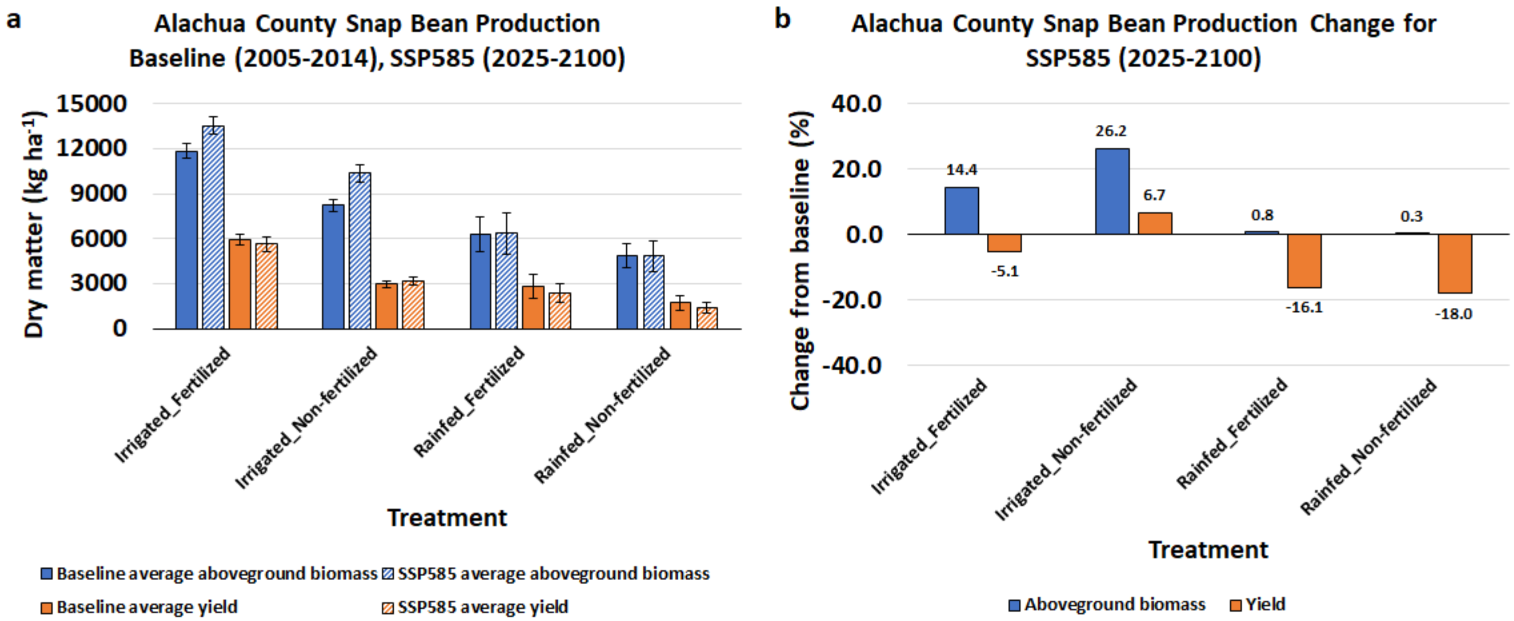
Note: The percent change is between the SSP585 future climate scenario and the corresponding baseline climate scenario.

Figure 3 shows the Alachua County a) average simulated snap bean production and b) future snap bean production change. Table 4 shows the average simulated growing season, seasonal maximum air temperature, minimum air temperature, atmospheric CO_2 concentration, and precipitation for snap bean crops under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2025 to 2100) for the four management treatments. Table 5 shows the average simulated cumulative seasonal irrigation, ET, and N uptake for snap bean under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2025 to 2100) for the four management treatments. The values represent the combined spring and fall harvests.

The total snap bean production contains two harvests per year, one in spring and one in fall. Figure 3b shows future projected annual snap bean yield losses due to the higher projected seasonal temperatures leading to increased heat stress and the slightly reduced seasonal rainfall resulting in increased water deficit stress in the rainfed treatments (Table 4). Although the average seasonal rainfall between the baseline and SSP585 scenarios is similar, the significantly less rainfall in the spring growing season resulted in higher water deficit stress and lower yields in the spring harvest, which on average produced more than the fall harvest. The warmer temperatures accelerated phenological development by 1 day for all treatments.

The simulated aboveground biomass gains across all treatments are due to the CO_2 fertilization effect and the increased resiliency to abiotic stresses in the vegetative growth stages compared to the reproductive growth stage. The CO_2 fertilization effect causes an increased rate of photosynthesis while limiting leaf transpiration driven by the increased CO_2 concentrations. This effect is often more beneficial to C3 crops (crops that produce a three-carbon compound via photosynthesis, e.g., snap bean) compared to C4 crops (crops that produce a four-carbon compound via photosynthesis, e.g., maize) because of the different photosynthetic pathways. The simulated yield losses are driven by the higher sensitivity to abiotic stresses and higher demand of resources for seed development during the reproductive stage (i.e., grain filling or seed formation stage). The simulated yield gain for the irrigated and non-fertilized treatment, 6.7 percent, is likely a result of the variation within the lower overall yield (3,200 ± 200 kg ha^{-1} for the SSP585 scenario and 3,000 ± 200 kg ha^{-1} for the baseline scenario) compared to the irrigated and fertilized treatment (5,600 ± 500 kg ha^{-1} for the SSP585 scenario and 5,900 ± 400 kg ha^{-1} for the baseline scenario). However, the lower cumulative season growth may have also resulted in a lower use of resources during the vegetative stages, allowing for increased resource availability during the higher-demanding reproductive stage. The rainfed treatments had higher yield losses and minimal biomass gain compared to the irrigated treatments because of the reduced rainfall in the spring harvests resulting in higher water deficit stress. Due to the projected decrease in seasonal rainfall, simulated irrigation increased 8 percent in the fertilized and non-fertilized treatments to mitigate water deficit stress (Table 5). The increase in N uptake for the future fertilized treatments indicates a higher N demand than the baseline treatments, which suggests that increases in the fertilizer amount or the N use efficiency of the crop will be necessary to achieve the simulated future yields.

Figure 3 Average Simulated Snap Bean Production and Future (2025 to 2100) Production Change



Note: The average simulated aboveground biomass (blue bars) and average simulated yield (orange bars) are shown for the four management treatments under the baseline climate scenario from 2005 to 2014 (solid bars) and the SSP585 future climate scenario from 2025 to 2100 (dashed bars). Error bars show the standard deviation of the simulated aboveground biomass and yield. The production change was calculated as the percent change between the SSP585 future climate scenario and the baseline climate scenario for the average simulated aboveground biomass and yield of each of the four management treatments (labeled).

Table 4 Average Simulated Snap Bean Seasonal Climate Variables for the Baseline (2005 to 2014) and SSP585 Future (2025 to 2100) Climate Scenarios

Treatment	Growing Season (days)	Maximum Temperature (°C)	Minimum Temperature (°C)	CO_2 (ppm)	Precipitation (mm)	Precipitation (inches)
Baseline_Irrigated_Fertilized	69	30.3	18.2	388.7	250.8	9.9
Baseline_Irrigated_Non-fertilized	69	30.3	18.2	388.7	250.8	9.9
Baseline_Rainfed_Fertilized	68	30.4	18.3	388.7	252.9	10.0
Baseline_Rainfed_Non-fertilized	68	30.4	18.3	388.7	252.2	9.9
SSP585_Irrigated_Fertilized	68	32.5	20.3	714.3	250.5	9.9
SSP585_Irrigated_Non-fertilized	68	32.5	20.3	714.3	250.5	9.9
SSP585_Rainfed_Fertilized	67	32.5	20.3	714.2	248.7	9.8
SSP585_Rainfed_Non-fertilized	67	32.5	20.3	714.2	249.1	9.8

Table 5 Average Simulated Cumulative Snap Bean Irrigation, ET, and N Uptake for the Baseline (2005 to 2014) and SSP585 Future (2025 to 2100) Climate Scenarios

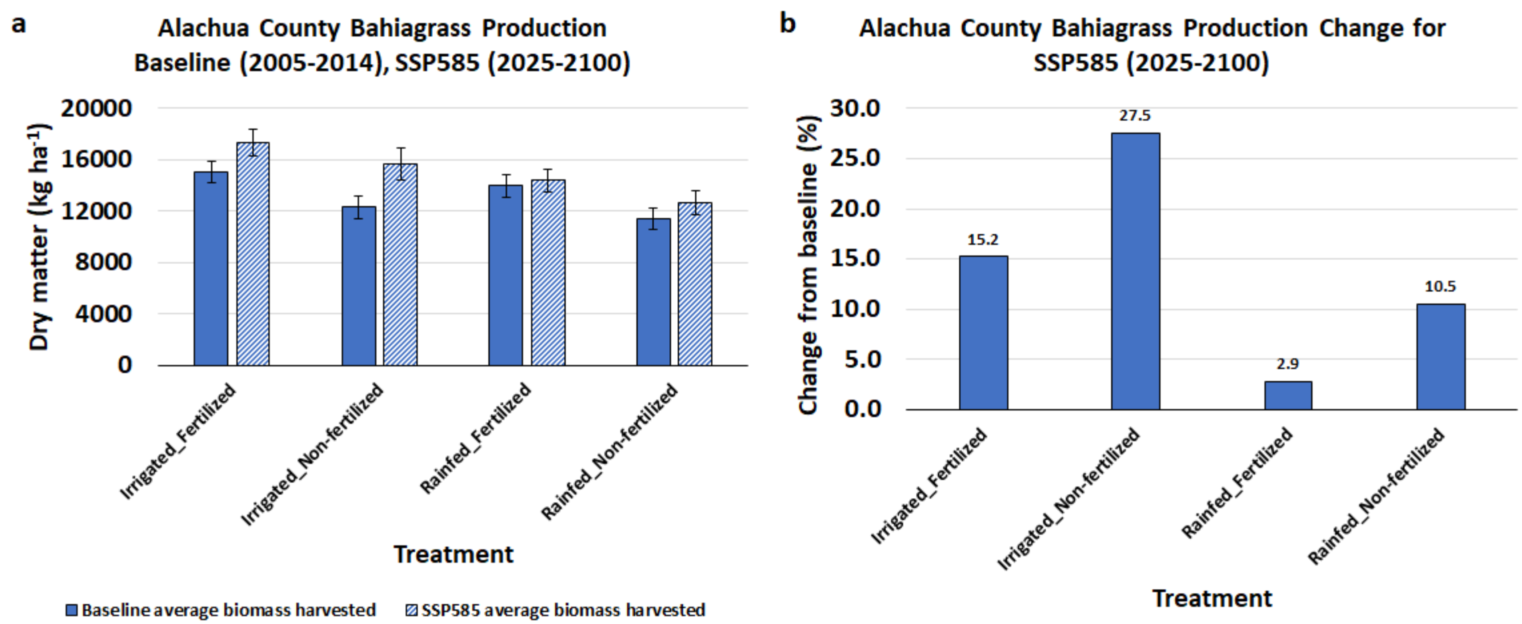
Treatment	Irrigation (mm)	Irrigation (inches)	% Change	ET (mm)	ET (inches)	% Change	N Uptake (kg N ha^{-1})	N Uptake (lb N ac^{-1})	% Change
Baseline_Irrigated_Fertilized	663	26.1		515	20.3		397	354	
Baseline_Irrigated_Non-fertilized	665	26.2		516	20.3		156	140	
Baseline_Rainfed_Fertilized	0	0.0		324	12.7		254	227	
Baseline_Rainfed_Non-fertilized	0	0.0		326	12.9		126	112	
SSP585_Irrigated_Fertilized	713	28.1	7.5	523	20.6	1.5	461	411	16.2
SSP585_Irrigated_Non-fertilized	715	28.1	7.6	525	20.7	1.6	187	167	19.6
SSP585_Rainfed_Fertilized	0	0.0		313	12.3	-3.3	263	235	3.8
SSP585_Rainfed_Non-fertilized	0	0.0		312	12.3	-4.5	122	109	-3.1

Note: The percent change is between the SSP585 future climate scenario and the corresponding baseline climate scenario.

Figure 4 shows the Alachua County a) average simulated bahiagrass production and b) future bahiagrass production change. Table 6 shows the average maximum air temperature, minimum air temperature, atmospheric CO_2 concentration, and precipitation for bahiagrass under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2025 to 2100) for the four management treatments. Table 8 shows the average of simulated cumulative irrigation, ET, and N uptake for bahiagrass under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2025 to 2100) for the four management treatments.

The aboveground biomass for bahiagrass is representative of the total herbage (i.e., yield) harvested throughout the season. Figure 4b shows future projected bahiagrass yield increases due to the CO_2 fertilization effect, where increased atmospheric CO_2 concentrations increased the rate of photosynthesis within the plant, especially in grasses. This effect paired with the abiotic stress resiliency and low-input adaptability in bahiagrass mitigates the impact of heat stress from the warmer temperatures (Table 6). Due to the projected slight increase in seasonal rainfall, simulated irrigation only increased 4 and 1 percent in the well-fertilized and non-fertilized treatments, respectively, to mitigate water deficit stress (Table 7). The rainfed treatments had lower yield gains compared to the irrigated treatments because of the higher water deficit stress affecting the growth, which was likely exacerbated by the higher temperatures. The increase in N uptake for all future treatments compared to the baseline treatments indicates a higher crop N demand, which suggests that increased N fertilization will be necessary to achieve the simulated future yields. The increase of N uptake in the non-fertilized treatments is because the simulated growth used more of the initial soil mineral N that was set at the beginning of the simulation. The N uptake percent change in the irrigated and non-fertilized treatment seems large, but that is because the non-fertilized treatments have a low overall N uptake compared to the fertilized treatments.

Figure 4 Average Simulated Bahiagrass Production and Future (2025 to 2100) Production Change



Note: Average simulated herbage, i.e., yield, are shown for the four management treatments under the baseline climate scenario from 2005 to 2014 (solid bars) and the SSP585 future climate scenario from 2025 to 2100 (dashed bars). Error bars show the standard deviation of the simulated yield. The production change was calculated as the percent change between the SSP585 future climate scenario and the baseline climate scenario for the average simulated yield of each of the four management treatments (labeled).

Table 6 Average Bahiagrass Seasonal Climate Variables for the Baseline (2005 to 2014) and SSP585 Future (2025 to 2100) Climate Scenarios

Treatment	Maximum Temperature (°C)	Minimum Temperature (°C)	CO_2 (ppm)	Precipitation (mm)	Precipitation (inches)
Baseline_Irrigated_Fertilized	28.8	16.5	388.7	1,295.6	51.0
Baseline_Irrigated_Non-fertilized	28.8	16.5	388.7	1,295.6	51.0
Baseline_Rainfed_Fertilized	28.8	16.5	388.7	1,295.6	51.0
Baseline_Rainfed_Non-fertilized	28.8	16.5	388.7	1,295.6	51.0
SSP585_Irrigated_Fertilized	30.9	18.6	714.4	1,306.1	51.4
SSP585_Irrigated_Non-fertilized	30.9	18.6	714.4	1,306.1	51.4
SSP585_Rainfed_Fertilized	30.9	18.6	714.4	1,306.1	51.4
SSP585_Rainfed_Non-fertilized	30.9	18.6	714.4	1,306.1	51.4

Table 7 Average Simulated Cumulative Bahiagrass Irrigation, ET, and N Uptake for the Baseline (2005 to 2014) and SSP585 Future (2025 to 2100) Climate Scenarios

Treatment	Irrigation (mm)	Irrigation (inches)	% Change	ET (mm)	ET (inches)	% Change	N Uptake (kg N ha^{-1})	N Uptake (lb N ac^{-1})	% Change
Baseline_Irrigated_Fertilized	647	25.5		1,303	51.3		825	736	
Baseline_Irrigated_Non-fertilized	680	26.8		1,271	50.0		147	131	
Baseline_Rainfed_Fertilized	0	0.0		1,021	40.2		796	711	
Baseline_Rainfed_Non-fertilized	0	0.0		972	38.3		167	149	
SSP585_Irrigated_Fertilized	675	26.6	4.3	1,323	52.1	1.6	886	791	7.4
SSP585_Irrigated_Non-fertilized	685	27.0	0.7	1,293	50.9	1.8	180	160	22.1
SSP585_Rainfed_Fertilized	0	0.0		993	39.1	-2.8	835	745	4.8
SSP585_Rainfed_Non-fertilized	0	0.0		949	37.4	-2.4	183	163	9.6

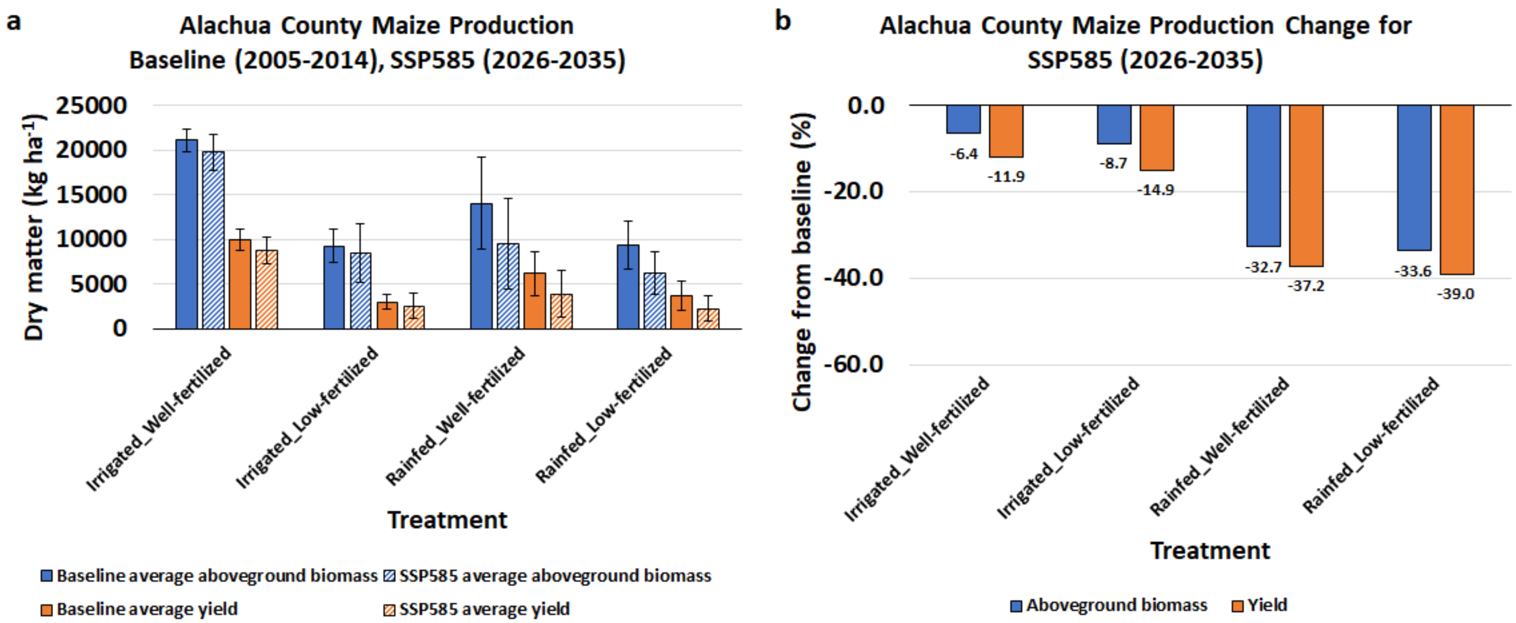
Note: The percent change is between the SSP585 future climate scenario and the corresponding baseline climate scenario.

3.3 Climate Change Assessment for 2030 (2026 to 2035)

Figure 5 shows the Alachua County a) average simulated maize production and future maize production change. Table 8 shows the average simulated growing season, seasonal maximum air temperature, minimum air temperature, atmospheric CO_2 concentration, and precipitation for maize under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2026 to 2035) for the four management treatments. Table 9 shows the average simulated cumulative seasonal irrigation, ET, and N uptake for maize under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2026 to 2035) for the four management treatments.

This assessment examined the period from 2026 to 2035. Figure 5b shows future projected maize yield losses due to the higher projected future seasonal temperatures leading to increased heat stress and faster phenological development (i.e., reduced growing seasons across all treatments by 4 to 5 days) and the reduced seasonal rainfall resulting in increased water deficit stress in the rainfed treatments (Table 8). Simulated yield losses are higher than the simulated aboveground biomass losses because the reproductive growth stage is more sensitive to abiotic stresses than the vegetative growth stages and requires a higher demand of resources for seed development. To mitigate water deficit stress from the projected decrease in seasonal rainfall, simulated irrigation increased 13 and 10 percent in the well-fertilized and low-fertilized treatments, respectively (Table 9). The decrease in future N uptake compared to the baseline treatments is driven by the lower N demand from the decreased overall crop growth.

Figure 5 Average Simulated Maize Production and Future (2026 to 2035) Production Change



Note: The average simulated aboveground biomass (blue bars) and average simulated yield (orange bars) are shown for the four management treatments under the baseline climate scenario from 2005 to 2014 (solid bars) and the SSP585 future climate scenario from 2026 to 2035 (dashed bars). Error bars show the standard deviation of the simulated aboveground biomass and yield. The production change was calculated as the percent change between the SSP585 future climate scenario and the baseline climate scenario for the average simulated aboveground biomass and yield of each of the four management treatments (labeled).

Table 8 Simulated Maize Seasonal Climate Variables for the Baseline (2005 to 2014) and SSP585 Future (2026 to 2035) Climate Scenarios

Treatment	Growing Season (days)	Maximum Temperature (°C)	Minimum Temperature (°C)	CO_2 (ppm)	Precipitation (mm)	Precipitation (inches)
Baseline_Irrigated_Well-fertilized	115	30.9	18.2	388.4	493.2	19.4
Baseline_Irrigated_Low-fertilized	115	30.9	18.2	388.4	493.2	19.4
Baseline_Rainfed_Well-fertilized	119	31.0	18.3	388.4	516.9	20.3
Baseline_Rainfed_Low-fertilized	119	31.0	18.3	388.4	516.9	20.3
SSP585_Irrigated_Well-fertilized	111	31.7	18.8	455.4	459.3	18.1
SSP585_Irrigated_Low-fertilized	111	31.7	18.8	455.4	459.3	18.1
SSP585_Rainfed_Well-fertilized	114	31.8	18.9	455.4	478.3	18.8
SSP585_Rainfed_Low-fertilized	114	31.8	18.9	455.4	478.3	18.8

Table 9 Simulated Cumulative Maize Irrigation, ET, and N Uptake for the Baseline (2005 to 2014) and SSP585 Future (2026 to 2035) Climate Scenarios

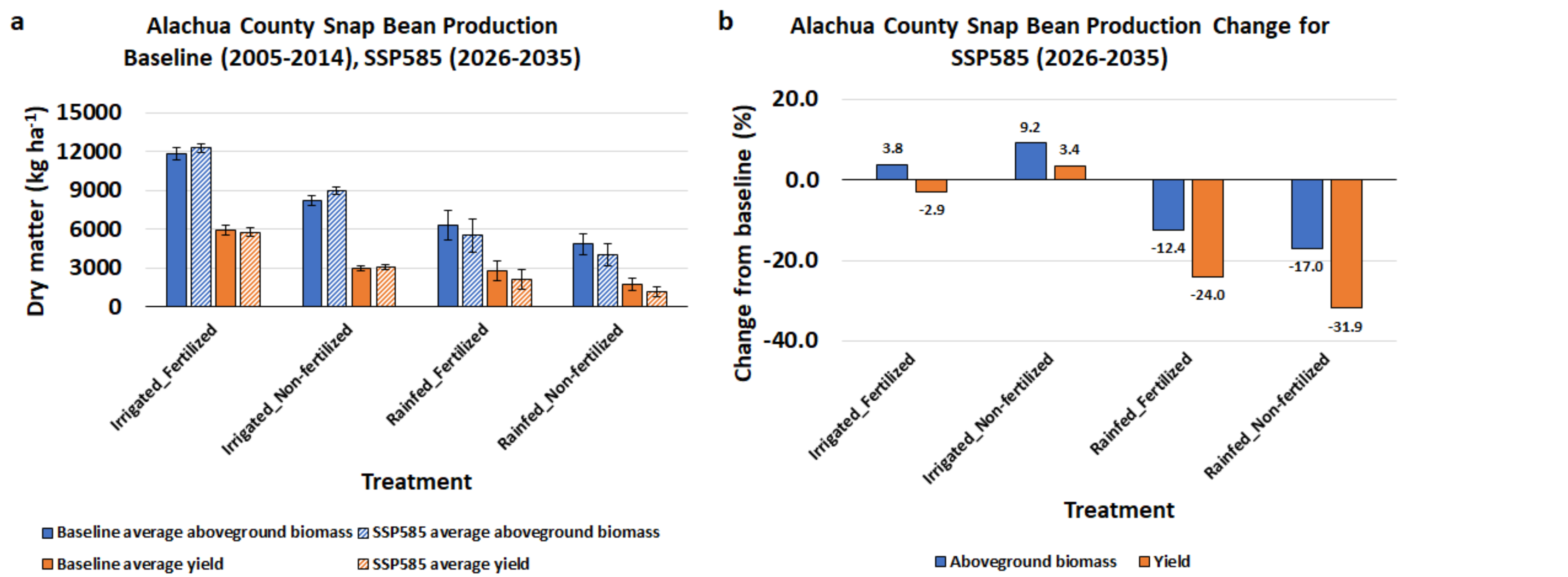
Treatment	Irrigation (mm)	Irrigation (inches)	% Change	ET (mm)	ET (inches)	% Change	N Uptake (kg N ha^{-1})	N Uptake (lb N ac^{-1})	% Change
Baseline_Irrigated_Well-fertilized	222	8.7		499	19.7		253	226	
Baseline_Irrigated_Low-fertilized	232	9.1		479	18.9		82	73	
Baseline_Rainfed_Well-fertilized	0	0.0		372	14.7		188	168	
Baseline_Rainfed_Low-fertilized	0	0.0		367	14.4		93	83	
SSP585_Irrigated_Well-fertilized	254	10.0	12.6	491	19.3	-1.7	249	222	-1.6
SSP585_Irrigated_Low-fertilized	259	10.2	10.2	465	18.3	-3.0	79	70	-4.1
SSP585_Rainfed_Well-fertilized	0	0.0		312	12.3	-19.5	135	120	-39.3
SSP585_Rainfed_Low-fertilized	0	0.0		302	11.9	-21.7	78	69	-19.0

Note: The percent change is between the SSP585 future climate scenario and the corresponding baseline climate scenario.

Figure 6 shows the Alachua County a) average simulated snap bean production and b) future snap bean production change. Table 10 shows the average simulated growing season, seasonal maximum air temperature, minimum air temperature, atmospheric CO_2 concentration, and precipitation for snap bean under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2026 to 2035) for the four management treatments. Table 11 shows the average simulated cumulative seasonal irrigation, ET, and N uptake for snap bean under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2026 to 2035) for the four management treatments. The values represent the combined spring and fall harvests.

The total snap bean production contains two harvests per year, one in spring and one in fall. Figure 6b shows future projected annual snap bean yield losses due to the higher projected seasonal temperatures leading to increased heat stress (Table 10). The warmer temperatures accelerated phenological development by 1 day for the irrigated treatments and 2 days for the rainfed treatments. The simulated yield losses are driven by the higher sensitivity to abiotic stresses and higher demand of resources for seed development during the reproductive growth stage. The simulated yield gain for the irrigated and non-fertilized treatment, 3.4 percent, is likely a result of the variation within the lower overall yield (3,100 ± 200 kg ha^{-1} for the SSP585 scenario and 3,000 ± 200 kg ha^{-1} for the baseline scenario) compared to the irrigated and fertilized treatment (5,800 ± 300 kg ha^{-1} for the SSP585 scenario and 5,900 ± 400 kg ha^{-1} for the baseline scenario). However, the lower cumulative season growth may also have resulted in a lower use of resources during the vegetative stages, allowing for increased resource availability during the higher-demanding reproductive stage. The simulated aboveground biomass gains in the irrigated treatments are due to the minimal water deficit stress, the increased CO_2 concentrations, and the resiliency to heat stress in the vegetative stages compared to the reproductive stage. The rainfed treatments had larger aboveground biomass and yield losses compared to the irrigated treatments because they experienced higher water deficit stress. Due to the projected increase in future seasonal rainfall, simulated irrigation only increased 6 percent in the fertilized and non-fertilized treatments to mitigate water deficit stress (Table 11). The increase in N uptake for the future irrigated treatments compared to the baseline irrigated treatments indicates a higher crop N demand which suggests that increased N fertilization will be necessary when applying irrigation to achieve the simulated future irrigated yields. The negligible increase in N uptake for the future rainfed treatments indicates that crop N demand was similar to the baseline N uptake, which means that no increase in N fertilization will be necessary under non-irrigated management to achieve the simulated future rainfed yields.

Figure 6 Average Simulated Snap Bean Production and Future (2026 to 2035) Production Change



Note: The average simulated aboveground biomass (blue bars) and average simulated yield (orange bars) are shown for the four management treatments under the baseline climate scenario from 2005 to 2014 (solid bars) and the SSP585 future climate scenario from 2026 to 2035 (dashed bars). Error bars show the standard deviation of the simulated aboveground biomass and yield. The production change was calculated as the percent change between the SSP585 future climate scenario and the baseline climate scenario for the average simulated aboveground biomass and yield of each of the four management treatments (labeled).

Table 10 Simulated Snap Bean Seasonal Climate Variables for the Baseline (2005 to 2014) and SSP585 Future (2026 to 2035) Climate Scenarios

Treatment	Growing Season (days)	Maximum Temperature (°C)	Minimum Temperature (°C)	CO_2 (ppm)	Precipitation (mm)	Precipitation (inches)
Baseline_Irrigated_Fertilized	69	30.3	18.2	388.7	250.8	9.9
Baseline_Irrigated_Non-fertilized	69	30.3	18.2	388.7	250.8	9.9
Baseline_Rainfed_Fertilized	68	30.4	18.3	388.7	252.9	10.0
Baseline_Rainfed_Non-fertilized	68	30.4	18.3	388.7	252.2	9.9
SSP585_Irrigated_Fertilized	68	30.9	18.8	456.1	271.7	10.7
SSP585_Irrigated_Non-fertilized	68	30.9	18.8	456.1	271.7	10.7
SSP585_Rainfed_Fertilized	66	30.9	18.7	456.0	266.3	10.5
SSP585_Rainfed_Non-fertilized	66	30.9	18.7	456.0	267.5	10.5

Table 2 Simulated Cumulative Snap Bean Irrigation, ET, and N Uptake for the Baseline (2005 to 2014) and SSP585 Future (2026 to 2035) Climate Scenarios

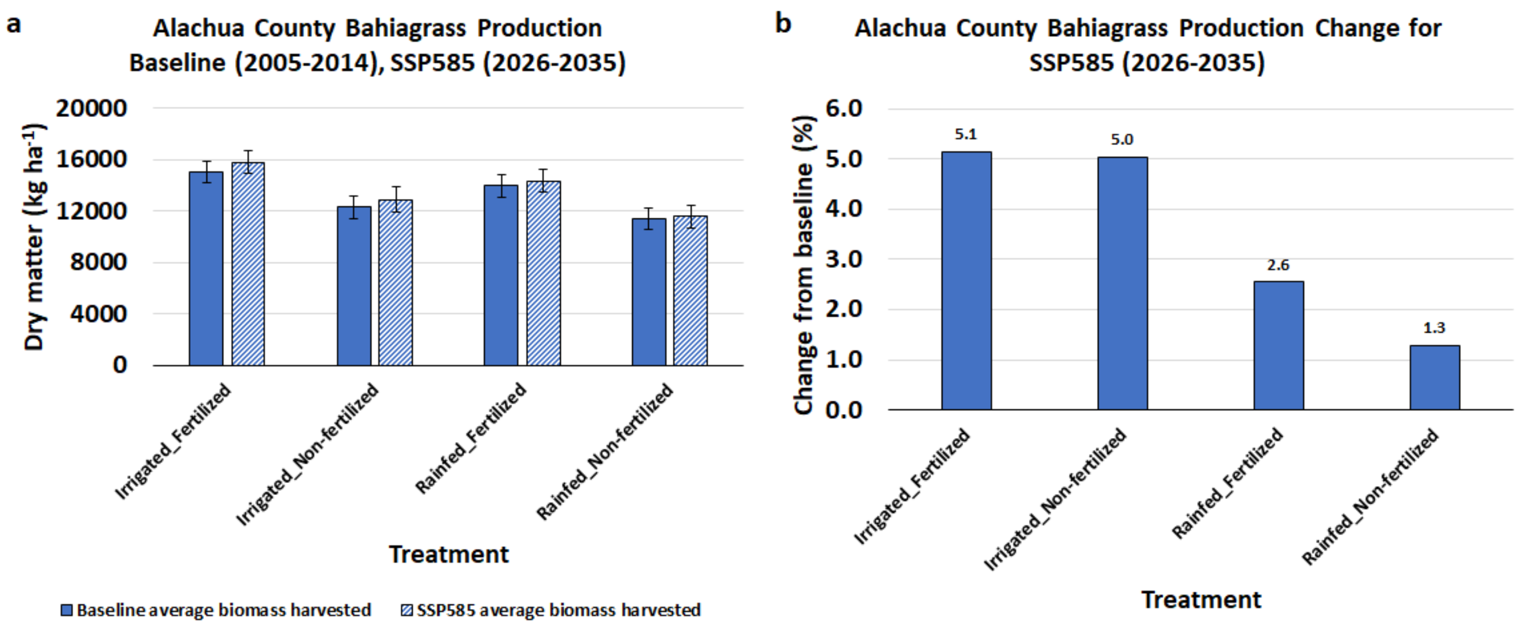
Treatment	Irrigation (mm)	Irrigation (inches)	% Change	ET (mm)	ET (inches)	% Change	N Uptake (kg N ha^{-1})	N Uptake (lb N ac^{-1})	% Change
Baseline_Irrigated_Fertilized	663	26.1		515	20.3		397	354	
Baseline_Irrigated_Non-fertilized	665	26.2		516	20.3		156	140	
Baseline_Rainfed_Fertilized	0	0.0		324	12.7		254	227	
Baseline_Rainfed_Non-fertilized	0	0.0		326	12.9		126	112	
SSP585_Irrigated_Fertilized	701	27.6	5.7	522	20.5	1.3	406	363	2.4
SSP585_Irrigated_Non-fertilized	703	27.7	5.7	523	20.6	1.3	157	140	0.6
SSP585_Rainfed_Fertilized	0	0.0		305	12.0	-5.6	218	194	-14.3
SSP585_Rainfed_Non-fertilized	0	0.0		304	12.0	-6.8	95	85	-24.1

Note: The percent change is between the SSP585 future climate scenario and the corresponding baseline climate scenario.

Figure 7 shows the Alachua County a) average simulated bahiagrass production and b) future bahiagrass production change. Table 12 shows the average maximum air temperature, minimum air temperature, atmospheric CO_2 concentration, and precipitation for bahiagrass under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2026 to 2035) for the four management treatments. Table 13 shows the average simulated cumulative irrigation, ET, and N uptake for bahiagrass under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2026 to 2035) for the four management treatments.

The aboveground biomass for bahiagrass is representative of the total herbage (i.e., yield) harvested throughout the season. Figure 7b shows future projected bahiagrass yield increases are due to the increased atmospheric CO_2 concentrations that benefit grasses. This CO_2 fertilization effect paired with the abiotic stress resiliency and low-input adaptability in bahiagrass mitigates the impact of heat stress from the warmer temperatures (Table 12). Due to the projected slight increase in seasonal rainfall, simulated irrigation only increased by 3 and 2 percent in the well-fertilized and non-fertilized treatments, respectively, to mitigate water deficit stress (Table 13). The rainfed treatments had lower yield gains compared to the irrigated treatments because of the increased water deficit stress affecting the growth. The 1-percent increase in N uptake for all future treatments indicates that crop N demand is similar to the baseline N uptake, which suggests that no increase in N fertilization will be necessary to achieve the simulated future yields.

Figure 7 Average Simulated Bahiagrass Production and Future (2026 to 2035) Production Change



Note: The average simulated herbage, i.e., yield, are shown for the four management treatments under the baseline climate scenario from 2005 to 2014 (solid bars) and the SSP585 future climate scenario from 2026 to 2035 (dashed bars). Error bars show the standard deviation of the simulated yield. The production change was calculated as the percent change between the SSP585 future climate scenario and the baseline climate scenario for the average simulated yield of each of the four management treatments (labeled).

Table 3 Simulated Bahiagrass Seasonal Climate Variables for the Baseline (2005 to 2014) and SSP585 Future (2026 to 2035) Climate Scenarios

Treatment	Maximum Temperature (°C)	Minimum Temperature (°C)	CO_2 (ppm)	Precipitation (mm)	Precipitation (inches)
Baseline_Irrigated_Fertilized	28.8	16.5	388.7	1,295.6	51.0
Baseline_Irrigated_Non-fertilized	28.8	16.5	388.7	1,295.6	51.0
Baseline_Rainfed_Fertilized	28.8	16.5	388.7	1,295.6	51.0
Baseline_Rainfed_Non-fertilized	28.8	16.5	388.7	1,295.6	51.0
SSP585_Irrigated_Fertilized	29.0	16.8	456.1	1,337.9	52.7
SSP585_Irrigated_Non-fertilized	29.0	16.8	456.1	1,337.9	52.7
SSP585_Rainfed_Fertilized	29.0	16.8	456.1	1,337.9	52.7
SSP585_Rainfed_Non-fertilized	29.0	16.8	456.1	1,337.9	52.7

Table 4 Simulated cumulative Bahiagrass Irrigation, ET, and N Uptake for the Baseline (2005 to 2014) and SSP585 Future (2026 to 2035) Climate Scenarios

Treatment	Irrigation (mm)	Irrigation (inches)	% Change	ET (mm)	ET (inches)	% Change	N Uptake (kg N ha^{-1})	N Uptake (lb N ac^{-1})	% Change
Baseline_Irrigated_Fertilized	647	25.5		1,303	51.3		825	736	
Baseline_Irrigated_Non-fertilized	680	26.8		1,271	50.0		147	131	
Baseline_Rainfed_Fertilized	0	0.0		1,021	40.2		796	711	
Baseline_Rainfed_Non-fertilized	0	0.0		972	38.3		167	149	
SSP585_Irrigated_Fertilized	667	26.2	3.1	1,311	51.6	0.6	835	746	1.3
SSP585_Irrigated_Non-fertilized	696	27.4	2.3	1,275	50.2	0.4	148	132	0.3
SSP585_Rainfed_Fertilized	0	0.0		993	39.1	-2.8	805	719	1.1
SSP585_Rainfed_Non-fertilized	0	0.0		936	36.8	-3.7	168	150	0.4

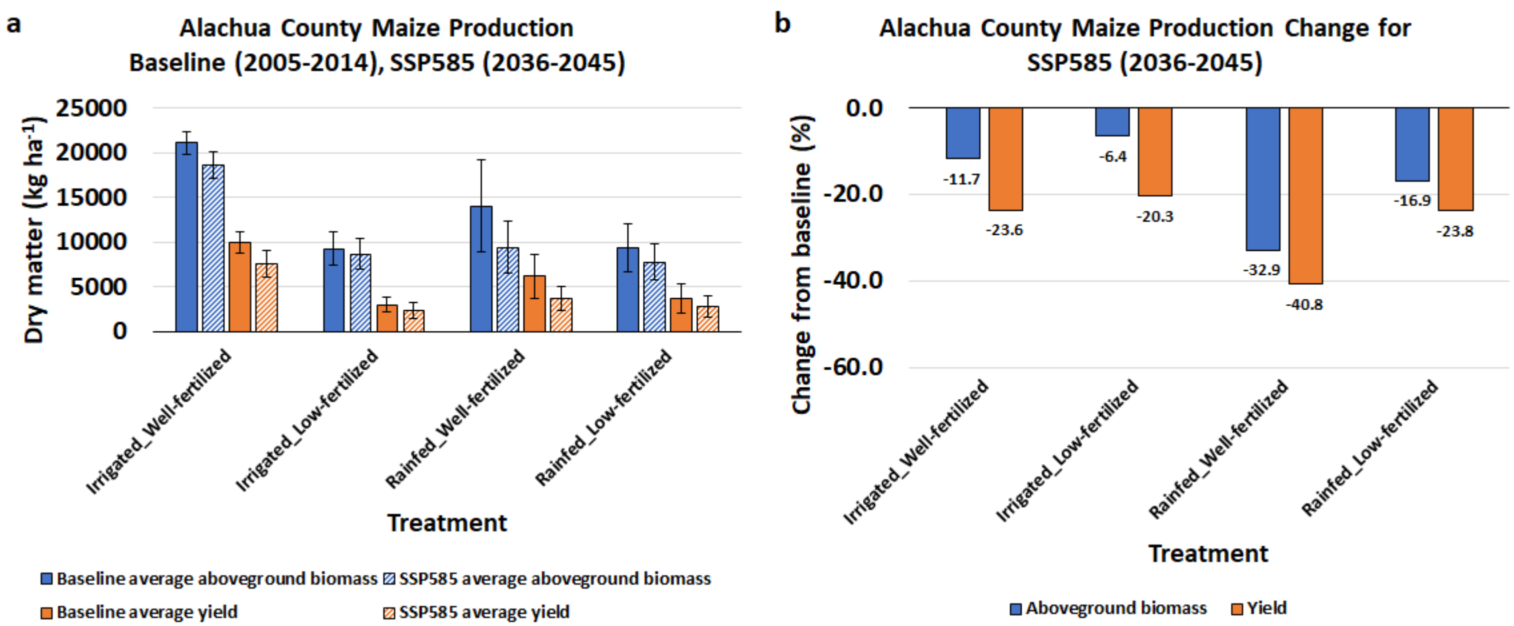
Note: The percent change is between the SSP585 future climate scenario and the corresponding baseline climate scenario.

3.4 Climate Change Assessment for 2040 (2036 to 2045)

Figure 8 shows the Alachua County a) average simulated maize production and b) future maize production change. Table 14 shows the average simulated growing season, seasonal maximum air temperature, minimum air temperature, atmospheric CO_2 concentration, and precipitation for maize under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2036 to 2045) for the four management treatments. Table 15 shows the average simulated cumulative seasonal irrigation, ET, and N uptake for maize under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2036 to 2045) for the four management treatments.

This assessment is for the future period from 2036 to 2045. Figure 8b shows future projected maize yield losses due to the higher projected future seasonal temperatures leading to increased heat stress and faster phenological development (i.e., reduced growing seasons across all treatments by 3 to 7 days) and the reduced seasonal rainfall resulting in increased water deficit stress in the rainfed treatments (Table 14). Simulated yield losses are higher than the simulated aboveground biomass losses because the reproductive growth stage is more sensitive to abiotic stresses than the vegetative growth stages and requires a higher demand of resources for seed development. To mitigate water deficit stress from the projected reduced seasonal rainfall, simulated irrigation increased 16 and 14 percent in the well-fertilized and low-fertilized treatments, respectively (Table 15). The decrease in future N uptake compared to the baseline treatments is driven by the lower N demand from the decreased crop growth. The small increase in N uptake for the irrigated and low-fertilized treatments is not significant because of the low overall uptake (i.e., 73 lb N ac^{-1} versus 77 lb N ac^{-1}), and the focus should be on the well-fertilized treatments.

Figure 8 Average Simulated Maize Production and Future (2036 to 2045) Production Change



Notes: The average simulated aboveground biomass (blue bars) and average simulated yield (orange bars) are shown for the four management treatments under the baseline climate scenario from 2005 to 2014 (solid bars) and the SSP585 future climate scenario from 2036 to 2045 (dashed bars). Error bars show the standard deviation of the simulated aboveground biomass and yield. The production change was calculated as the percent change between the SSP585 future climate scenario and the baseline climate scenario for the average simulated aboveground biomass and yield of each of the four management treatments (labeled).

Table 54 Simulated Maize Seasonal Climate Variables for the Baseline (2005 to 2014) and SSP585 Future (2036-2045) Climate Scenarios

Treatment	Growing Season (days)	Maximum Temperature (°C)	Minimum Temperature (°C)	CO_2 (ppm)	Precipitation (mm)	Precipitation (inches)
Baseline_Irrigated_Well-fertilized	115	30.9	18.2	388.4	493.2	19.4
Baseline_Irrigated_Low-fertilized	115	30.9	18.2	388.4	493.2	19.4
Baseline_Rainfed_Well-fertilized	119	31.0	18.3	388.4	516.9	20.3
Baseline_Rainfed_Low-fertilized	119	31.0	18.3	388.4	516.9	20.3
SSP585_Irrigated_Well-fertilized	112	31.8	18.6	505.1	469.0	18.5
SSP585_Irrigated_Low-fertilized	112	31.8	18.6	505.1	469.0	18.5
SSP585_Rainfed_Well-fertilized	112	31.9	18.6	505.1	472.5	18.6
SSP585_Rainfed_Low-fertilized	112	31.9	18.6	505.1	472.5	18.6

Table 65 Simulated Cumulative Maize Irrigation, ET, and N Uptake for the Baseline (2005 to 2014) and SSP585 Future (2036 to 2045) Climate Scenarios

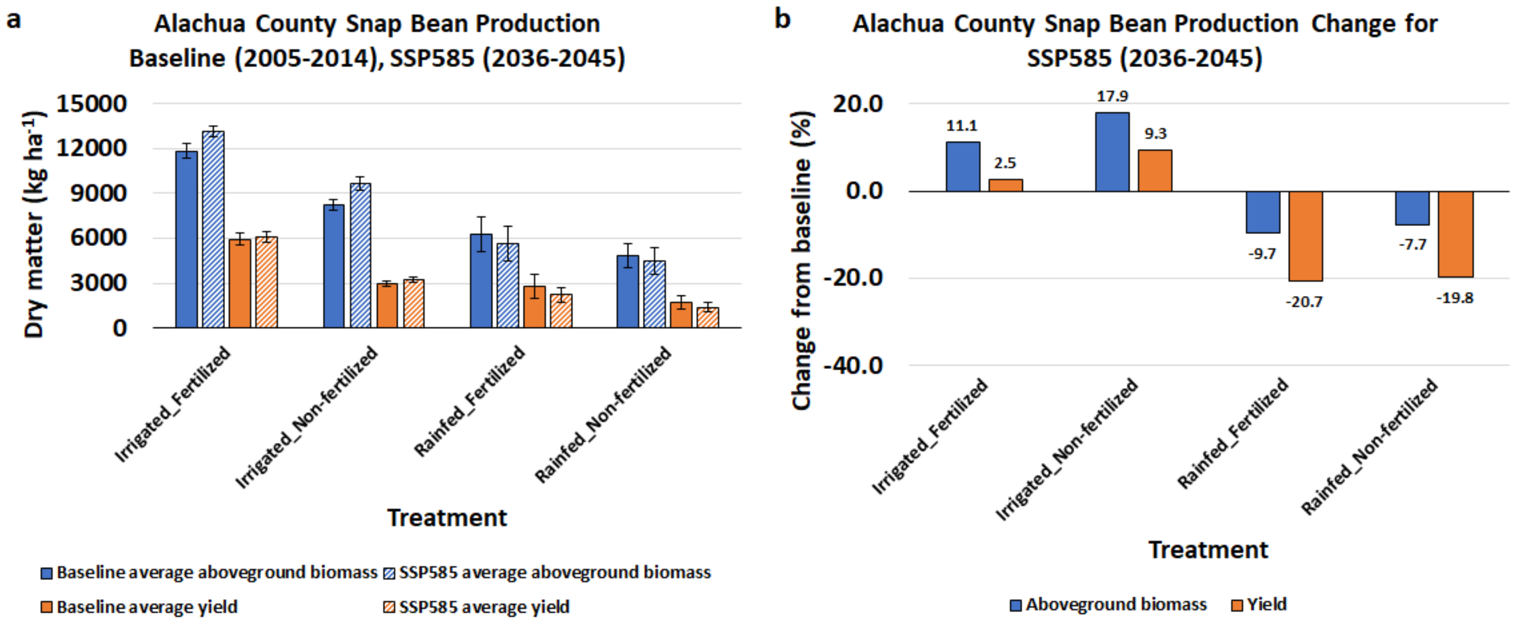
Treatment	Irrigation (mm)	Irrigation (inches)	% Change	ET (mm)	ET (inches)	% Change	N Uptake (kg N ha^{-1})	N Uptake (lb N ac^{-1})	% Change
Baseline_Irrigated_Well-fertilized	222	8.7		499	19.7		253	226	
Baseline_Irrigated_Low-fertilized	232	9.1		479	18.9		82	73	
Baseline_Rainfed_Well-fertilized	0	0.0		372	14.7		188	168	
Baseline_Rainfed_Low-fertilized	0	0.0		367	14.4		93	83	
SSP585_Irrigated_Well-fertilized	266	10.5	16.4	500	19.7	0.1	244	218	-3.7
SSP585_Irrigated_Low-fertilized	269	10.6	13.6	482	19.0	0.7	86	77	5.0
SSP585_Rainfed_Well-fertilized	0	0.0		301	11.8	-23.9	137	122	-37.2
SSP585_Rainfed_Low-fertilized	0	0.0		301	11.9	-21.8	87	77	-6.9

Note: The percent change is between the SSP585 future climate scenario and the corresponding baseline climate scenario.

Figure 9 shows the Alachua County a) average simulated snap bean production and b) future snap bean production change. Table 16 shows the average simulated growing season, seasonal maximum air temperature, minimum air temperature, atmospheric CO_2 concentration, and precipitation for snap bean under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2036 to 2045) for the four management treatments. Table 17 shows the average simulated cumulative seasonal irrigation, ET, and N uptake for snap bean under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2036 to 2045) for the four management treatments. The values represent the combined spring and fall harvests.

The total snap bean production includes two harvests per year, one in spring and one in fall. Figure 9b shows future projected annual snap bean yield losses due to the higher projected seasonal temperatures leading to increased heat stress and reduced seasonal rainfall resulting in increased water deficit stress in the rainfed treatments (Table 16). The decrease in rainfall during the spring growing season resulted in higher water deficit stress and lower yields in the spring harvest, which on average produced more than the fall harvest. The simulated aboveground biomass and yield gain for the irrigated treatments is due to the increased CO_2 fertilization and the reduced water deficit stress affecting crop growth and the rainfed treatments experienced higher water deficit stress. The simulated aboveground biomass gains are larger than the yield gains because of the resiliency to abiotic stresses in the vegetative stages compared to the more sensitive reproductive stage. Due to the projected decrease in seasonal rainfall, simulated irrigation increased 11 percent in the fertilized and non-fertilized treatments to mitigate water deficit stress (Table 17), which is higher than the simulated irrigation increases from 2026-2035 (6%). The increase in N uptake for the future irrigated treatments compared to baseline irrigated treatments indicates a higher crop N demand, which suggests that increased N fertilization will be necessary when applying irrigation to achieve the simulated future yields. The projected increase in N uptake for the fertilized treatments for 2036-2045 is higher than the projected N uptake for 2026-2035 because of the higher simulated biomass production leading to increased N demand. The negligible increase in N uptake for the future rainfed treatments indicates that crop N demand was similar to the baseline N uptake suggesting that no increase in N fertilization will be necessary under non-irrigated conditions to achieve the simulated future yields.

Figure 9 Average Simulated Snap Bean Production and Future (2036 to 2045) Production Change



Notes: The average simulated aboveground biomass (blue bars) and average simulated yield (orange bars) are shown for the four management treatments under the baseline climate scenario from 2005 to 2014 (solid bars) and the SSP585 future climate scenario from 2036 to 2045 (dashed bars). Error bars show the standard deviation of the simulated aboveground biomass and yield. The production change was calculated as the percent change between the SSP585 future climate scenario and the baseline climate scenario for the average simulated aboveground biomass and yield of each of the four management treatments (labeled).

Table 76 Simulated Snap Bean Seasonal Climate Variables for the Baseline (2005 to 2014) and SSP585 Future (2036 to 2045) Climate Scenarios

Treatment	Growing Season (days)	Maximum Temperature (°C)	Minimum Temperature (°C)	CO_2 (ppm)	Precipitation (mm)	Precipitation (inches)
Baseline_Irrigated_Fertilized	69	30.3	18.2	388.7	250.8	9.9
Baseline_Irrigated_Non-fertilized	69	30.3	18.2	388.7	250.8	9.9
Baseline_Rainfed_Fertilized	68	30.4	18.3	388.7	252.9	10.0
Baseline_Rainfed_Non-fertilized	68	30.4	18.3	388.7	252.2	9.9
SSP585_Irrigated_Fertilized	69	31.3	18.9	505.9	236.8	9.3
SSP585_Irrigated_Non-fertilized	69	31.3	18.9	505.9	236.8	9.3
SSP585_Rainfed_Fertilized	68	31.3	18.9	505.9	229.5	9.0
SSP585_Rainfed_Non-fertilized	69	31.3	18.9	505.9	231.0	9.1

Table 8 Simulated Cumulative Snap Bean Irrigation, ET, and N Uptake for the Baseline (2005 to 2014) and SSP585 Future (2036 to 2045) Climate Scenarios

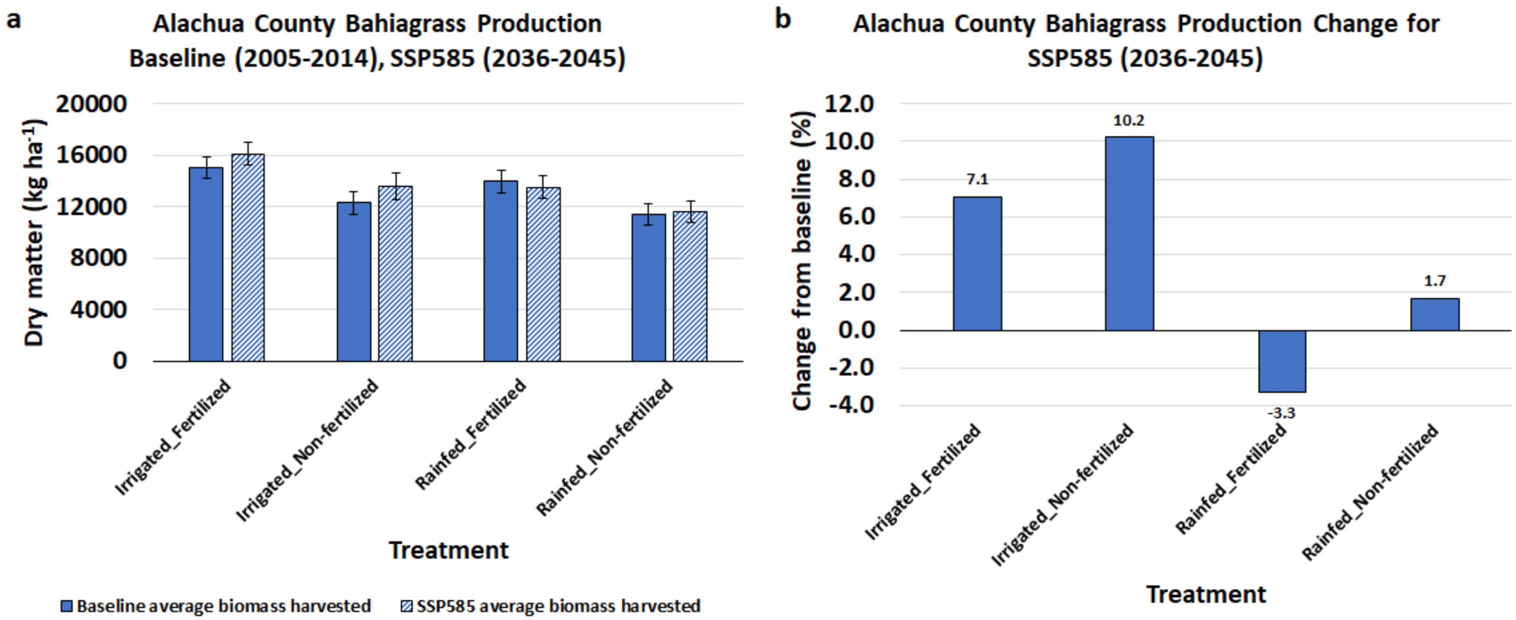
Treatment	Irrigation (mm)	Irrigation (inches)	% Change	ET (mm)	ET (inches)	% Change	N Uptake (kg N ha^{-1})	N Uptake (lb N ac^{-1})	% Change
Baseline_Irrigated_Fertilized	663	26.1		515	20.3		397	354	
Baseline_Irrigated_Non-fertilized	665	26.2		516	20.3		156	140	
Baseline_Rainfed_Fertilized	0	0.0		324	12.7		254	227	
Baseline_Rainfed_Non-fertilized	0	0.0		326	12.9		126	112	
SSP585_Irrigated_Fertilized	737	29.0	11.2	532	20.9	3.2	446	398	12.4
SSP585_Irrigated_Non-fertilized	739	29.1	11.1	533	21.0	3.2	176	157	12.5
SSP585_Rainfed_Fertilized	0	0.0		304	12.0	-6.1	241	215	-5.1
SSP585_Rainfed_Non-fertilized	0	0.0		306	12.1	-6.1	119	106	-5.3

Note: The percent change is between the SSP585 future climate scenario and the corresponding baseline climate scenario.

Figure 10 shows the Alachua County a) average simulated bahiagrass production and b) future bahiagrass production change. Table 18 shows the simulated average of maximum air temperature, minimum air temperature, atmospheric CO_2 concentration, and precipitation for bahiagrass under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2036 to 2045) for the four management treatments. Table 19 shows the average simulated cumulative irrigation, ET, and N uptake for bahiagrass under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2036 to 2045) for the four management treatments.

The aboveground biomass for bahiagrass is representative of the herbage (i.e., yield) harvested throughout the season. Figure 10b shows the future projected bahiagrass yield increases due to the increased atmospheric CO_2 concentrations that benefit grasses. This CO_2 fertilization effect paired with the abiotic stress resiliency in bahiagrass mitigates the impact of heat stress from the warmer temperatures (Table 18). Due to the projected slight decrease in seasonal rainfall, simulated irrigation increased 7 and 5 percent in the well-fertilized and non-fertilized treatments, respectively, to mitigate water deficit stress (Table 19). The rainfed treatments had lower yield gains compared to the irrigated treatments due to the increased water deficit stress limiting the growth. The increase in N uptake for the future irrigated treatments compared to the baseline irrigated treatments indicates a higher crop N demand due to increased biomass/leaf tissue growth suggesting that increased N fertilization will be necessary when applying irrigation to achieve the simulated future yields. The negligible increase in N uptake for the future rainfed treatments indicates that crop N demand was similar to the baseline N uptake, which suggests that no increase in N fertilization will be necessary under non-irrigated conditions to achieve the simulated future yields.

Figure *10*   Average Simulated Bahiagrass Production and Future (2036 to 2045) Production Change



Notes: The average simulated herbage (i.e., yield) are shown for the four management treatments under the baseline climate scenario from 2005 to 2014 (solid bars) and the SSP585 future climate scenario from 2036 to 2045 (dashed bars). Error bars show the standard deviation of the simulated yield. The production change was calculated as the percent change between the SSP585 future climate scenario and the baseline climate scenario for the average simulated yield of each of the four management treatments (labeled).

Table 18 Simulated Bahiagrass Seasonal Climate Variables for the Baseline (2005 to 2014) and SSP585 Future (2036 to 2045) Climate Scenarios

Treatment	Maximum Temperature (°C)	Minimum Temperature (°C)	CO_2 (ppm)	Precipitation (mm)	Precipitation (inches)
Baseline_Irrigated_Fertilized	28.8	16.5	388.7	1,295.6	51.0
Baseline_Irrigated_Non-fertilized	28.8	16.5	388.7	1,295.6	51.0
Baseline_Rainfed_Fertilized	28.8	16.5	388.7	1,295.6	51.0
Baseline_Rainfed_Non-fertilized	28.8	16.5	388.7	1,295.6	51.0
SSP585_Irrigated_Fertilized	29.7	17.4	506.0	1,269.9	50.0
SSP585_Irrigated_Non-fertilized	29.7	17.4	506.0	1,269.9	50.0
SSP585_Rainfed_Fertilized	29.7	17.4	506.0	1,269.9	50.0
SSP585_Rainfed_Non-fertilized	29.7	17.4	506.0	1,269.9	50.0

Table 19 Simulated cumulative Bahiagrass Irrigation, ET, and N Uptake for the Baseline (2005 to 2014) and SSP585 Future (2036 to 2045) Climate Scenarios

Treatment	Irrigation (mm)	Irrigation (inches)	% Change	ET (mm)	ET (inches)	% Change	N Uptake (kg N ha^{-1})	N Uptake (lb N ac^{-1})	% Change
Baseline_Irrigated_Fertilized	647	25.5		1,303	51.3		825	736	
Baseline_Irrigated_Non-fertilized	680	26.8		1,271	50.0		147	131	
Baseline_Rainfed_Fertilized	0	0.0		1,021	40.2		796	711	
Baseline_Rainfed_Non-fertilized	0	0.0		972	38.3		167	149	
SSP585_Irrigated_Fertilized	691	27.2	6.8	1,321	52.0	1.4	847	757	2.8
SSP585_Irrigated_Non-fertilized	712	28.0	4.6	1,284	50.5	1.0	157	140	6.7
SSP585_Rainfed_Fertilized	0	0.0		991	39.0	-2.9	800	714	0.5
SSP585_Rainfed_Non-fertilized	0	0.0		949	37.4	-2.4	167	149	-0.2

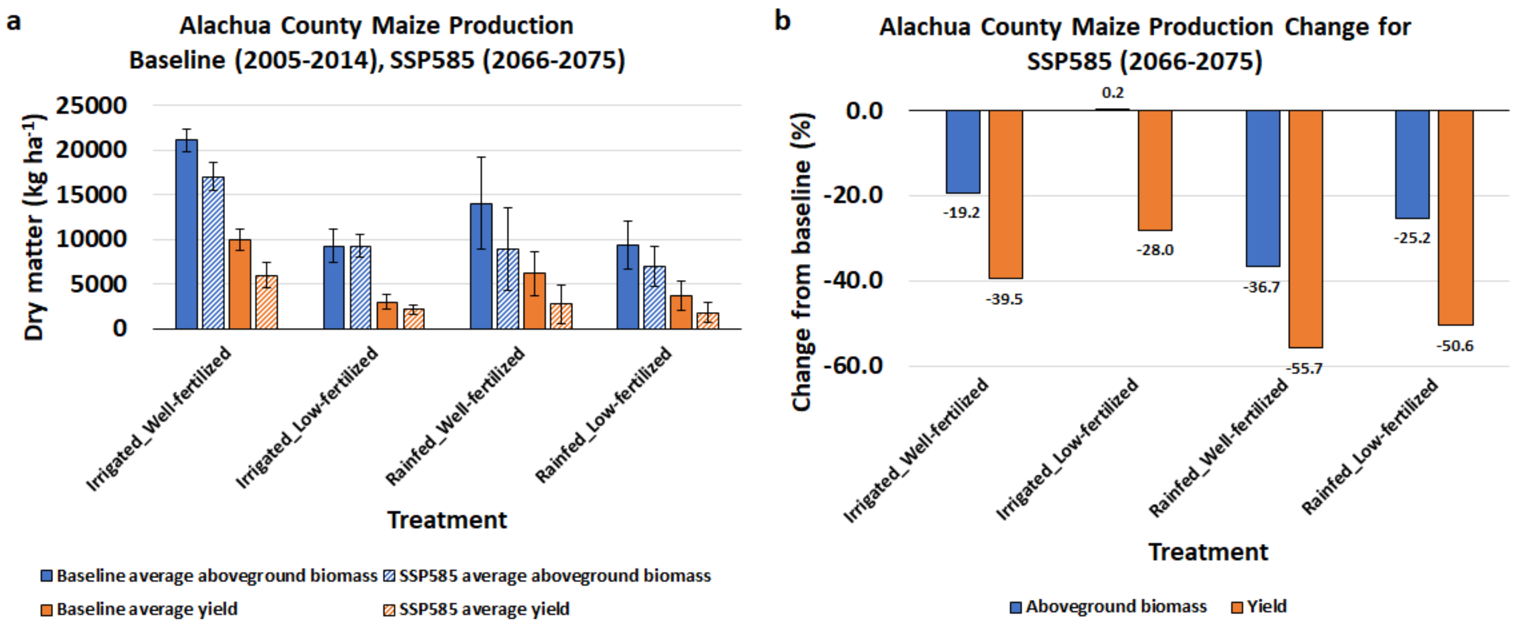
Note: The percent change is between the SSP585 future climate scenario and the corresponding baseline climate scenario.

3.5 Climate Change Assessment for 2070 (2066 to 2075)

Figure 11 shows the Alachua County a) average simulated maize production and b) future production change. Table 20 shows the average simulated growing season, seasonal maximum air temperature, minimum air temperature, atmospheric CO_2 concentration, and precipitation for maize under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2066 to 2075) for the four management treatments. Table 21 shows the average simulated cumulative seasonal irrigation, ET, and N uptake for maize under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2066 to 2075) for the four management treatments.

This assessment examined the future period from 2066 to 2075. Figure 11b shows future projected maize yield losses due to the higher projected future seasonal temperatures leading to increased heat stress and faster phenological development (i.e., reduced growing seasons across all treatments by 9 to 11 days) and the reduced seasonal rainfall resulting in increased water deficit stress in the rainfed treatments (Table 20). Simulated yield losses are higher than the simulated aboveground biomass losses because the reproductive growth stage is more sensitive to abiotic stresses than the vegetative stage and requires a higher demand of resources for seed development. To mitigate water deficit stress from the projected reduced seasonal rainfall, simulated irrigation increased 18 and 15 percent in the well-fertilized and low-fertilized treatments, respectively (Table 21). The decrease in future N uptake compared to the baseline treatments is driven by the lower N demand from decreased crop growth. The increase in N uptake for the irrigated and low-fertilized treatment is not significant because of the low overall uptake (i.e., 73 lb N ac^{-1} versus 84 lb N ac^{-1}), and the focus should be on the well-fertilized treatments.

Figure 11 Average Simulated Maize Production and Future (2066 to 2075) Production Change



Notes: The average simulated aboveground biomass (blue bars) and average simulated yield (orange bars) are shown for the four management treatments under the baseline climate scenario from 2005 to 2014 (solid bars) and the SSP585 future climate scenario from 2066 to 2075 (dashed bars). Error bars show the standard deviation of the simulated aboveground biomass and yield. The production change was calculated as the percent change between the SSP585 future climate scenario and the baseline climate scenario for the average simulated aboveground biomass and yield of each of the four management treatments (labeled).

Table 9 **Simulated Maize Seasonal Climate Variables for the Baseline (2005 to 2014) and SSP585 Future (2066 to 2075) Climate Scenario**

Treatment	Growing Season (days)	Maximum Temperature (°C)	Minimum Temperature (°C)	CO_2 (ppm)	Precipitation (mm)	Precipitation (inches)
Baseline_Irrigated_Well-fertilized	115	30.9	18.2	388.4	493.2	19.4
Baseline_Irrigated_Low-fertilized	115	30.9	18.2	388.4	493.2	19.4
Baseline_Rainfed_Well-fertilized	119	31.0	18.3	388.4	516.9	20.3
Baseline_Rainfed_Low-fertilized	119	31.0	18.3	388.4	516.9	20.3
SSP585_Irrigated_Well-fertilized	106	33.4	19.8	753.3	344.7	13.6
SSP585_Irrigated_Low-fertilized	106	33.4	19.8	753.3	344.7	13.6
SSP585_Rainfed_Well-fertilized	107	33.4	19.9	753.3	360.5	14.2
SSP585_Rainfed_Low-fertilized	107	33.4	19.9	753.3	360.5	14.2

Table 10 **Simulated Cumulative Maize Irrigation, ET, N Uptake for the Baseline (2005 to 2014) and SSP585 Future (2066 to 2075) Climate Scenarios**

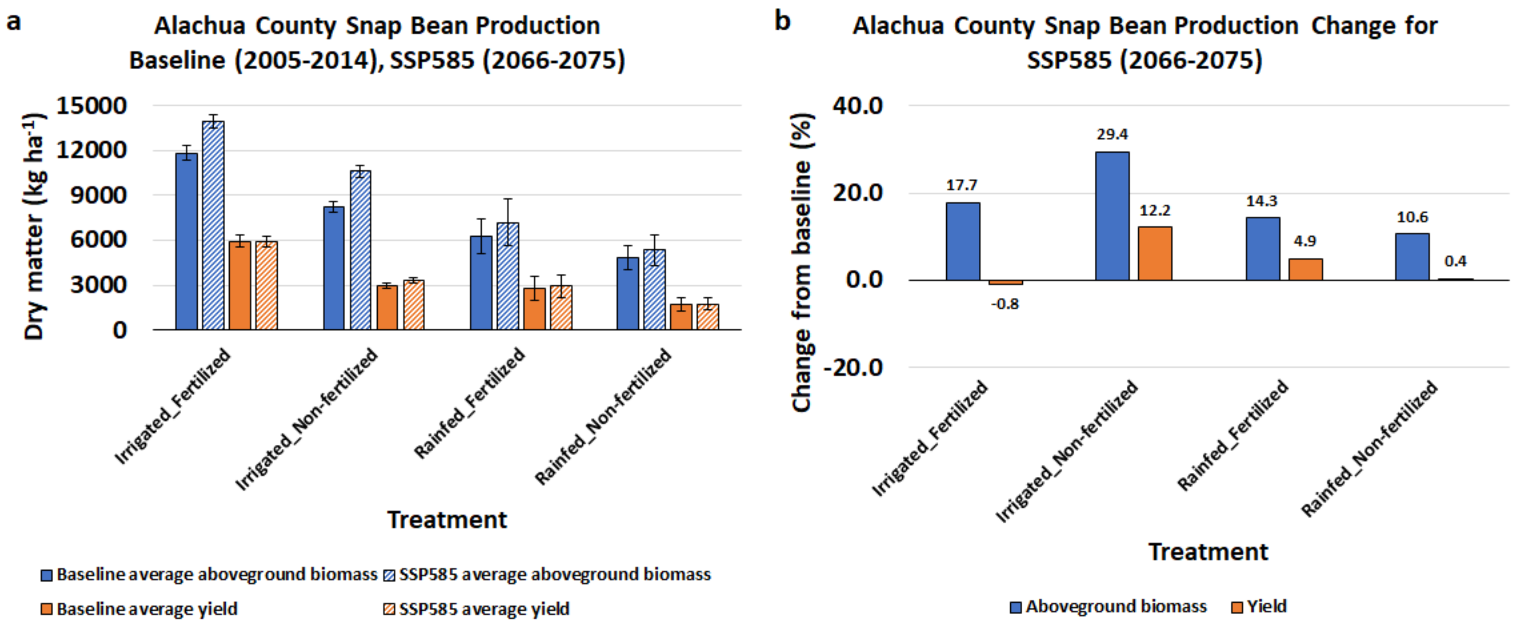
Treatment	Irrigation (mm)	Irrigation (inches)	% Change	ET (mm)	ET (inches)	% Change	N Uptake (kg N ha^{-1})	N Uptake (lb N ac^{-1})	% Change
Baseline_Irrigated_Well-fertilized	222	8.7		499	19.7		253	226	
Baseline_Irrigated_Low-fertilized	232	9.1		479	18.9		82	73	
Baseline_Rainfed_Well-fertilized	0	0.0		372	14.7		188	168	
Baseline_Rainfed_Low-fertilized	0	0.0		367	14.4		93	83	
SSP585_Irrigated_Well-fertilized	269	10.6	17.5	487	19.2	-2.6	231	206	-9.5
SSP585_Irrigated_Low-fertilized	272	10.7	14.5	475	18.7	-0.9	95	84	13.2
SSP585_Rainfed_Well-fertilized	0	0.0		296	11.6	-25.9	137	122	-37.6
SSP585_Rainfed_Low-fertilized	0	0.0		295	11.6	-24.4	90	80	-3.2

Note: The percent change is between the SSP585 future climate scenario and the corresponding baseline climate scenario.

Figure 12 shows the Alachua County a) average simulated snap bean production and b) future snap bean production change. Table 22 shows the average simulated growing season, seasonal maximum air temperature, minimum air temperature, atmospheric CO_2 concentration, and precipitation for snap bean under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2066 to 2075) for the four management treatments. Table 23 shows the average simulated cumulative seasonal irrigation, ET, and N uptake for snap bean under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2066 to 2075) for the four management treatments. The values represent the combined spring and fall harvest seasons.

The total snap bean production includes two harvests per year, one in spring and one in fall. Figure 12b shows future projected annual snap bean yield losses are negligible due to the similar seasonal rainfall between the SSP585 and baseline scenarios (Table 22). The simulated aboveground biomass and yield gains for the treatments are due to the increased CO_2 fertilization and the reduced water deficit stress affecting crop growth. The higher simulated aboveground biomass gains compared to the yield gains are due to the resiliency to abiotic stresses in the vegetative growth stages compared to the reproductive stage. Due to the projected slight decrease in seasonal rainfall, simulated irrigation increased 7 percent in the fertilized and non-fertilized treatments to mitigate water deficit stress (Table 23). The increase in N uptake for all the future treatments compared to the baseline treatments indicates a higher crop N demand, which suggests that increased N fertilization will be necessary to achieve the simulated future yields. The increase of N uptake in the non-fertilized treatments is because the simulated growth used more of the initial soil mineral N that was set at the beginning of the simulation. The N uptake percent change in the irrigated and non-fertilized treatment seems large, but that is because the non-fertilized treatments have a low overall N uptake compared to the fertilized treatments.

Figure 12 Average Simulated Snap Bean Production and Future (2066 to 2075) Production Change



Notes: The average simulated aboveground biomass (blue bars) and average simulated yield (orange bars) are shown for the four management treatments under the baseline climate scenario from 2005 to 2014 (solid bars) and the SSP585 future climate scenario from 2066 to 2075 (dashed bars). Error bars show the standard deviation of the simulated aboveground biomass and yield. The production change was calculated as the percent change between the SSP585 future climate scenario and the baseline climate scenario for the average simulated aboveground biomass and yield of each of the four management treatments (labeled).

Table 11 Simulated Snap Bean Seasonal Climate Variables for the Baseline (2005 to 2014) and SSP585 Future (2066 to 2075) Climate Scenarios

Treatment	Growing Season (days)	Maximum Temperature (°C)	Minimum Temperature (°C)	CO_2 (ppm)	Precipitation (mm)	Precipitation (inches)
Baseline_Irrigated_Fertilized	69	30.3	18.2	388.7	250.8	9.9
Baseline_Irrigated_Non-fertilized	69	30.3	18.2	388.7	250.8	9.9
Baseline_Rainfed_Fertilized	68	30.4	18.3	388.7	252.9	10.0
Baseline_Rainfed_Non-fertilized	68	30.4	18.3	388.7	252.2	9.9
SSP585_Irrigated_Fertilized	67	32.8	20.7	755.1	248.9	9.8
SSP585_Irrigated_Non-fertilized	67	32.8	20.7	755.1	248.9	9.8
SSP585_Rainfed_Fertilized	67	32.7	20.7	755.1	249.7	9.8
SSP585_Rainfed_Non-fertilized	67	32.7	20.7	755.1	249.7	9.8

Table 123 Simulated Cumulative Snap Bean Irrigation, ET, and N Uptake for the Baseline (2005 to 2014) and SSP585 Future (2066 to 2075) Climate Scenarios

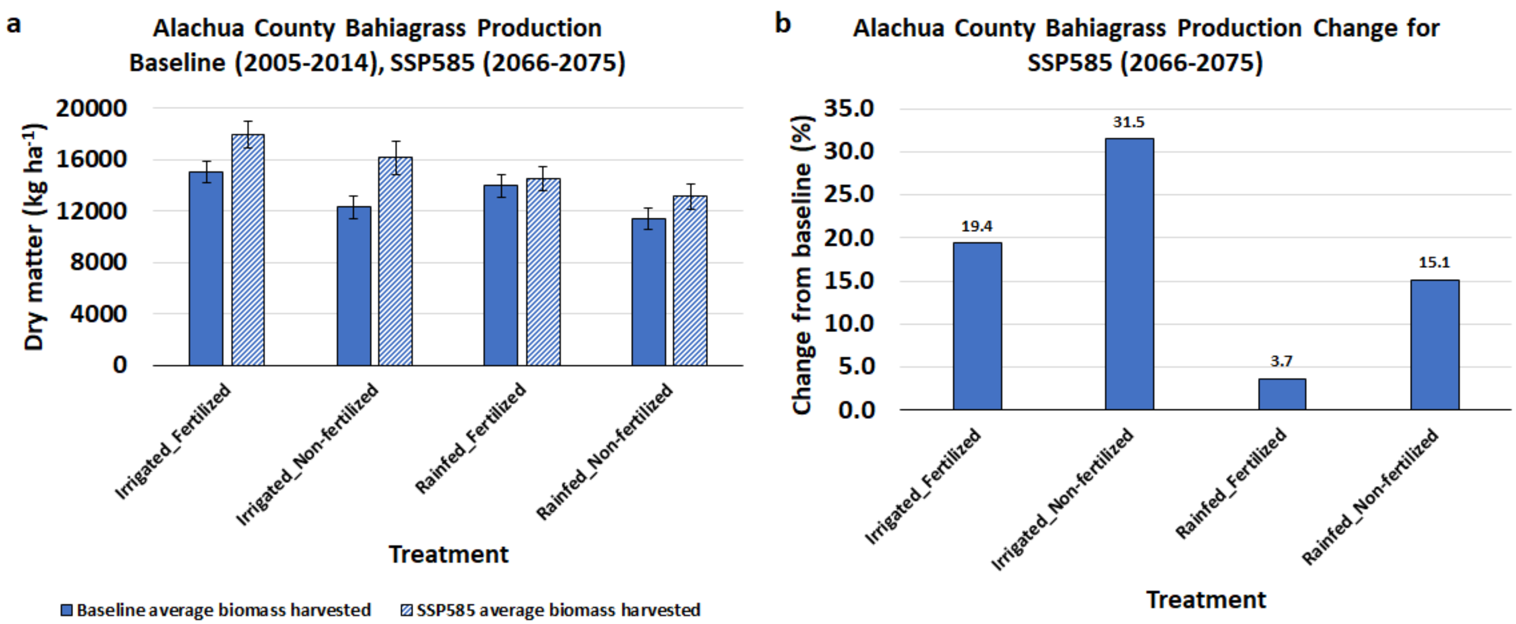
Treatment	Irrigation (mm)	Irrigation (inches)	% Change	ET (mm)	ET (inches)	% Change	N Uptake (kg N ha^{-1})	N Uptake (lb N ac^{-1})	% Change
Baseline_Irrigated_Fertilized	663	26.1		515	20.3		397	354	
Baseline_Irrigated_Non-fertilized	665	26.2		516	20.3		156	140	
Baseline_Rainfed_Fertilized	0	0.0		324	12.7		254	227	
Baseline_Rainfed_Non-fertilized	0	0.0		326	12.9		126	112	
SSP585_Irrigated_Fertilized	709	27.9	7.0	509	20.1	-1.1	472	422	19.1
SSP585_Irrigated_Non-fertilized	710	28.0	6.8	512	20.1	-0.9	194	174	24.3
SSP585_Rainfed_Fertilized	0	0.0		313	12.3	-3.2	294	263	16.0
SSP585_Rainfed_Non-fertilized	0	0.0		312	12.3	-4.4	140	125	11.2

Note: The percent change is between the SSP585 future climate scenario and the corresponding baseline climate scenario.

Figure 13 shows the Alachua County a) average simulated bahiagrass production and b) future bahiagrass production change. Table 24 shows the average maximum air temperature, minimum air temperature, atmospheric CO_2 concentration, and precipitation for bahiagrass under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2066 to 2075) for the four management treatments. Table 25 shows the average simulated cumulative irrigation, ET, and N uptake for bahiagrass under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2066 to 2075) for the four management treatments.

The aboveground biomass for bahiagrass is representative of the herbage (i.e., yield) harvested throughout the season. Figure 13b shows future projected bahiagrass yield increases due to the increased atmospheric CO_2 concentrations that benefit C3 crops and grasses. This CO_2 fertilization effect paired with the abiotic stress resiliency and low-input adaptability in bahiagrass mitigates the impact of heat stress from the warmer temperatures (Table 24). Due to the projected increase in seasonal rainfall, simulated irrigation only increased 1 percent and decreased 4 percent in the well-fertilized and non-fertilized treatments, respectively (Table 25). The increase in N uptake for all future treatments compared to the baseline treatments indicates a higher crop N demand, which suggests that increased N fertilization will be necessary to achieve the simulated future yields. The increase of N uptake in the non-fertilized treatments is because the simulated growth used more of the initial soil mineral N that was set at the beginning of the simulation. The N uptake percent change in the irrigated and non-fertilized treatment seems large, but that is because the non-fertilized treatments have a low overall N uptake compared to the fertilized treatments.

Figure 13 Average Simulated Bahiagrass Production and Future (2066 to 2075) Production Change



Notes: The average simulated herbage (i.e., yield) are shown for the four management treatments under the baseline climate scenario from 2005 to 2014 (solid bars)and the SSP585 future climate scenario from 2066 to 2075 (dashed bars). Error bars show the standard deviation of the simulated yield. The production change was calculated as the percent change between the SSP585 future climate scenario and the baseline climate scenario for the average simulated yield of each of the four management treatments (labeled).

Table 13 Simulated Bahiagrass Seasonal Climate Variables for the Baseline (2005 to 2014) and SSP585 Future (2066 to 2075) Climate Scenarios

Treatment	Maximum Temperature (°C)	Minimum Temperature (°C)	CO_2 (ppm)	Precipitation (mm)	Precipitation (inches)
Baseline_Irrigated_Fertilized	28.8	16.5	388.7	1,295.6	51.0
Baseline_Irrigated_Non-fertilized	28.8	16.5	388.7	1,295.6	51.0
Baseline_Rainfed_Fertilized	28.8	16.5	388.7	1,295.6	51.0
Baseline_Rainfed_Non-fertilized	28.8	16.5	388.7	1,295.6	51.0
SSP585_Irrigated_Fertilized	31.2	19.1	755.4	1,362.6	53.6
SSP585_Irrigated_Non-fertilized	31.2	19.1	755.4	1,362.6	53.6
SSP585_Rainfed_Fertilized	31.2	19.1	755.4	1,362.6	53.6
SSP585_Rainfed_Non-fertilized	31.2	19.1	755.4	1,362.6	53.6

Table 14 Simulated Cumulative Bahiagrass Irrigation, ET, and N Uptake for the Baseline (2005 to 2014) and SSP585 Future (2066 to 2075) Climate Scenarios

Treatment	Irrigation (mm)	Irrigation (inches)	% Change	ET (mm)	ET (inches)	% Change	N Uptake (kg N ha^{-1})	N Uptake (lb N ac^{-1})	% Change
Baseline_Irrigated_Fertilized	647	25.5		1,303	51.3		825	736	
Baseline_Irrigated_Non-fertilized	680	26.8		1,271	50.0		147	131	
Baseline_Rainfed_Fertilized	0	0.0		1,021	40.2		796	711	
Baseline_Rainfed_Non-fertilized	0	0.0		972	38.3		167	149	
SSP585_Irrigated_Fertilized	655	25.8	1.2	1,301	51.2	-0.2	889	793	7.8
SSP585_Irrigated_Non-fertilized	655	25.8	-3.7	1,266	49.8	-0.4	180	161	22.5
SSP585_Rainfed_Fertilized	0	0.0		1,013	39.9	-0.7	852	761	7.0
SSP585_Rainfed_Non-fertilized	0	0.0		963	37.9	-0.9	186	166	11.3

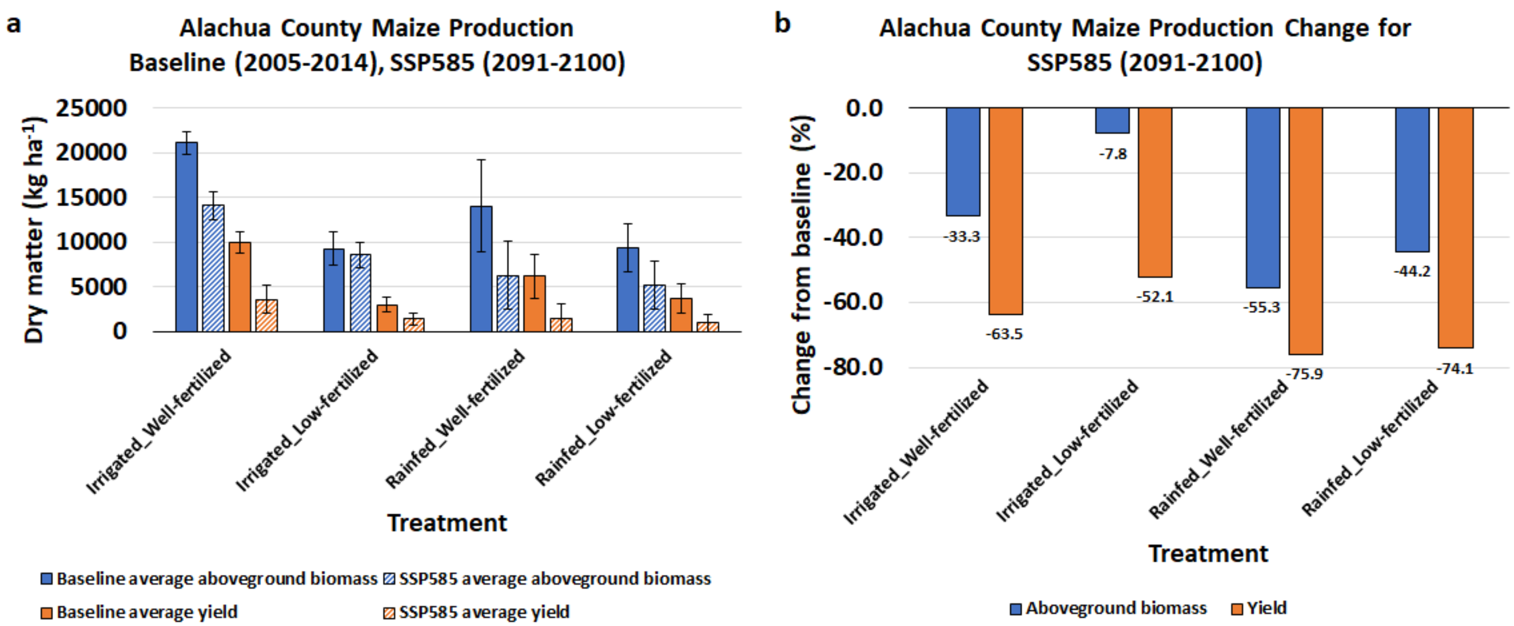
Note: The percent change is between the SSP585 future climate scenario and the corresponding baseline climate scenario.

3.6 CLIMATE CHANGE ASSESSMENT FOR 2100 (2091 TO 2100)

Figure 14 shows the Alachua County a) average simulated maize production and b) future maize production change. Table 26 shows the average simulated growing season, seasonal maximum air temperature, minimum air temperature, atmospheric CO_2 concentration, and precipitation for maize under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2091 to 2100) for the four management treatments. Table 27 shows the average simulated cumulative seasonal irrigation, ET, and N uptake for maize under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2091 to 2100) for the four management treatments.

This assessment examined the future period from 2091 to 2100. Figure 14b shows future projected maize yield losses due to the higher projected future seasonal temperatures leading to increased heat stress and faster phenological development (i.e., reduced growing seasons across all treatments by 15 to 25 days), and the reduced seasonal rainfall resulting in increased water deficit stress in the rainfed treatments (Table 26). Simulated yield losses are higher than the simulated aboveground biomass losses because the reproductive growth stage is more sensitive to abiotic stresses than the vegetative growth stages and requires a higher demand of resources for seed development. To mitigate water deficit stress from the projected decrease in seasonal rainfall, simulated irrigation increased 30 and 26 percent in the well-fertilized and low-fertilized treatments, respectively (Table 27). The decrease in future N uptake compared to the baseline treatments is driven by the lower N demand from decreased crop growth. The increase in N uptake for the irrigated and low-fertilized treatment is not significant because of the low overall uptake (i.e., 73 lb N ac^{-1} versus 84 lb N ac^{-1}), and the focus should be on the well-fertilized treatments.

Figure 14 Average Simulated Maize Production and Future (2091 to 2100) Production Change



Notes: The average simulated aboveground biomass (blue bars) and average simulated yield (orange bars) are shown for the four management treatments under the baseline climate scenario from 2005 to 2014 (solid bars) and the SSP585 future climate scenario from 2091 to 2100 (dashed bars). Error bars show the standard deviation of the simulated aboveground biomass and yield. The production change was calculated as the percent change between the SSP585 future climate scenario and the baseline climate scenario for the average simulated aboveground biomass and yield of each of the four management treatments (labeled).

Table 15 Simulated Maize Seasonal Climate Variables for the Baseline (2005 to 2014) and SSP585 Future (2091 to 2100) Climate Scenarios

Treatment	Growing Season (days)	Maximum Temperature (°C)	Minimum Temperature (°C)	CO_2 (ppm)	Precipitation (mm)	Precipitation (inches)
Baseline_Irrigated_Well-fertilized	115	30.9	18.2	388.4	493.2	19.4
Baseline_Irrigated_Low-fertilized	115	30.9	18.2	388.4	493.2	19.4
Baseline_Rainfed_Well-fertilized	119	31.0	18.3	388.4	516.9	20.3
Baseline_Rainfed_Low-fertilized	119	31.0	18.3	388.4	516.9	20.3
SSP585_Irrigated_Well-fertilized	100	35.0	21.2	1077.1	272.9	10.7
SSP585_Irrigated_Low-fertilized	100	35.0	21.2	1077.1	272.9	10.7
SSP585_Rainfed_Well-fertilized	94	34.8	20.7	1076.9	258.1	10.2
SSP585_Rainfed_Low-fertilized	94	34.8	20.7	1076.9	258.1	10.2

Table 16 Simulated Cumulative Maize Irrigation, ET, and N Uptake for the Baseline (2005 to 2014) and SSP585 Future (2091 to 2100) Climate Scenarios

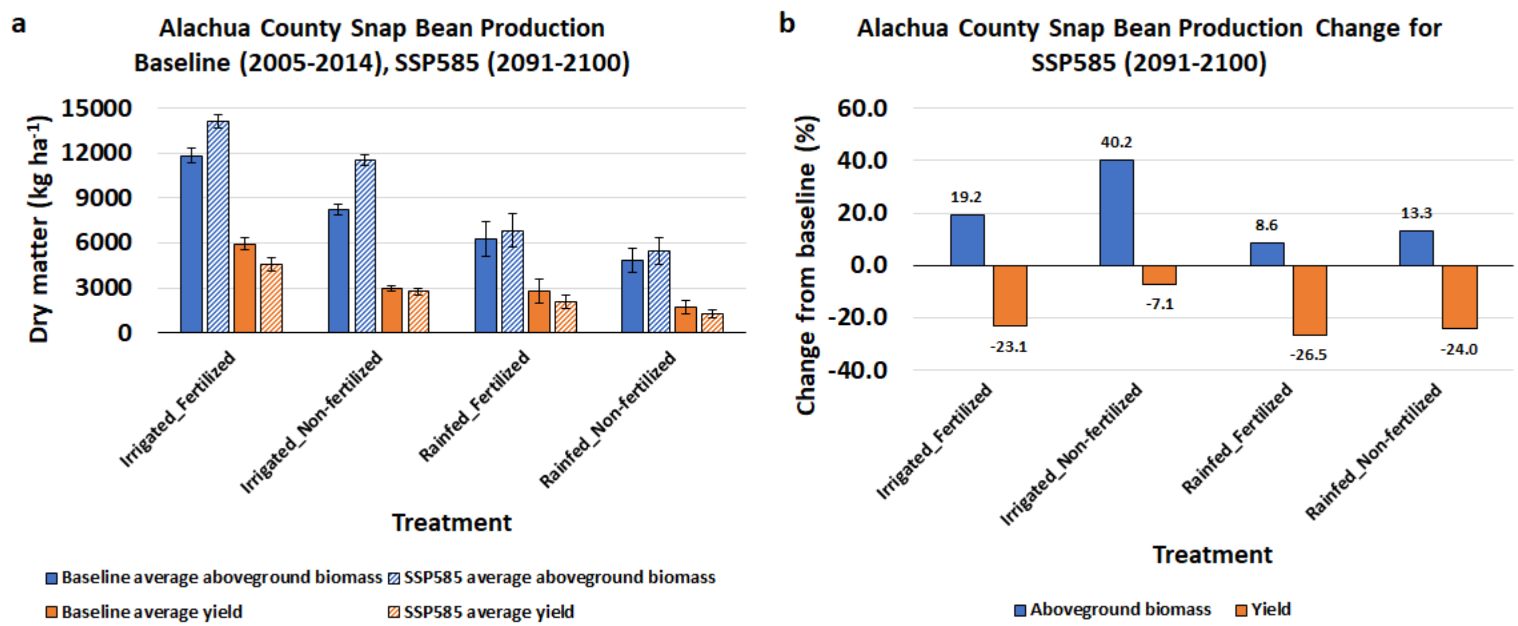
Treatment	Irrigation (mm)	Irrigation (inches)	% Change	ET (mm)	ET (inches)	% Change	N Uptake (kg N ha^{-1})	N Uptake (lb N ac^{-1})	% Change
Baseline_Irrigated_Well-fertilized	222	8.7		499	19.7		253	226	
Baseline_Irrigated_Low-fertilized	232	9.1		479	18.9		82	73	
Baseline_Rainfed_Well-fertilized	0	0.0		372	14.7		188	168	
Baseline_Rainfed_Low-fertilized	0	0.0		367	14.4		93	83	
SSP585_Irrigated_Well-fertilized	315	12.4	29.5	496	19.5	-0.6	197	176	-28.2
SSP585_Irrigated_Low-fertilized	315	12.4	26.3	487	19.2	1.6	94	84	12.8
SSP585_Rainfed_Well-fertilized	0	0.0		229	9.0	-62.7	104	93	-80.8
SSP585_Rainfed_Low-fertilized	0	0.0		231	9.1	-58.8	70	62	-32.5

Note: The percent change is between the SSP585 future climate scenario and the corresponding baseline climate scenario.

Figure 15 shows the Alachua County a) average simulated snap bean production and b) future snap bean production change. Table 28 shows the average simulated growing season, seasonal maximum air temperature, minimum air temperature, atmospheric CO_2 concentration, and precipitation for snap bean under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2091 to 2100) for the four management treatments. Table 29 shows the average simulated cumulative seasonal irrigation, ET, and N uptake for snap bean under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2091 to 2100) for the four management treatments. The values represent the combined spring and fall harvests.

The total snap bean production includes two harvests per year, one in spring and one in fall. Figure 15b shows future projected annual snap bean yield losses due to the higher projected seasonal temperatures leading to increased heat stress (Table 28). The warmer temperatures accelerated phenological development by 2 days for the SSP585 treatments. The simulated aboveground biomass gains in all treatments are due to the increased CO_2 fertilization, the minimal water deficit stress, and the resiliency to heat stress in the vegetative stage compared to the reproductive stage. The simulated yield losses are because of the higher sensitivity to abiotic stresses and higher demand of resources for seed development during the reproductive growth stage. The rainfed treatments had higher yield losses compared to the irrigated treatments because of increased water deficit stress. Simulated irrigation increased 9 percent in the fertilized and non-fertilized treatments to mitigate water deficit stress (Table 29). The increase in N uptake for all the future treatments compared to the baseline treatments indicates a higher crop N demand, which suggests that increased N fertilization will be necessary to achieve the simulated future yields. The increase of N uptake in the non-fertilized treatments is because the simulated growth used more of the initial soil mineral N that was set at the beginning of the simulation. The N uptake percent change in the irrigated and non-fertilized treatment seems large, but that is because the non-fertilized treatments have a low overall N uptake compared to the fertilized treatments.

Figure 15 Average Simulated Snap Bean Production and Future (2091 to 2100) Production Change



Notes: The average simulated aboveground biomass (blue bars) and average simulated yield (orange bars) are shown for the four management treatments under the baseline climate scenario from 2005 to 2014 (solid bars) and the SSP585 future climate scenario from 2091 to 2100 (dashed bars). Error bars show the standard deviation of the simulated aboveground biomass and yield. The production change was calculated as the percent change between the SSP585 future climate scenario and the baseline climate scenario for the average simulated aboveground biomass and yield of each of the four management treatments (labeled).

Table 17 Simulated Snap Bean Seasonal Climate Variables for the Baseline (2005 to 2014) and SSP585 Future (2091 to 2100) Climate Scenarios

Treatment	Growing Season (days)	Maximum Temperature (°C)	Minimum Temperature (°C)	CO_2 (ppm)	Precipitation (mm)	Precipitation (inches)
Baseline_Irrigated_Fertilized	69	30.3	18.2	388.7	250.8	9.9
Baseline_Irrigated_Non-fertilized	69	30.3	18.2	388.7	250.8	9.9
Baseline_Rainfed_Fertilized	68	30.4	18.3	388.7	252.9	10.0
Baseline_Rainfed_Non-fertilized	68	30.4	18.3	388.7	252.2	9.9
SSP585_Irrigated_Fertilized	67	34.2	22.1	1079.1	255.7	10.1
SSP585_Irrigated_Non-fertilized	67	34.2	22.1	1079.1	255.7	10.1
SSP585_Rainfed_Fertilized	66	34.2	22.1	1079.1	254.6	10.0
SSP585_Rainfed_Non-fertilized	66	34.2	22.1	1079.1	254.8	10.0

Table 29 Simulated Cumulative Snap Bean Irrigation, ET, and N Uptake for the Baseline (2005 to 2014) and SSP585 Future (2091 to 2100) Climate Scenarios

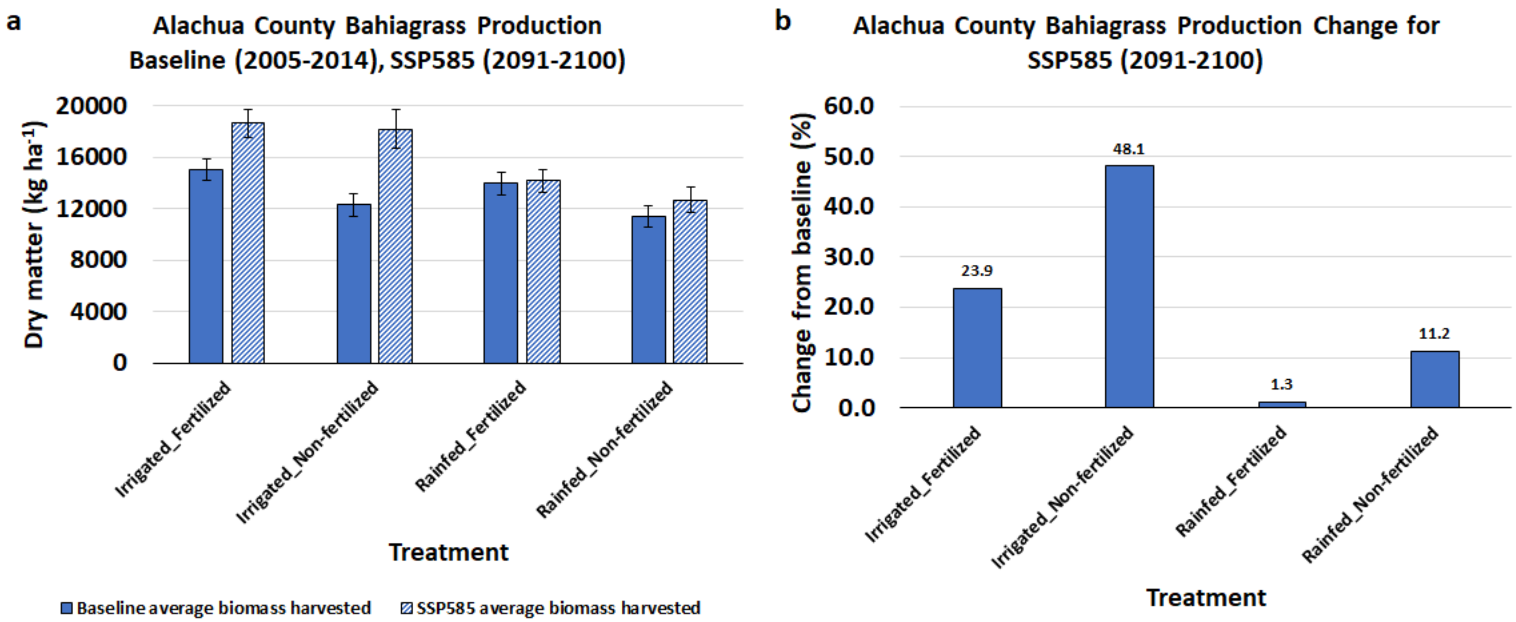
Treatment	Irrigation (mm)	Irrigation (inches)	% Change	ET (mm)	ET (inches)	% Change	N Uptake (kg N ha^{-1})	N Uptake (lb N ac^{-1})	% Change
Baseline_Irrigated_Fertilized	663	26.1		515	20.3		397	354	
Baseline_Irrigated_Non-fertilized	665	26.2		516	20.3		156	140	
Baseline_Rainfed_Fertilized	0	0.0		324	12.7		254	227	
Baseline_Rainfed_Non-fertilized	0	0.0		326	12.9		126	112	
SSP585_Irrigated_Fertilized	722	28.4	8.9	528	20.8	2.4	494	441	24.6
SSP585_Irrigated_Non-fertilized	725	28.5	9.0	530	20.8	2.5	208	186	32.9
SSP585_Rainfed_Fertilized	0	0.0		324	12.8	0.1	288	258	13.7
SSP585_Rainfed_Non-fertilized	0	0.0		323	12.7	-1.0	130	116	3.9

Note: The percent change is between the SSP585 future climate scenario and the corresponding baseline climate scenario.

Figure 16 shows the Alachua County a) average simulated bahiagrass production and b) future bahiagrass production change. Table 30 shows the average maximum air temperature, minimum air temperature, atmospheric CO_2 concentration, and precipitation for bahiagrass under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2091 to 2100) for the four management treatments. Table 32 shows the average simulated cumulative irrigation, ET, and N uptake for bahiagrass under the baseline climate scenario (2005 to 2014) and the SSP585 future climate scenario (2091 to 2100) for the four management treatments.

The aboveground biomass for bahiagrass is representative of the herbage (i.e., yield) harvested throughout the season. Figure 16b shows future projected bahiagrass yield increases due to the increased atmospheric CO_2 concentrations that benefit grasses. This CO_2 fertilization effect paired with the abiotic stress resiliency and low-input adaptability in bahiagrass mitigates the impact of heat stress from the warmer temperatures (Table 30). Simulated irrigation increased 13 and 5 percent in the well-fertilized and non-fertilized treatments, respectively, to mitigate water deficit stress (Table 31). The rainfed treatments had lower yield gains compared to the irrigated treatments because of the increased water deficit stress affecting the growth. The increase in N uptake for all future treatments compared to the baseline treatments indicates a higher crop N demand, which suggests that increased N fertilization will be necessary to achieve the simulated future yields. The increase of N uptake in the non-fertilized treatments is because the simulated growth used more of the initial soil mineral N that was set at the beginning of the simulation. The N uptake percent change in the irrigated and non-fertilized treatment seems large, but that is because the non-fertilized treatments have a low overall N uptake compared to the fertilized treatments.

Figure 16 Average Simulated Bahiagrass Production and Future (2091 to 2100) Production Change



Notes: The average simulated herbage (i.e., yield) are shown for the four management treatments under the baseline climate scenario from 2005 to 2014 (solid bars) and the SSP585 future climate scenario from 2091 to 2100 (dashed bars). Error bars show the standard deviation of the simulated yield. The production change was calculated as the percent change between the SSP585 future climate scenario and the baseline climate scenario for the average simulated yield of each of the four management treatments (labeled).

Table 18 Simulated Bahiagrass Seasonal Climate Variables for Baseline (2005 to 2014) and SSP585 Future (2091 to 2100) Climate Scenarios

Treatment	Maximum Temperature (°C)	Minimum Temperature (°C)	CO_2 (ppm)	Precipitation (mm)	Precipitation (inches)
Baseline_Irrigated_Fertilized	28.8	16.5	388.7	1,295.6	51.0
Baseline_Irrigated_Non-fertilized	28.8	16.5	388.7	1,295.6	51.0
Baseline_Rainfed_Fertilized	28.8	16.5	388.7	1,295.6	51.0
Baseline_Rainfed_Non-fertilized	28.8	16.5	388.7	1,295.6	51.0
SSP585_Irrigated_Fertilized	32.6	20.3	1079.4	1,304.7	51.4
SSP585_Irrigated_Non-fertilized	32.6	20.3	1079.4	1,304.7	51.4
SSP585_Rainfed_Fertilized	32.6	20.3	1079.4	1,304.7	51.4
SSP585_Rainfed_Non-fertilized	32.6	20.3	1079.4	1,304.7	51.4

Table 19 Simulated Cumulative Bahiagrass Irrigation, ET, and N Uptake for the Baseline (2005 to 2014) and SSP585 Future (2091 to 2100) Climate Scenarios

Treatment	Irrigation (mm)	Irrigation (inches)	% Change	ET (mm)	ET (inches)	% Change	N Uptake (kg N ha^{-1})	N Uptake (lb N ac^{-1})	% Change
Baseline_Irrigated_Fertilized	647	25.5		1,303	51.3		825	736	
Baseline_Irrigated_Non-fertilized	680	26.8		1,271	50.0		147	131	
Baseline_Rainfed_Fertilized	0	0.0		1,021	40.2		796	711	
Baseline_Rainfed_Non-fertilized	0	0.0		972	38.3		167	149	
SSP585_Irrigated_Fertilized	729	28.7	12.7	1,384	54.5	6.3	921	822	11.7
SSP585_Irrigated_Non-fertilized	711	28.0	4.5	1,351	53.2	6.3	202	180	37.3
SSP585_Rainfed_Fertilized	0	0.0		968	38.1	-5.2	829	740	4.1
SSP585_Rainfed_Non-fertilized	0	0.0		941	37.1	-3.1	185	165	10.6

Note: The percent change is between the SSP585 future climate scenario and the corresponding baseline climate scenario.

4 CONCLUSION

Overall, significant reductions in maize production, moderate reductions in snap bean production, and moderate increases in bahiagrass production are projected for the County by the end of the century under the SSP585 climate change scenario. These findings are in line with global agricultural assessments used by the IPCC that highlight large yield losses by the end of the century in maize (-24.1 percent), moderate losses in soybean (-2.1 percent) (a legume similar to snap beans), and large gains in wheat (17.5 percent) (a C3 cereal similar to grasses) (Jagermeyr et al., 2021). Maize production in the County is projected to decrease more significantly than the other two crops because the higher temperatures accelerate the phenological development (i.e., reduced time from planting to harvest) and often exceed the crop-limiting temperature threshold (32 °C or 90 °F) resulting in significant heat stress. Additionally, the C4 carbon fixation process within maize does not benefit as much from the CO_2 fertilization effect (increased rate of photosynthesis driven by the increased CO_2 concentrations) as the C3 carbon fixation process within snap bean or grasses. Because of the higher projected seasonal temperatures and reduced seasonal rainfall, increased irrigation will be necessary to mitigate the projected increase in water deficit stress for all three crops as shown in the simulated irrigation management tables. For maize, higher amounts of N fertilization may not be needed because the reduced growth decreased the overall N uptake of the crop. For snap bean, the increased N uptake in the future scenario compared to the baseline scenario suggests that increased N fertilization or improved N use efficiency of the crop will be necessary to achieve the simulated future yields. For bahiagrass, the rainfed and non-fertilized management still increased production by the end of century, so additional management input may not be needed to maintain current levels of production.

Maize production in the County is usually irrigated and well-fertilized. The simulated maize yields under this management are projected to continuously decline, reaching 63.5 percent losses by the end of the century under the SSP585 climate change scenario. These large-yield losses are driven by the combined interaction of heat and water deficit stress, which become increasingly limiting in the maize growing season by the end of century. For the irrigated and well-fertilized treatment to even reach the lower simulated yields, irrigation is projected to steadily increase up to 30%, while N uptake is projected to decrease 28% by the end of the century due to the reduced overall growth and N demand.

Snap bean production in the County is usually irrigated and fertilized. The simulated snap bean yields under this management are projected to increase 2.5 percent by mid-century followed by yield losses of 23.1 percent by the end of the century. This variable response is because the snap bean growth benefits from the increased CO_2 fertilization in the coming decades, but the continuously increasing temperature will eventually mitigate these minimal gains by the end of century. For the irrigated and fertilized treatment, irrigation and N uptake are projected to increase 9% and 25% by the end of the century, respectively. This suggests that increased applications of irrigation and fertilizer, and/or improvements to the crop water- and N- use efficiency, will be required to meet the simulated yields under the SSP585 climate change scenario.

Bahiagrass production in the County is usually rainfed and non-fertilized. The simulated bahiagrass yields under this management are projected to increase 11.2 percent by the end of the century because of the increased CO_2 fertilization and the resiliency of bahiagrass to heat and water deficit stress compared to most other crops. Additionally, the bahiagrass irrigated and fertilized and irrigated and non-fertilized treatments showed increases in production of 24% and 48% by the end of century, respectively. This suggests that the sustainable irrigation of bahiagrass pastures in the coming decades could maximize production under higher CO_2 concentrations, although it may not be necessary.

Overall, these results suggest that current maize and snap bean producers within the County may soon face fundamental challenges to maintain large and profitable production under the SSP585 climate change scenario, which projects the highest temperature and CO_2 concentration increases out of the SSP scenarios. Bahiagrass producers may not face these same production challenges; however, bahiagrass is primarily used for forage instead of for human consumption because of its low nutritive value, and it is not as profitable as maize or snap bean. This assessment did not consider shifts in livestock grazing practices due to climate change that may affect the production of bahiagrass. This assessment focuses on the direct impacts from abiotic stresses caused by climate change (e.g., heat stress, water deficit stress, and nutrient limitation), but there may also be changes in stresses and extreme events not considered within the crop models that may affect crop production (e.g., prevalence of pests, diseases, and/or weeds, lodging from high winds and storms, or flooding). Despite prevailing uncertainties within the climate and crop models, the strong projected decreasing trends in the major field and vegetable crops within the County suggest the need for targeted agricultural production adaptation, and improved risk management (e.g., implementation of improved heat tolerant cultivars and/or earlier/later planting strategies) in the coming decades.

These results assume a constant planting date for maize and snap bean and a scheduled 30-day harvest for bahiagrass, but these standard planting and scheduled harvest dates may change in the future due to warming temperatures. Examining crop production with variable planting dates is possible but takes additional resources and computational time that was outside the scope of this assessment. Planting earlier or later may reduce the heat-stress effects on the crop later in the season (e.g., during the sensitive reproductive stage), potentially mitigating some of the yield losses shown here. However, this adaptation strategy would require further analysis. Additionally, examining the impact of cultivars with improved physiological traits (e.g., increased heat or water deficit stress tolerance or increased harvest index) would also have a large effect on production. To simulate specific cultivars and/or traits with the crop models, observational data from field experiments conducted in the County would be needed for model calibration. This adaptation strategy would also require further analysis.

5 REFERENCES

Bennett JM, Mutti LSM, Rao PSC, and Jones JW. (1989) *Interactive effects of nitrogen and water stresses on biomass accumulation, nitrogen uptake, and seed yield of maize.* Field Crops Research 19 (4):297-311. doi:10.1016/0378-4290(89)90100-7.

Djidonou D. (2008) *Adapting the CROPGRO legume model to simulate growth and fresh market yield of snap bean.* University of Florida, Gainesville, Florida.

FDACS. (2021) *Florida agriculture by the numbers 2020.* Florida Department of Agriculture and Consumer Services, Tallahassee, Florida.

Frey C, Dittmar PJ, Seal DR, Zhang S, Freeman JH, Desaeger J, and Wang Q. (2022) Chapter 11. Legume Production. University of Florida Institute of Food and Agricultural Sciences 2022-2023 *Vegetable Production Handbook of Florida,* vol HS727. UF IFAS, Gainesville, FL. doi:doi.org/10.32473/edis-cv125-2022.

Hochmuth G, and Hanlon E. (2020) *A summary of N, P, and K research with snap bean in Florida*. University of Florida Institute of Food and Agricultural Sciences (SL 331):1-13.

Hoogenboom G, Porter CH, Boote KJ, Shelia V, Wilkens PW, Singh U, White JW, Asseng S, Lizaso JI, Moreno LP, Pavan W, Ogoshi R, Hunt LA, Tsuji GY, and Jones JW. (2019) *The DSSAT crop modeling ecosystem*. In: Boote KJ (ed) Advances in Crop Modeling for a Sustainable Agriculture. Burleigh Dodds Science Publishing, Cambridge, United Kingdom, pp 173-216. doi:10.19103/AS.2019.0061.10.

IPCC. (2021) *Climate Change 2021: The Physical Science Basis.* Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

Jagermeyr J, Muller C, Ruane AC, Elliott J, Balkovic J, Castillo O, Faye B, Foster I, Folberth C, Franke JA, Fuchs K, Guarin JR, Heinke J, Hoogenboom G, Iizumi T, Jain AK, Kelly D, Khabarov N, Lange S, Lin TS, Liu WF, Mialyk O, Minoli S, Moyer EJ, Okada M, Phillips M, Porter C, Rabin SS, Scheer C, Schneider JM, Schyns JF, Skalsky R, Smerald A, Stella T, Stephens H, Webber H, Zabel F, and Rosenzweig C. (2021) *Climate impacts on global agriculture emerge earlier in new generation of climate and crop models*. Nature Food 2 (11):875-+. doi:10.1038/s43016-021-00400-y.

Johnson CR, Reiling BA, Mislevy P, and Hall MB. (2001) *Effects of nitrogen fertilization and harvest date on yield, digestibility, fiber, and protein fractions of tropical grasses*. Journal of Animal Science 79 (9):2439-2448.

Mylavarapu R, Hanlon EA, Mackowiak CL, and Silveira ML. (2019) *Development of bahiagrass fertilization recommendations: 1990–2008*. University of Florida Institute of Food and Agricultural Science (SL-237):1-13.

Natural Resources Conservation Service, United States Department of Agriculture. *Web Soil Survey (2021)* http://websoilsurvey.sc.egov.usda.gov/. Accessed 08/04/2021.

Snodgrass CA, Ozores-Hampton M, Raid R, McAvoy E, and Sui D. (2011) *Snap bean variety evaluation on yield and postharvest quality in Florida sandy and muck soils* .Proceedings of the Florida State Horticultural Society (124):166-169.

United States Department of Agriculture National Agricultural Statistics Service. NASS - Quick Stats (2022) USDA National Agricultural Statistics Service. https://quickstats.nass.usda.gov/. Accessed 09/25/2022.

Wallau M, Vendramini J, Dubeux J, and Blount A. (2019) *Bahiagrass (paspalum notatum Fluegge): Overview and pasture management.* University of Florida Institute of Food and Agricultural Sciences (SS-AGR-332):1-10. doi:doi.org/10.32473/edis-ag342-2019.

Wright D, Small I, Mackowiak C, Grabau Z, Devkota P, and Paula-Moraes S. (2022) *Field Corn Production Guide*. University of Florida Institute of Food and Agricultural Sciences (SS-AGR-85):1-13. doi:doi.org/10.32473/edis-ag202-2022.