Linking Soil and Water Conservation Practices to Greenhouse Gas Flux and Fine Root Dynamics: A Comparison of Sugarcane and Napier Grass Grown for Bioenergy Production

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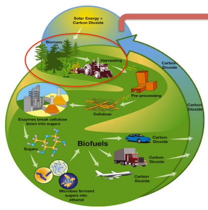
Introduction

Sugarcane (*Saccharum officinarum*) and Napier grass (*Pennisetum purpureum*) are promising candidate species for local biofuel production in the Hawaiian Islands. Both species are warm-season perennial grasses that are known to produce large quantities of biomass under favorable environmental conditions [1,2].



Key Issues

- Increases in greenhouse gas flux from agricultural practices [3]
- Loss of soil organic carbon (SOC) resulting from land-use change [4]
- Identifying the factors responsible for the long-term sustainability of these systems

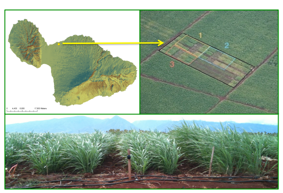
Objectives

1. To determine the effects of deficit irrigation on gas flux from the soil under two promising feedstock species
2. To quantify the fluxes in carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) in tropical soils.
3. To identify the effect of deficit irrigation on root dynamics and biomass

Hypotheses

1. Fluxes in CO_2, N_2O, and CH_4 will vary by species and by irrigation treatment level
2. Root biomass and distribution will be influenced by treatment level and harvest frequency

Methods



Site Description

- *Soil*: Typic Eutrotorrox of the Molokai Series
- *Experimental Design*: Group Balanced Block in Split-Plot arrangement (40m x 70m plots)
- *Three irrigation treatments*: 100, 75, & 50% of current practice

Gas Flux Monitoring

- 108 static vented chambers installed across the field (row and inter-row locations) [5]
- Samples were collected monthly for one year; analyzed for CH_4, CO_2, and N_2O using a Shimadzu GC2014 Gas Chromatograph
- Focused sampling occurred at harvest and following a fertilization event

Soil & Root Sampling

- Soil cores were collected at planting & at 1 year; analyzed for C & N concentration
- Root biomass was sampled at 1 year for both species

Results

Napier Grass

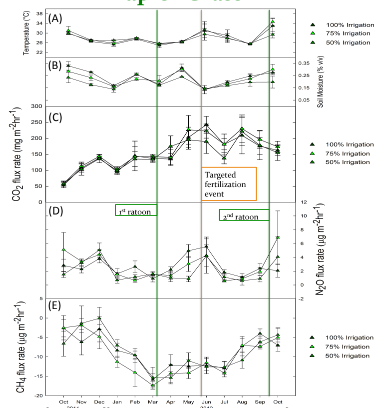


Figure 1: Monthly soil moisture, temperature, and soil surface fluxes of CO_2, N_2O, and CH_4 from October 2011 to October 2012 for Napier grass (Error bars indicate S.E.)

Sugarcane

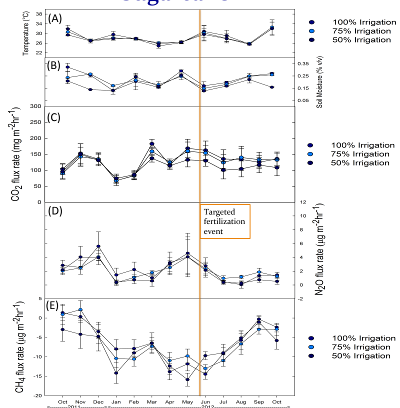


Figure 2: Monthly soil moisture, temperature, and soil surface fluxes of CO_2, N_2O, and CH_4 from October 2011 to October 2012 for Sugarcane (Error bars indicate S.E.)

- ◆ Species and treatment was significant for soil moisture (**Figure 1: B; Figure 2: B**)
- ◆ No significant treatment or species differences in soil temperature (**Figure 1: A; Figure 2: A**)
- ◆ Plant growth (**Figure 3**) was found to be negatively correlated to fluxes in CH_4 ($r = -0.115$, $p = 0.04$) and positively correlated to CO_2 emissions ($r = 0.198$, $p < 0.005$)

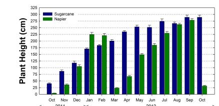


Figure 3: Monthly above ground growth measurements for both species (Error bars indicate S.E.)

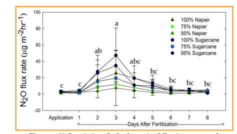


Figure 5: N_2O emissions for both species following a targeted fertilizer event in May 2012 (Error bars indicate S.E.)

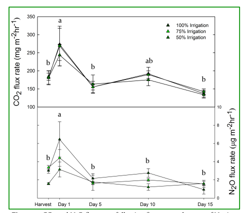


Figure 4: CO_2 and N_2O flux rates following first ratoon harvest of Napier grass in March 2012 (Error bars indicate S.E.)

- ▲ Napier did not show significant differences between treatments for CO_2 or CH_4 fluxes (**Figure 1: C & E**)
- ▲ For Napier N_2O emissions: the 100% treatment was significantly higher than either of the 75% or 50% treatments, the deficit treatments were not significantly different from each other (**Figure 1: D**)
- ▲ Following harvest, Napier plots experienced a flush of CO_2 and N_2O from the soil. Fluxes returned to pre-harvest levels within 5 days (**Figure 4: A &B**)
- ● Sugarcane showed significantly lower CO_2 emissions under the 50% deficit; both 75% and 100% treatments were higher (**Figure 2: C**)
- ● No treatment differences were significant for N_2O or CH_4 fluxes under Sugarcane (**Figure 2: D &E**)

* All tests were conducted at a $\alpha=0.05$; Tukey's multiple comparisons were used to test for significant mean differences between treatments

- ◆ After fertilization (**Figure 5**)
  - ◆ Sugarcane and Napier showed significant increases in N_2O flux; rates returned to pre-fert. levels by day 5
  - ◆ Sugarcane N_2O was higher than Napier ($p = 0.005$)
  - ◆ Treatment was significant, 100% irrigation had the greatest fluxes ($p = 0.04$)

Root Data

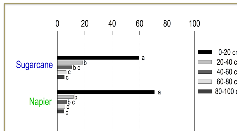


Figure 6: Distribution of sampled roots by depth after 1 full year of growth

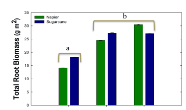


Figure 7: Root biomass by species and irrigation treatment level

- ✦ Total root biomass was greatest under the Sugarcane crop although this was not significant
- ✦ Root distribution was similar between the species, with the majority of roots being located in the surface soil (**Figure 6**)
- ✦ Root biomass varied by treatment level, greatest biomass was found under the 100% and 75% treatments (**Figure 7**)

Discussion & Conclusion

1: Fluxes in CO_2, N_2O, & CH_4:

- Napier had greater soil CO_2 emissions, a lesser sink potential for CH_4, and no difference in N_2O efflux when compared to Sugarcane annually
- Irrigation treatments were only significant for soil N_2O emissions: 50% was significantly higher than 100%

2: Root biomass and distribution:

- Both species showed similar patterns in root distribution by depth and irrigation level
- Although Napier was ratoon harvested, there was no difference between the total biomass of either species after 1 year

After 1 year, Sugarcane has contributed to less GHG efflux from the soil when compared to Napier grass. Continued monitoring of this system following future ratoon harvests of Napier and the final harvest of Sugarcane is needed to determine the full effect of these species on this system. Additionally, a comparison of the changes in soil organic carbon in response to treatment level and species is essential to determine the long-term sustainability of biofuel systems in Hawaii.

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