Above and belowground biomass and C dynamics under ratoon and plant crop practices for biofuel feedstock production in Hawaii

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HC&S Mill

Introduction

• Renewable biomass resources presents a promising alternative energy and environment friendly by minimizing the net production of GHGs (Lynde, 2008).
• High biomass production of biofuel feedstock can be achieved via both crop improvements and management practices and need to be sustainable in term of soil, water and environment.
• Allometric models can predict biomass, growth phases and economic yield non-destructively at any time (Ares *et al*., 2002).
• Sugarcane, energycane and napier as biofeul grasses can produce large amounts of ABG and BG biomass (Meki *et al*., 2014).
• These C_4 grasses can be grown by ratooning (no-till) (Fig. 1), which leaves the lower part of the plant and soil intact, undisturbed.
• Compare to burning harvest (Fig. 2), ratooning can increase soil C sequestration and contributing to the sustainability of production system (Clifton-Brown *et al*., 2007), while simultaneously providing potential ABG biomass for energy production.


Fig. 1: Ratooning (no- till)


Fig. 2: Burning sugarcane

Overall Objectives

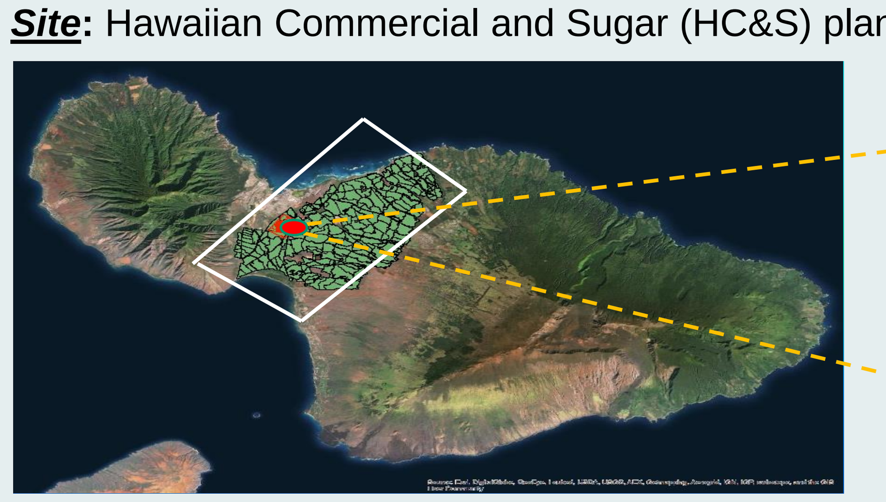
• Estimate ABG & BG biomass, C and N inputs for different biofuel crops cultivated as plant crop and ratoon cycles.
• Develop optimal allometric relationships to predict ABG biomass, C and N inputs.
• Determine root death vs live proportion following ratoon harvest of napier and energycane and convention sugarcane as plant crop.
• Study the root decomposition pattern at different time series within soil depths to determine the decay constant *(k)* for each crop.

Hypothesis

• The quantities of ABG & BG biomass, C and N inputs differ across the biofuel crops due to positive relationship between ABG & BG pools,
• Ratooning (no-till) system will increase BG biomass and its C and N inputs.
• The proportion of dead vs live root after harvest differ between crops and will control the recovery system of each crop.
• The root decay constant (*k*) differ across species and soil depths.

Materials and Methods

Site: Hawaiian Commercial and Sugar (HC&S) plantation in Central Maui (Fig.3).



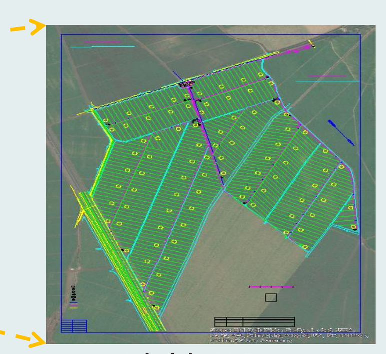

Field 718

Fig. 3: HC&S plantation and field map

• Nine plots (15x11m each) were established with 4 rows of grasses, and 2 lines/row.
• For all crops, 45 cm stem cuttings were planted on Oct. 3, 2011.
• The ABG biomass of ratoon napier and energycane was quantified using standard plant growth protocol.
• Alometric models were developed to predict ABG biomass for each crop.
• 30 representative stalks of each crop that spanned a range of stalk (D) were selected.
• Basal stalk (D), canopy and dewlap (H) for each individual stalk were measured.
• ABG biomass estimates for individual stalks derived from the allometric models developed here compared to some existing generalized equations or predicting biomass of tropical species.

Materials and Methods

• Sugarcane, energycane and napier were selected as biofuel crops (Fig. 4).

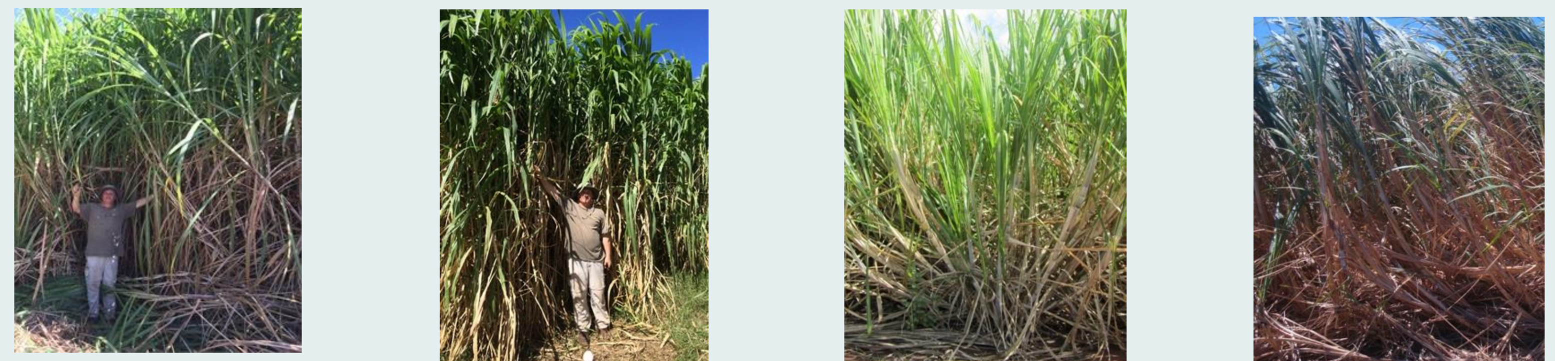

Energycane | Napier | Sugarcane (1 yr) | Sugarcane (2 yrs)

Fig. 4: One year ratoon energycane, napier and 1 & 2 yrs plant crop sugarcane

• The root biomass of ratoon napier, energycane and plant crop sugarcane were determined volumetrically from excavated soil pits by depth: 0-40, 40-80 and 80-120 cm.
• 6 pits, each (5x4ft) with 4ft depth were opened for each crop (Fig.5).
• Dead and live roots were sorted, and quantified.
• The C and N content of ABG & BG biomass were analyzed using elemental analyzer.
• Root:Shoot and C:N ratio were calculated for all crops.
• Root decay experiment was carried out within 3 depths using litter bag method for 1, 2, 3, 4, 6, and 9 months (Fig. 5).
• Root decay rates is fitted to a negative exponential decay model: $L_t = L_0\, e^{-kt}$
L_t is the proportion of root mass at time *t*, L_0 is the proportion of root mass at time zero, *k* is decomposition rate over the measured time interval. (Wider & Lang, 1982);


Fig. 5: Root decay profile


Fig. 6: Dead vs Live roots for sugarcane, napier and energycane

Results

• The 1yr ABG and BG biomass and C input were ranked as:
energycane > sugarcane > napier grass (Table 1).
• Energycane has deeper root system than napier grass and sugarcane.
• The root biomass and its C input of 2 yrs sugarcane increased with tremendous spike. by (231%) & (175%) respectively compared to 1 yr sugarcane (Table 1).
• The root systems of all crops were mainly restricted to the top 40 cm of soil.
• The ratoon root masses of EC were significantly larger than SC plant crop.
• The highest and significant average root:shoot ratio and root:total biomass proportion was found for one year napier grass, compare to energycane and sugarcane (Table 1),
• The C:N ratios of total biomass ranged widely from 65 for napier grass to 124.29 for energycane and it was significantly (p > 0.01) different across crops.

Table 1: Biomass, C and N components

	EC 1 year	Napier 1 year	SC 1 year	SC 2 year	SC Change Yr1 - Yr2
	Biomass (Mg ha^{-1})				(%)
Aboveground	44.62 A	27.16 B	40.24 A	80.46	99.95
Belowground	4.63 A	3.82 B	3.83 B	12.70	231.59
Total	49.25 A	30.98 B	44.07 A	93.16	111.39
Root:Shoot ratio	0.10 B	0.14 A	0.10 B	0.16	65.84
Root:Total ratio	0.09 B	0.12 A	0.09 B	0.14	43.23
	Carbon (Mg ha^{-1})				(%)
Aboveground	19.20 A	11.52 B	18.13 A	36.34	100.44
Belowground	1.93 A	1.53 B	1.95 A	5.37	175.38
Total	21.13 A	13.05 B	20.08 A	41.71	107.72
	Nitrogen (Mg ha^{-1})				(%)
Aboveground	0.15 B	0.18 A	0.20 A	0.36	80.00
Belowground	0.02 A	0.02 A	0.01 A	0.07	16.67
Total	0.17 B	0.20 A	0.21 A	0.43	65.38
C:N ratio	124.29 A	65.25 C	95.62 B	97	25.60

Results & Discussion

• For all allometric equations, a simple power model (Y= aX^b) provided the optimal prediction of ABG biomass and its C and N inputs.
• Stalk D (Fig. 7) and dewlap H were good predictors for ABG biomass.

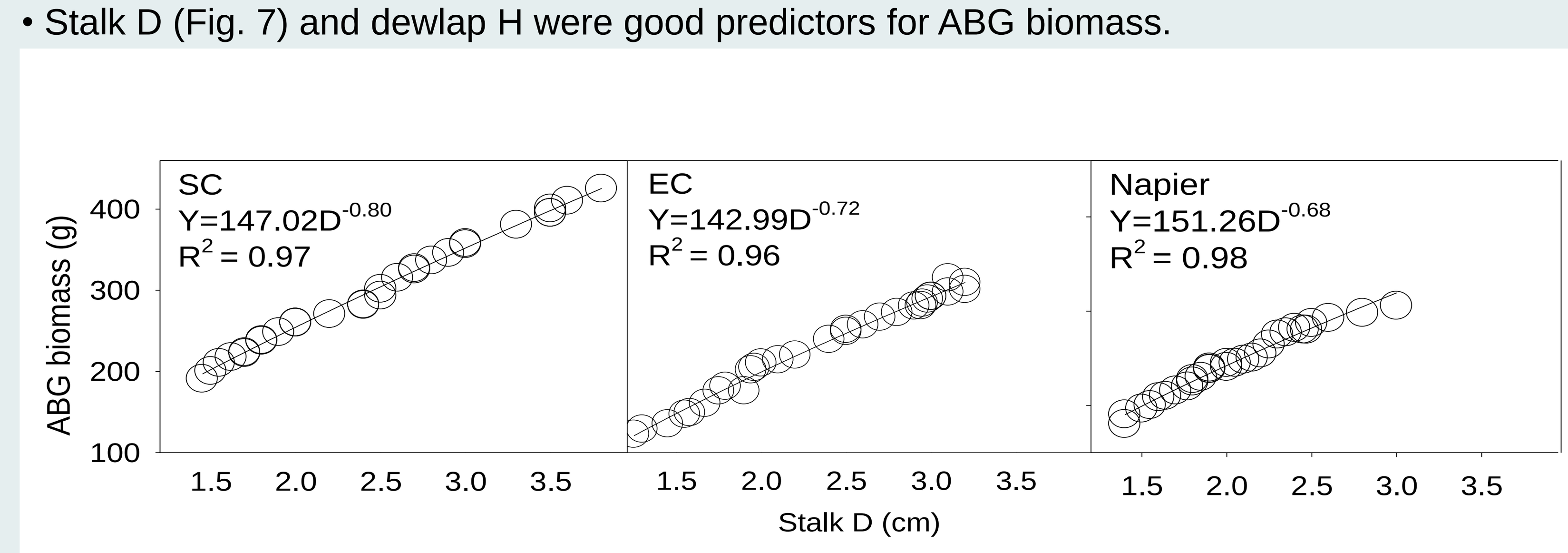


Fig. 7: Allometric models for predicting ABG biomass (g) from stalk D (cm) in individuals of: biofuel crops.

• The dead versus live roots% for ratoon energycane and napier grass were 70 to 30% and 11 to 89% respectively (Fig. 8), and for 2 yrs plant crop sugarcane were 41 to 59% after harvest.

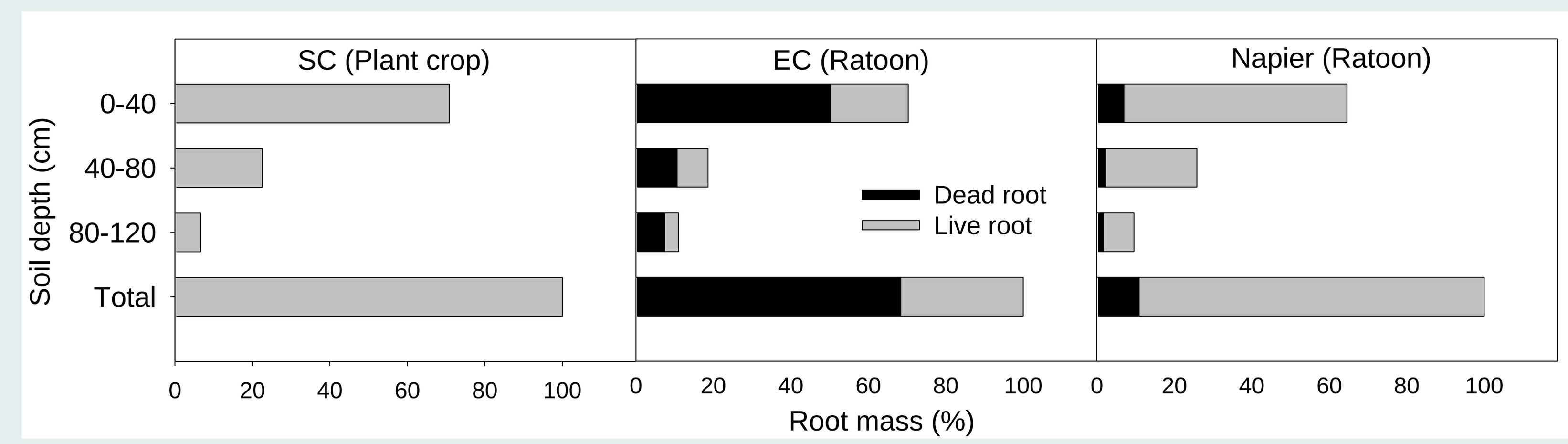


Fig. 8: Dead vs live root mass (%) proportion for one year biofuel crops

• Decay constants *(K)* were different at marginal significance across species (Fig. 10).
• Napier grass had statistically greater (*k*).
• Root decay constants for all crops were higher at surface soil (0-40 cm).

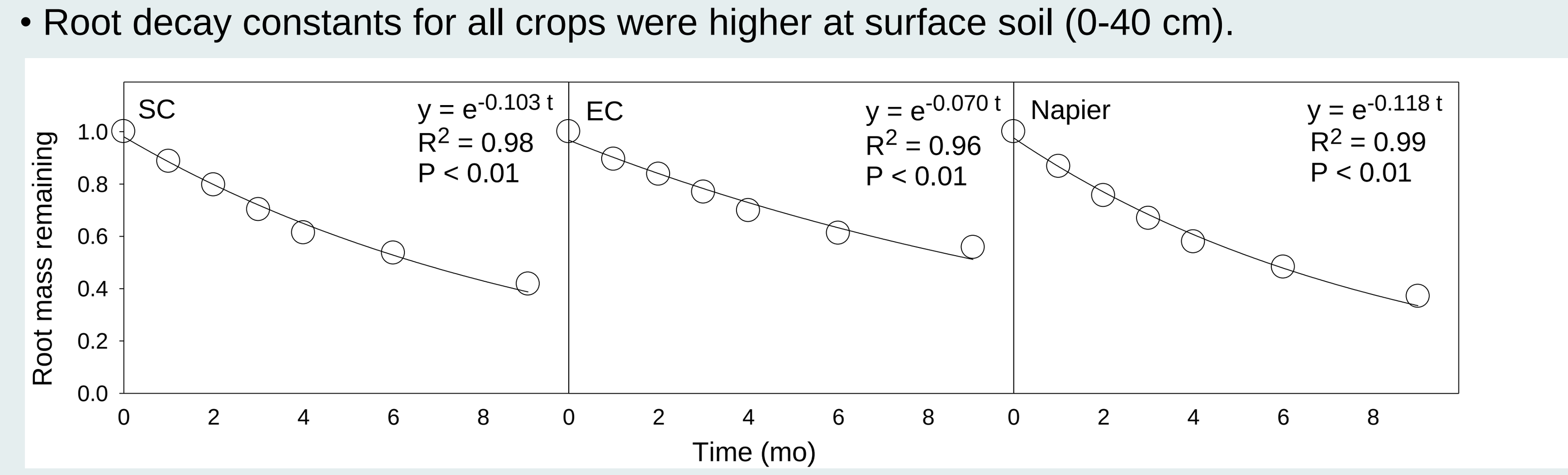


Fig. 9: Root decay constant *(K)* of: sugarcane, energycane and napier grass at (0-40) cm depth

• The root turnover results shows good evidence of quick recovery and rapid flush of new shoots by the root system we have observed with napier grass after harvest.


Napier

Recovery growth after ratooning


Energycane

• The high biomass production characteristic of ratooning grown biofuel crops can sequester and add a large quantity of C back to the soil in the form of root biomass to achieve a sustainable cropping system of biofuel feedstock.

Conclusion

• The study showed that the energycane production system meets the most important criteria (especially the potential for high yields, its deep rooting characteristics, and its potential value in C sequestration) for a reliable feedstock candidate for future sustainable energy production system.

Acknowledgements

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