Belowground biomass and C Dynamics in Sugarcane, Ratooning Energycane cultivated as biofuel production in Hawaii

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Introduction

- There is a lack of information on belowground input quantity and quality and their impact on SOC pool for biofuel crops.
- Root system depth of biofuel crops is a key parameter for water and mineral uptake but it is still very little known.
- Root turnover is a key component of C cycling within soil systems.
- Sugarcane (Fig.1) and Energycane as perennial and C4 biofuel grasses produce large amounts of above and belowground biomass (Samson *et al*., 2005).
- Sugarcane and Energycane can be harvested by ratooning (no-till) which leaves the roots and soil intact, thereby improving soil aggregation, fertility with potential to increase soil C sequestration while simultaneously provides aboveground biomass for energy production (Clifton-Brown *et al*., 2007).
- Belowground biomass and soil C pools are important input parameters for crop modeling (e.g. ALMANAC & EPIC models) .


2yrs sugarcane

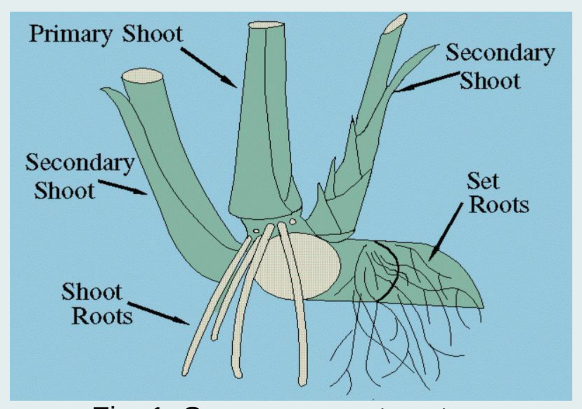
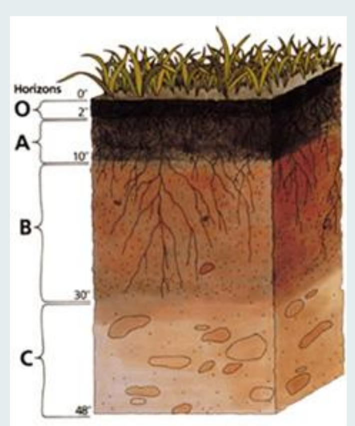


Fig. 1: Sugarcane root system.
Source:http://agropedia.iitk.ac.in/content


1 yr energycane

Overall Project Objectives

- Monitor soil parameters as necessary to refine ALMANAC model simulation.
- Quantify belowground biomass and root death following after 1yr cycle of ratooning (no-till) energy cane, and 2yrs cycle of sugarcane cultivation in Hawaii.
- Examine the plant biopolymer composition of root C inputs for both crops and trajectory of residue chemistry during decay.
- Investigate soil C pool size change and incorporation of recent root inputs into soil C pool.
- Quantify the potential SOC sequestration and dynamic changes in both soil and root C overtime; validate ALMANAC model simulation output.


Soil & root profile

Hypothesis

- Root biomass quantity, and distribution will be influenced by root origin, depth and harvest frequency
- Root decay of ratooning energycane ,and 2 yrs sugarcane varies with root origin and depth due to:
  - ✓ Negative relationship between root decay constant (k) and lignin concentration,
  - ✓ Greater amount of root lignin will result in slower decomposition

Materials and Methods

- **Site:** Hawaiian Commercial and Sugar (HC&S) plantation in Central Maui (Fig. 2).

Fig. 2: HC&S Mill & plantation


Burning sugarcane


Ratooning (no- till)

Materials and Methods

- The root system of ratooning energycane and 2yrs sugarcane was excavated.
- Six pits, each (5x4ft) with 4ft depth were opened for each crop.
- Roots of each pit were collected and quantified from 0-40, 40-80 and 120 cm depth.
- Dead and live roots of ratooning energycane were sorted, separated and quantified.
- Root decay experiment was carried out for both crops (Fig. 3&4).


Fig 3: energycane root decay


Fig. 4: sugarcane root decay


Fig. 5: root decay bags

- The root decay experiment started Feb 2013, and will continue as proposed to determine root decomposition constant (*k*) using litter bag method (Fig. 5) collected from each replicate at 1,2,3,4,6, and 9 months.
- Subsamples (1g) of air dried root materials were placed in 5x10 cm nylon mesh bags .
- The bags burial site was established on the root surface site of each pit and depth.
- 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);
- Soil samples for SOC and bulk density cores from 0-20, 40-80 and 80-120 cm were collected randomly from each pit.
- The experiment layout was a randomized complete block design with 3 replicates.

Results

The preliminary results showed that:

Root biomass: was significantly linked to soil depth

- Most root biomass is found close to the surface and declines with depth
- <u>For energycane:</u> (ratooning), total root masses (living+dead) was 0.459 kg m^{-2} (Fig. 6)
- Dead roots was greater than live roots (70% to 30%)
- The proportions of dead roots at depths 0-40, 40-80, and 80-120 cm were 71.59, 18.01, and 10.40% respectively
- <u>For sugarcane :</u>(2yrs cycle), total root mass (all live) was 0.311 kgm^{-2}
- Root mass proportion at depths 0-40, 40-80 and 80-120 cm were 70.06, 22.97, and 6.97 % respectively.

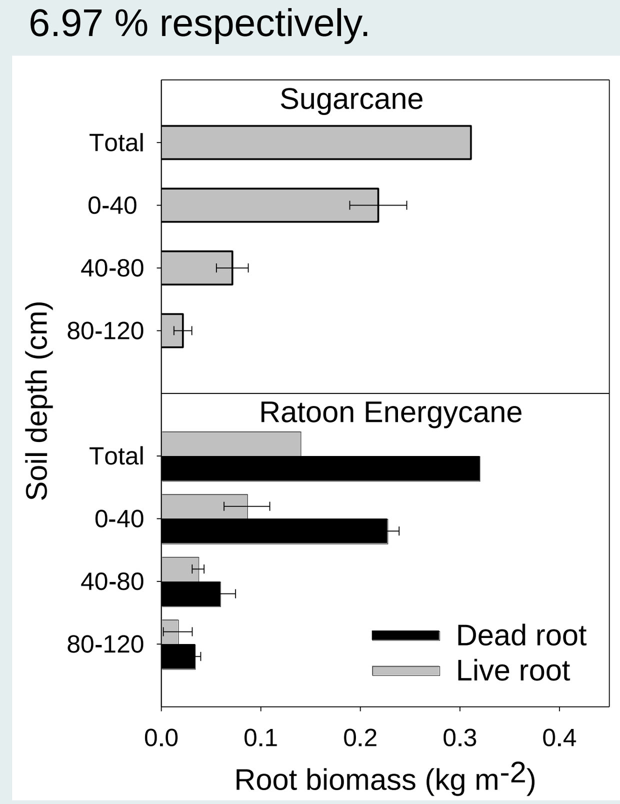
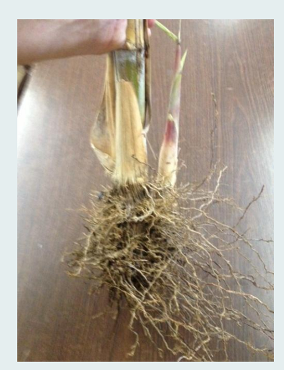


Fig. 6: root mass and soil depths



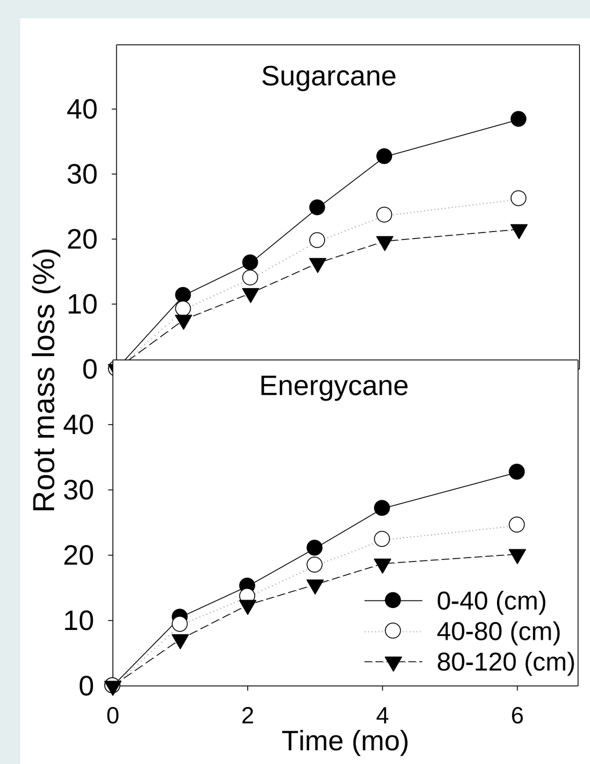
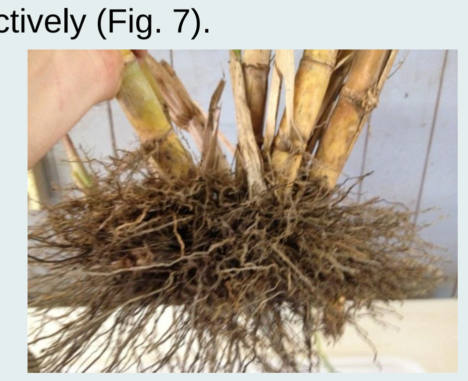
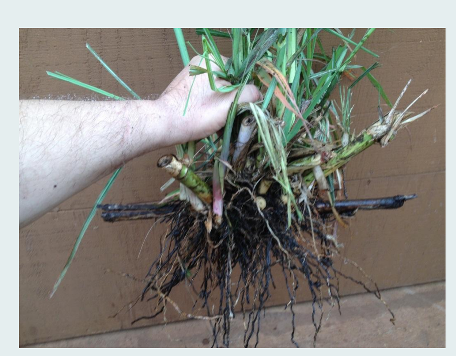


Fig. 7: Root mass loss with decay time series

Root decay:

- The root mass loss through out the decay period of 6 months at 0-40, 40-80 and 80-120 cm, for sugarcane was (38.4, 26.21 and 21.5%) respectively, and for energycane was (32.7, 24.6 and 20.16 %) respectively (Fig. 7).


sugarcane


Energycane

Next steps:

Roots & Soil Analysis:

- Root samples will be analyzed for C and N content, $\delta^{13}C$ and $\delta^{15}N$
- Root lignin quantity and quality will be determined for all decay samples.
- Soil samples will subject to physical and chemical fractionation according to Golchin method.
- Determine the mean residence time of the soil C from select samples and fractions using radiocarbon dating (^{14}C).

Belowground biomass for Napier and hybrids

- The belowground biomass and root death proportion following 6 mo cycle of ratooning (no-till) Napier and other hybrids cultivated in Hawaii will be determined by using the same procedure.

ALMANAC model: (Fig. 8)

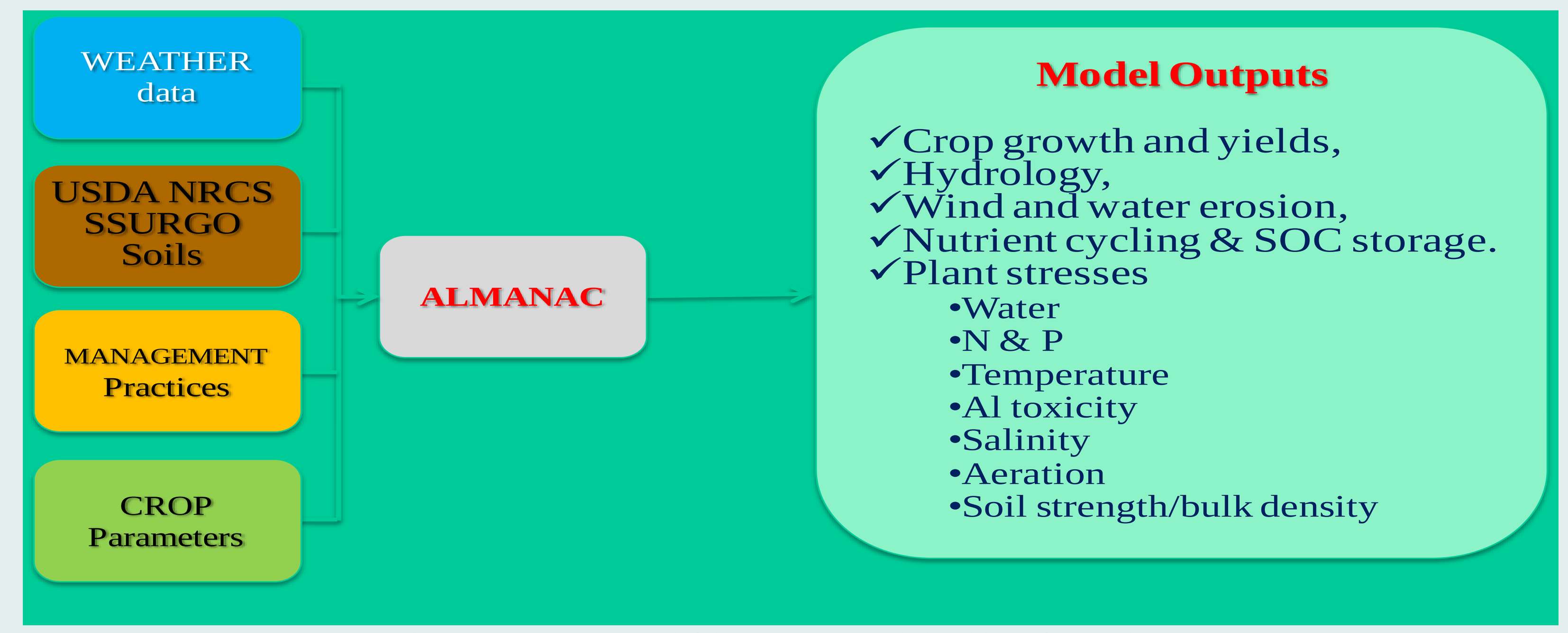


Fig. 8: ALMANAC model (Input & Output)-(Meki *et al*.,2012)

- Gathered soil input parameters and belowground biomass data of ratooning energycane and 2 yrs sugarcane (Table1) will be used to parameterize the ALMANAC model prior to conducting simulations of biomass yield variability and associated environmental impacts.

Table 1: soil input parameters and root biomass needed to test and validate ALMANAC model

	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	OC (%)	BD (gcm^{-3})	Total root Biomass (kgm^{-2})	Max root depth (cm)
Energycane	0-40	19.53	54.65	25.82	1.61	1.17	0.459	1.30
	40-80	25.16	61.73	13.12	0.72	1.25		
	80-100	29.39	61.09	9.52	0.53	1.31		
Sugarcane	0-40	23.23	57.32	19.45	1.33	1.18	0.311	1.20
	40-80	43.4	43.27	14.07	0.82	1.28		
	80-100	42.59	48.48	8.93	0.42	1.32		

Conclusion

- Excavating the root system from soil pits should speed the development of our understanding of belowground biomass and soil C pools for sugarcane and ratooning energycane as biofuel crops.
- The belowground biomass results for both crops might show in the long term, a trend for higher C stocks in the ratooning (no-till) and unburned system.
- It is important to evaluate the root system throughout the crop cycle in order to estimate adequately the contribution of root system to supply C to the soil and consequently improve the SOC sequestration.

Acknowledgements

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Related References

- Meki N. Manyowa, Jim R. Kiniry, Adel H. Youkhana, Mae H. Nakahata, Susan E. Crow, Richard M. Ogoshi and Jeff J. Steiner. 2012. Parameterization of the ALMANAC model to evaluate novel high biomass crops on Maui Island, Hawaii. Abstract and Poster. Proc. ASA-CSSA-SSSA Meetings. October 21-24, 2012. Cincinnati, OH.