Dynamics of Soil Carbon and Nitrogen from Perennial BioenergyCropping System

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ABSTRACT

The purpose of this research was to study perennial energy cropping system with energy cane (*Saccharum spp.*) and elephant grass (*Pennisetum purpureum* (L.) Schum.) on marginal lands and analyze the soil organic carbon and nitrogen dynamics with nitrogen (N) fertilizer applications and winter cover crops. Data was collected for four years (2011-2014) from Fort Valley State University, GA research plots. The treatments consisted of two perennial grasses, one winter cover crop (clover) and three N fertilization rates (0,100 and 200 Kg N/ha) with four replications. Soil samples were collected from two depths (0-15 and 15-30 cm) and were analyzed for soil organic carbon (SOC) and soil total nitrogen (STN). The average SOC and STN were found higher in soil with elephant grass (14.24 Mg C/ha and 1.502 Mg N/ha) than energy cane (13.53 Mg C/ha and 1.442 Mg N/ha). Soil surface depth (0-15 cm) had higher SOC and STN compared to subsurface (15-30 cm). Winter cover crop (clover) was found to be significant in both carbon sequestration and nitrogen fixation compared to control (no cover). The application of nitrogen fertilizers (100 kg and 200 Kg N/ha) was not statistically different with no fertilizer, both for soil organic carbon and soil total nitrogen. Soil organic carbon (SOC) was higher in second (2012) and third year (2013) of planting in comparison to the establishment year (2011), which significantly decreased in fourth year (2014) and was found statistically non-significant with establishment year. Soil total nitrogen was significantly higher in second, third and fourth year compared to establishment year. It is concluded that growing perennial bioenergy crops sequesters significant organic carbon and fixes nitrogen into soil. Planting winter leguminous cover crops is beneficial for higher carbon sequestration and nitrogen fixation on soil whereas the effect of applying inorganic N fertilizer needs further evaluation.

INTRODUCTION

- Perennial crops like energy cane (*Saccharum spp.*) and elephant grass (also called as napier grass) (*Pennisetum purpureum* (L.) Schum.) which produces cellulosic bio-ethanol are prioritized as renewable source of energy.
- These can be grown in marginal lands with minimum inputs.
- How these crops may effect on soil organic carbon (SOC) pools (soil C fraction concentrations) and soil total nitrogen (STN) in response to nitrogen(N) fertilization and winter cover crop like Clover (*Trifolium incarnatum*) is poorly known.
- Results from past study of other perennial lignocellosic grasses are also not consistent.
- Jung and Lal (2011), and Gauder et al.(2016) has claimed SOC increased under N- fertilization in case of Miscanthus, however no significant effect on SOC was found by Ferchaud et al.(2016) and Higashi et al. (2014).
- SOC and STN increased due to leguminous cover crops (hairy vetch) and due to non leguminous crop (rye) in lignocellulosic grasses (Sainju et al., 2015).

PURPOSE OF THE STUDY

- Analyze the SOC and STN in energy cane and elephant grass crop field grown in marginal land with
  - -three nitrogen fertilizers treatment (0,100 and 200 Kg N/ha)
  - -two cover crop treatments (control vs winter clover)

MATERIALS AND METHODS

PLANTING AND FERTILIZATION

- Two perennial grasses energy cane and elephant grass were planted in 2011 and harvested every fall (November). Clover (*Trifolium incarnatum*), a leguminous crop, was planted as cover crop.
- The experiment was designed in randomly complete block design.
- There were total 8 treatments including control, cover+0 Kg N/ha, cover+100 Kg N/ha and cover + 200 Kg N/ha for each crop.

T1 =Energy cane control ,
T2 = Energy cane + cover + 0 KgN/ha ,
T3 = Energy cane+ cover + 100 kg N/ha,
T4 = Energy cane + cover + 200 Kg N/ha

T5 = Elephant grass control,
T6 = Elephant grass + cover+ 0 kg N/ha,
T7 = Elephant grass + cover + 100 Kg N/ha,
T8 = Elephant grass + cover + 200 kg N/ha

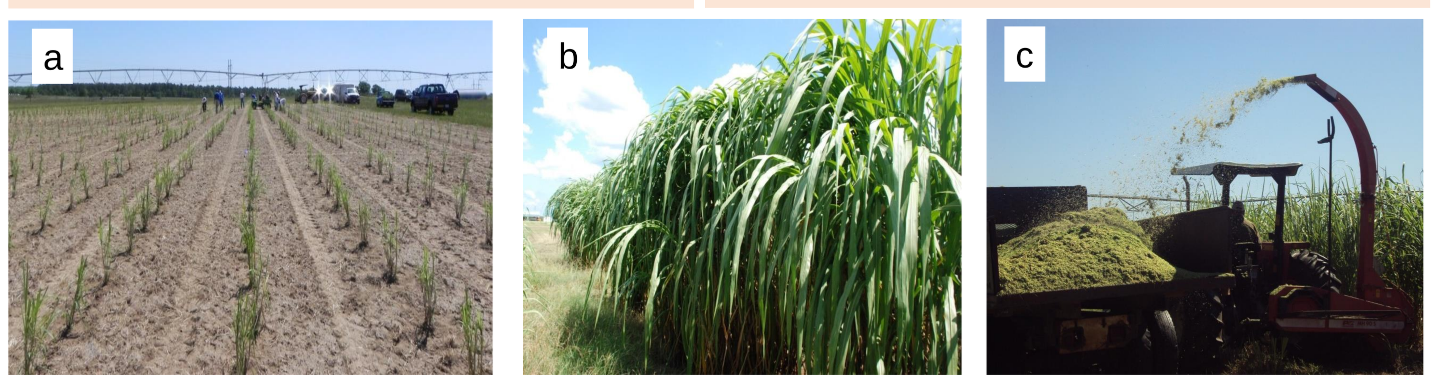

Fig 1: Establishment of perennial grasses (a) Field just after planting (b) growing elephant grass (c) harvesting of perennial grasses

SOIL SAMPLING AND ANALYSIS

- Soil samples were collected using a probe (3.5 cm inside diameter) randomly within the plot after biomass harvesting in the fall.
- Each core was separated into 0-5, 5-15, 15-30, 30-60, and 60-90 cm depth intervals, composited within a depth, air-dried, ground, and sieved to 2 mm.
- Samples were analyzed for soil total C and STN concentrations with a high-induction furnace C and N analyzer (Elementar, Mt Laurel, New Jersey) after grinding a subsample to 0.5 mm.
- Since pH in the soil samples were less than 7.0, soil total C was considered as SOC (Nelson and Sommers 1996).
- Data for baseline study was analyzed for all soil depths, whereas, data after harvest of crop for years 2011-2014 were analyzed for two depths 0-15 cm and 15-30 cm using statistical software R (ver. 3.0. RFSC, Vienna, Austria)

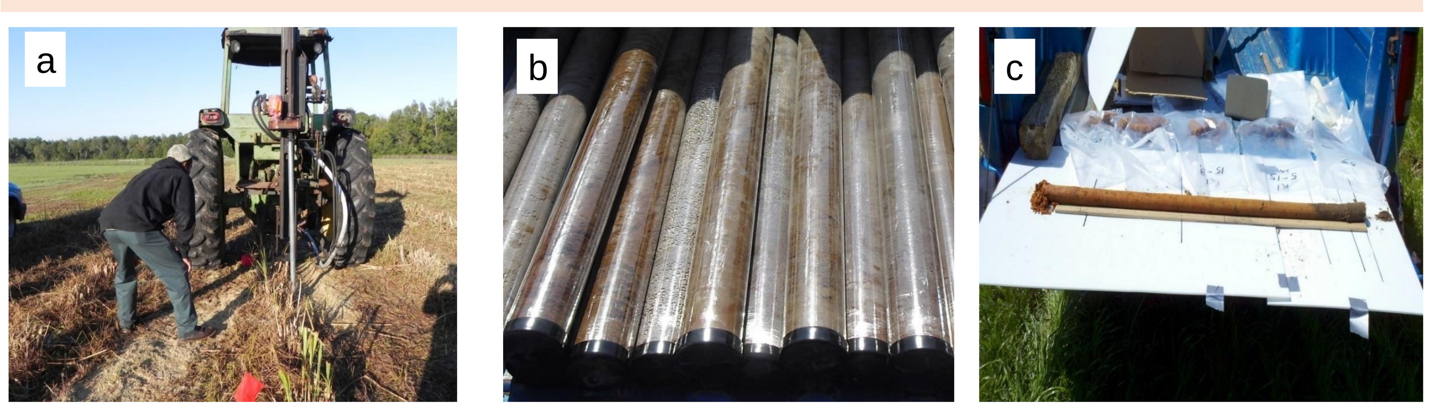

Fig 2: Soil sampling and analysis (a) Soil core sample extraction by using soil probe (b) Storing sample in plastic tube liners (c) Cutting and sorting different layers of soil for lab analysis

RESULTS

Table 1. Average baseline soil C fraction concentrations (mean ± standard deviation) at different depths

Soil depth (cm)	SOC ($g\ C\ Kg^{-1}$)	POC ($g\ C\ Kg^{-1}$)	MBC ($g\ C\ Kg^{-1}$)	PMC ($g\ C\ Kg^{-1}$)
0-5	10.1±0.6	4.3±0.6	109±26	53±3
5-15	7.4±0.6	2.5±0.5	80±10	32±13
15-30	3.5±0.2	1.4±0.2	39±3	21±5
30-60	2.4±0.9	0.8±0.4	42±4	17±3
60-90	1.2±0.3	0.5±0.2	39±4	13±1

SOC = Soil organic C, POC = Particulate organic C, MBC = Microbial biomass C, and PCM = Potential C mineralization.

Table 2. Average baseline soil N fraction concentrations (mean ± standard deviation) at different depths

Soil depth (cm)	STN ($g\ N\ Kg^{-1}$)	PON ($g\ N\ Kg^{-1}$)	MBN ($mg\ N\ Kg^{-1}$)	PNM ($mg\ N\ Kg^{-1}$)	NH_4-N ($mg\ N\ Kg^{-1}$)	NH_3-N ($mg\ N\ Kg^{-1}$)
0-5	858±38	403±84	30.7±1.9	8.5±1.4	1.4±0.2	0.4±0.1
5-15	657±69	258±56	18.7±3.9	7.0±1.8	1.4±0.2	0.8±0.2
15-30	390±22	100±18	2.5±1.4	1.2±0.5	1.5±0.2	0.5±0.1
30-60	348±60	103±17	1.9±1.8	0.5±0.4	0.9±0.3	0.5±0.2
60-90	287±53	100±27	0.8±0.8	0.5±1.6	0.5±0.1	1.1±0.1

STN = Soil total N, PON = Particulate organic N, MBN = Microbial biomass N, and PNM = Potential N mineralization

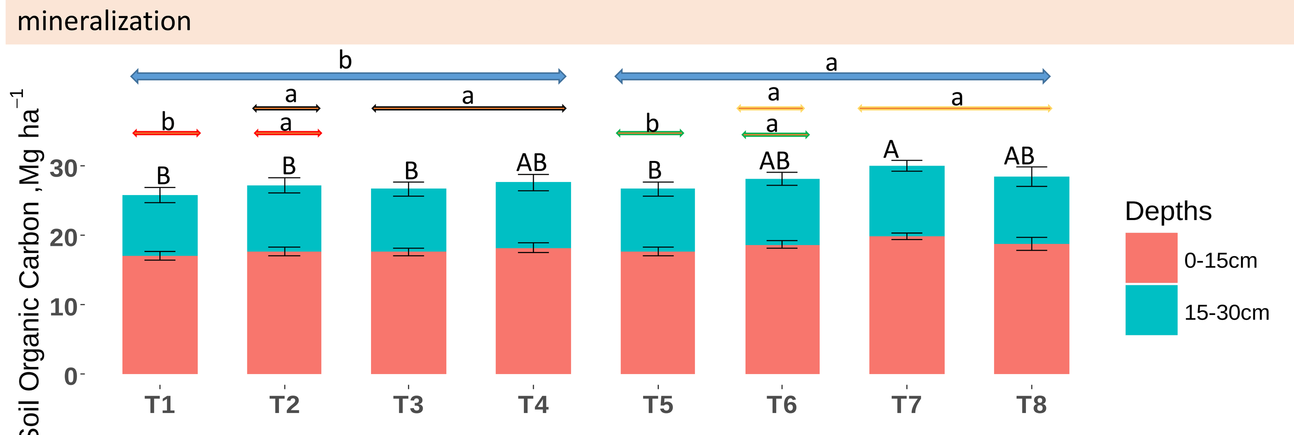

Fig :3 Average SOC at different depths and treatments over the years

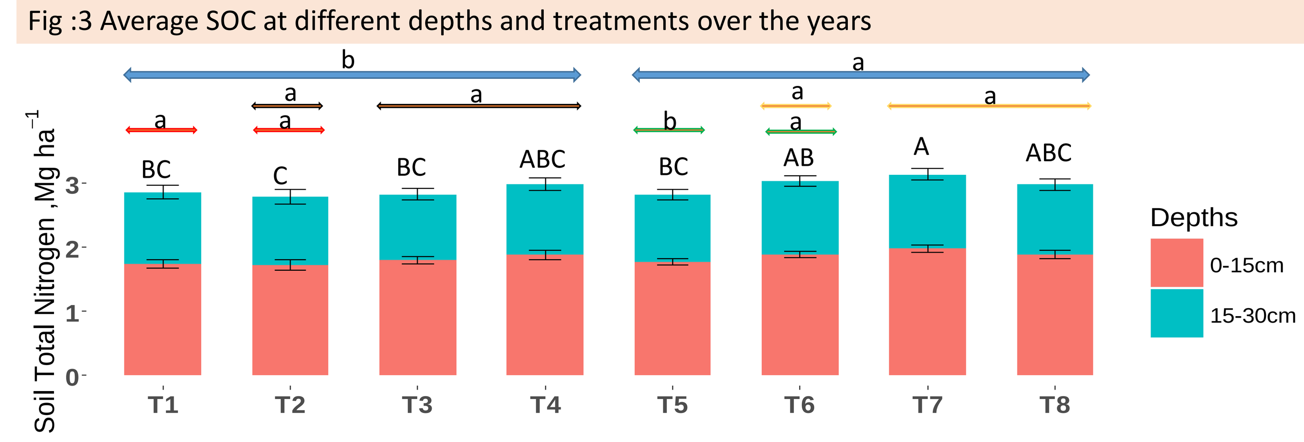

Fig :4 Average STN at different depths and treatments over the years

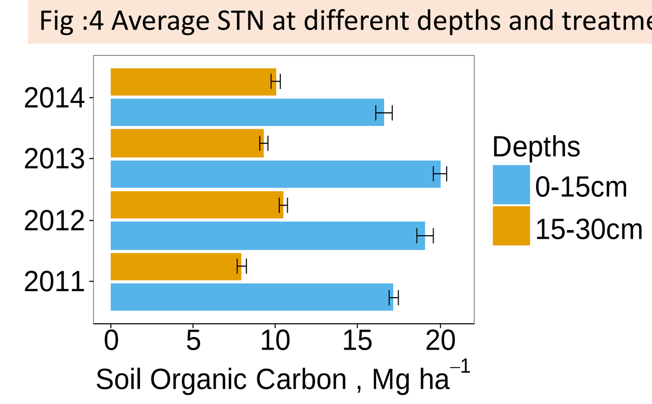

Fig 5: SOC levels compared for different years at two soil depths

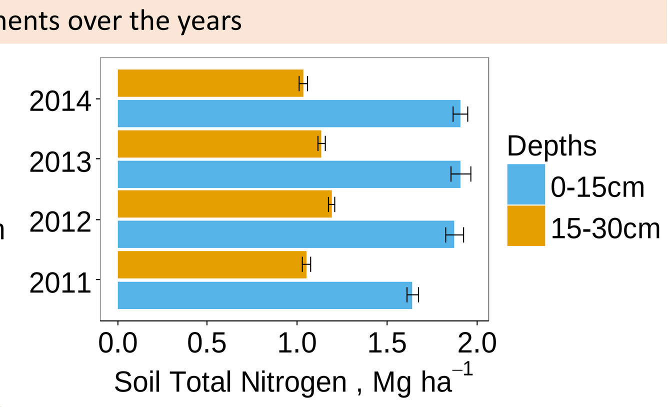

Fig 6: STN levels compared for different years at two soil depths

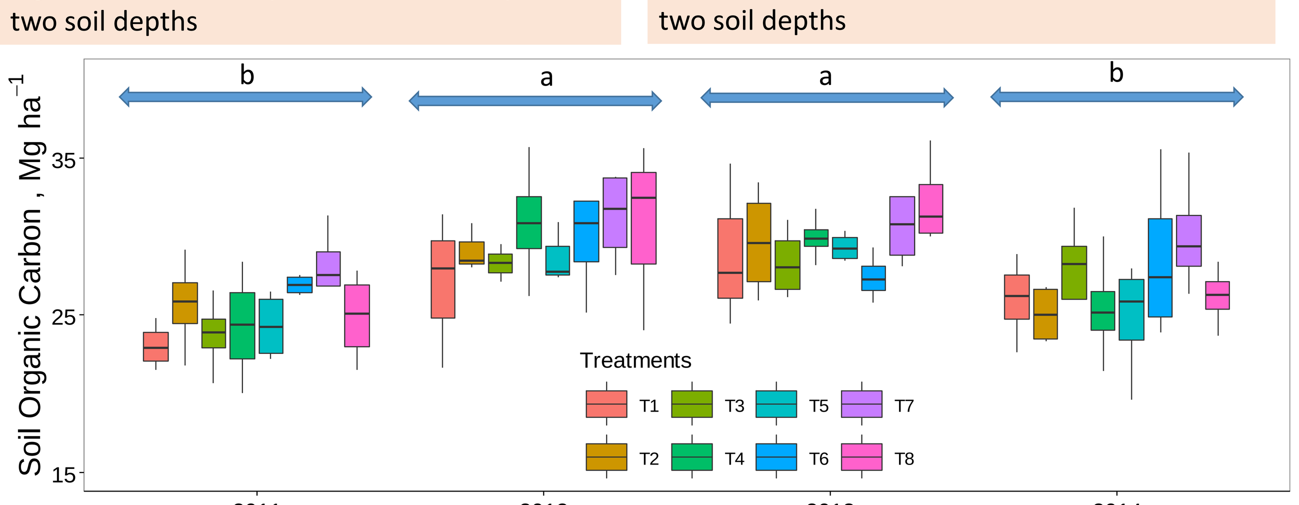

Fig 7: SOC among treatments over the years, for 0-30 cm soil depth

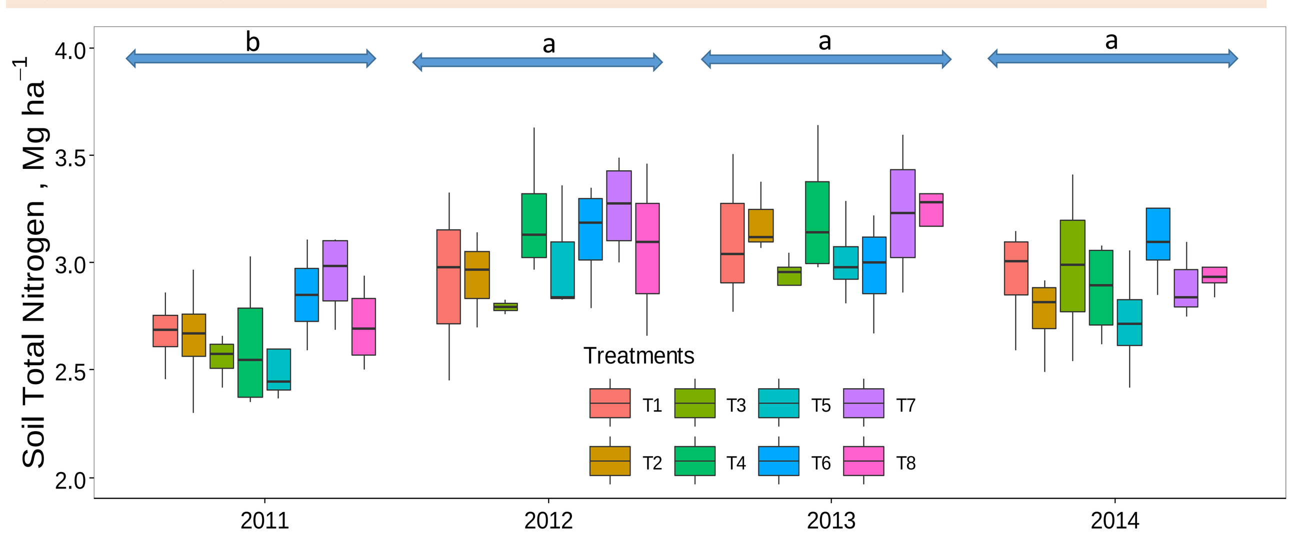

Fig 8: STN among treatments over the years, for 0-30 cm soil depth

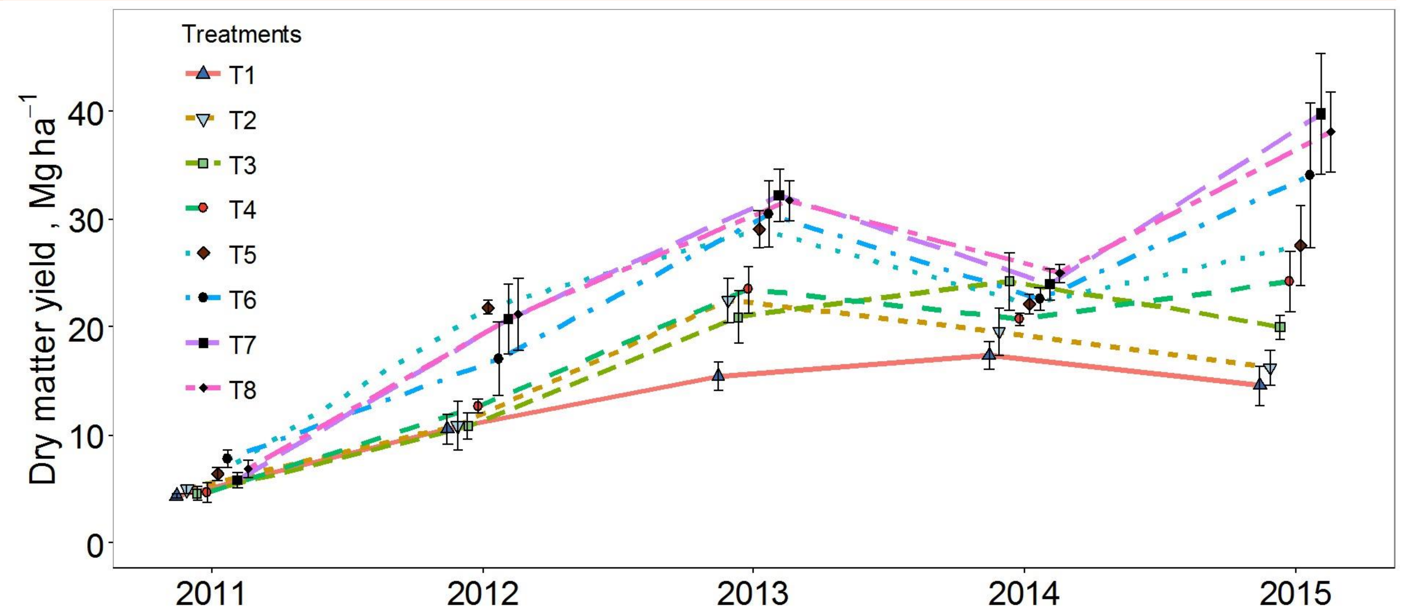

Fig 9: Dry matter (biomass) yield of the crops under different N fertilizer and cover crop treatments

DISCUSSION

- Soil C and N fraction concentration from baseline samples decreased with soil depth (Table 1&2). Mostly biomass residue and microbial activities might have higher level at top soil contributing for higher soil C and N fraction.
- The SOC and STN when compared between two crop showed elephant grass field had significantly higher than energy cane(Fig 3&4- 1st arrow from top).
- There was no significant difference between SOC and STN in both crops with and without N fertilizers (Fig 3 &4- 2nd arrow from top).
- Crop with winter cover was significantly higher in SOC and STN levels except for STN in energy cane, which was not significantly different (Fig 3 &4 – 3rd arrow from top).
- Irrespective of crops elephant grass with cover and 100 Kg of N sequestered more SOC and STN in soil (Fig 3 &4 – significance with upper case).
- Both SOC and STN were found to be significantly higher in top soil (0-15 cm) compared to sub-soil (15-30 cm) (Fig 5 &6).
- Different treatments when compared among the year showed significantly higher SOC level in second and third year (2012 & 2013), which then decreased in year 2014 and was not significantly different compared to establishment year (2011) (Fig 7).
- STN was significantly higher in year 2012, 2013 and 2014 compared to establishment year (2011) (Fig 8).
- Low SOC level in year 2014 could be due to low rainfall during active vegetative growth stage of the crop (August-24mm precipitation). The attainable SOC decreases with low rainfall (Hoyle et al.,2013).
- The SOC and STN were found to have an affect on biomass yield of the crop. The biomass yield increased till year 2013 and then decreased in year 2014, which later increased in 2015, for which soil analysis is ongoing (Fig 9). The pattern of increment in SOC/STN and yield was similar, indicating direct positive relationship between them.

CONCLUSIONS

- Soil C and N fraction concentrations were higher in top layer of soil and that remained higher for all the years
- The application of nitrogen fertilizer did not have significant impact on SOC and STN which implies strongly that energy cane and elephant crops can be grown in limited input cropping system.
- The winter cover crop had significant impact on SOC and STN and can be recommended in lieu of external fertilizer application.

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