Original Research Article

Effect of Agroforestry System on Soil Properties in an Acid *Inceptisol* under Tropical Climatic Situation of Eastern India.

Abstract

An experiment was carried out using the existing Field of AICRP on Agroforestry Project in Central Research Station of O.U.A.T, Bhubaneswar at a Latitude $20^0$15' N and longitude of 85^0 52' E in order to study the effect of agroforestry system on soil properties in the surface soil. In the year 2013, the system had two tree species *Dalbergia sissoo* and *Gmelina arborea* along with 4 intercrops such as pineapple, mango ginger, turmeric and arrowroot. Soil samples were collected after 13 years of agroforestry system in the post harvest period during 2014-15 for soil properties study. With Agro forestry system there was improvement in soil bulk density, organic matter and available nutrients as compared to open field where there was loss of nutrients. Between the trees, *Gmelina arborea* maintained higher level of soil organic carbon ,available N, available P and available K on top soil than *Dalbergia sissoo*. Inclusion of intercrops maintained significantly higher organic carbon and available status of NPK on the surface soil than non inter cropped system. Pine apple crop recycled a major part of the absorbed N and K causing more accumulation of N and K in all the treated plots. Among the eight combinations of tree and intercrop, *Gmelina arborea* +pine apple combination is considered the best agroforestry system for maintaining better soil health and sustaining the system in acidic *Inceptisols* under humid tropical climatic situation.

Key words: Agroforestry system, soil properties, intercrops, trees

Introduction : Agroforestry which is an ecologically based traditional farming practice, integrates trees into the farming systems to ameliorate soil fertility and increase agricultural productivity, control soil erosion, conserve biodiversity and diversify income for households and communities (Bishaw et al., 2013). Trees have deep and spreading roots and hence are capable of taking up nutrients and water from deeper soil layers usually where herbaceous crop roots cannot reach. The growth and development of root system of multipurpose tree governs the nutrient pumping in agroforestry systems. The deep root system act as 'safety net' and absorb leached nutrients, and pump it to the aboveground growing part of the tree (Suprayogo et al 2010, Kumar 2011). Trees may also enhance above- and belowground microclimate, while meso- and microfauna and microflora around plant roots may alter soil chemical, biological, and physical properties(Visser and Parkinson, 1992).This process mainly depends on characteristics of tree species and other soil, climatic and topographic factors(Makumba et al., 2009; Schroth and Sinclair, 2003; Schroth, 1999).Productivity and sustainability of particular agroforestry system depends upon the soil properties which are influenced by the trees and intercrops. Agroforestry systems have been considered sustainable land-use alternatives for the humid tropics because they may imitate characteristics of natural ecosystems notably those that have beneficial effects on soil properties. The soil properties varied with the perennial tree type, its rooting pattern, canopy and leaf litterfall. Similarly the properties are also influenced by type of intercrops and biomass removed.

Under humid tropical climate a number of agro forestry systems are followed. Very few works are available for claiming their suitability on the basis of productivity and sustainability. All these commonly followed systems need to be evaluated on their effect on soil fertility in order to assess the sustainability.In this present investigation, four common intercrops (pineapple, mango ginger, turmeric and arrowroot)grown under two common multipurpose tree species (*Dalbergia sissoo* and *Gmelina arborea*) have been evaluated with respect to their influence on common and important soil properties such as BD, soil pH, EC, SOC, Ca, Mg, CEC, available N,P and K using a 13 year old existing Agro forestry system.

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Materials and Methods

Location of the Experimental Field

Theexperimental field is located in Central Research Station of O.U.A.T, Bhubaneswar at a Latitude 20^{0}15' N and longitude of 85^{0} 52' E.The climate of experimental site is hot and humid with mean annual rainfall of 1493.7mm.

Details of the Experiment

Existing system of agroforestry system was started in 2001 under the aegis of AICRP on Agroforestry of ICAR, New Delhi with two tree species *Dalbergia sissoo* (Sissoo) and *Gmelina arborea* (Gambhar) which continued with different intercrops which got changed time to time.In the year 2013, the system included 4 intercrops such as pineapple, mango ginger, turmeric and arrowroot. The initial physico-chemical properties of the surface soil are presented in the table1.The soil is sandy loam on surface layers with acidic pH (4.85) ,EC (0.127 dSm-1), Ca (1.85 cmol (p+)kg-1), Mg (0.82 cmol (p+) kg-1), CEC (5.21 cmol (p+)kg-1), low organic carbon (3.9gkg-1) , low available N(181.6 kgha-1), medium available P (27.5 kgha-1) and medium available K(138.5 kg ha^{-1}). For the present investigation the experiment was conducted with 11 treatments as T_1-control (without tree and intercrop), T_2-*D.sissoo*, T_3-*G.arborea*, T_4- *D.sissoo* +Pineapple,T_5-*D.sissoo* + mango ginger, T_6-*D.sissoo* + turmeric, T_7-*D.sissoo* + arrowroot, T_8- *G.arborea* + pineapple, T_9-*G.arborea* + mango ginger, T_{10}-*G.arborea* + turmeric and T_{11}-*G.arborea* + arrowroot in RBD with 3 replications. Surface soil samples were collected in the post harvest period of the year 2014-15 (after 13 years of agroforestry system), processed and analysed the soil properties. The growth parameters of both trees and intercrops were recorded . The analysis of soil properties was done following standard methods as detailed below.

Soil properties

Soil Textural Class

Mechanical analysis of the soil was done to find out the percentage ofsand, silt and clay separately by means of Bouyoucos hydrometer method to determine the texture of soil (Piper, 1950).

Bulk density (BD)

Bulk density was determined by core sampler method with dividing theoven-dry soil sample by the total volume of the sample. The bulk density equation is as follows:

Soil bulk density (g cm-3) = Oven-dry sample mass (g) / Total volume of soil (cm^3)

pH

Soil pH was determined in 1:2.5 soil and water suspension by using glasselectrode pH meter (Jackson, 1967).

Electrical conductivity

Soil EC was determined in 1:2.5 soil and water suspension by using conductivity meter (Jackson, 1967).

Organic carbon

Organic carbon content of the soil sample was determined byWalkley and Black's rapid titration method (Piper, 1950).

Ca and Mg

Exchangeable Ca and Mg were extracted by NH_4OAc method (Jackson, 1968) and determined by Perkins Elmer Atomic Absorption Spectrophotometer method after necessary dilution.

CEC

Cation exchange capacityofsoilwasdetermined by neutral 1N ammonium acetate method and ammonium saturated soil was washed with 90% alcohol then washed with 80% alcohol. After distillation, it was titrated against 0.02N H_2SO_4 till the colour change to red.The CEC was calculated from the titration values (Jackson,1967).

Available nitrogen

Available nitrogen was determined by alkaline potassium permanganate method . Nitrogen released as ammonia during distillation of 20-gram soil with 100 ml 0.32% of $KMnO_4$ and 100 ml of 2.5% NaOH was received in 2% boric acid containing mixed indicator and ammonium borate complex was titrated against standard 0.02 N H_2SO_4.

Available phosphorous

It was determined by Bray's-I method with shaking 5-gram soil in 35 ml of extracting solution (0.03N NH_4F in 0.025N HCl) for 5 minutes. The filtrate was estimated by spectrophotometer for phosphorous after development of colour by $SnCl_2$ and measured at 660nm (Jackson, 1973).

Available potassium

Five gm of processed soil was taken in a 150 ml conical flask and shaked with 25 ml 1N neutral ammonium acetate for 5 minutes in a mechanical shaker (reciprocating type). Then, the suspensions were filtered through Whatman no 1 filter paper and filtrate was collected in 50ml beaker. The K concentration of the filtrate was determined by Flame photometer after suitable dilution. (Jackson,1967)

Statistical Analysis

The soil properties data were subjected to analysis of variance following statistical procedure of (Panse and Sukhatme, 1985 and Gomez and Gomez,1984). It was done by DMRT to know the difference among the treatments and contrasting to know the difference between the individual tree and intercrops within the group under agroforestry system. Relationship between various soil and plant parameters was established through linear correlation.

Results and Discussion

Soil Properties: Result on post harvest soil properties of surface layer (0-15cm) is presented in Table 2 and contrasting between groups of variables in Table 3.

Bulk Density

Data in respect to soil bulk density of top soil (Table 2) revealed that in the present study, Agro forestry system of two perennial Trees *Gmelina arborea* and *Dalbergia sissoo* with or without intercrops resulted in decrease in bulk density with improvement in soil physical health in contrast to increase in Open field condition from the initial value of 1,54kg m^{-3} .Both the tree species were however, at par in influencing the surface soil BD. On the other hand , intercropping had significant positive effect on the BD. Among the intercrops pineapple had highest positive effect on BD followed by mango ginger, turmeric and least with arrowroot. The fall of BD in cropped soil is due to the decomposition of tree litter and crop residues left for recycling in the field. Beneficial effect of the trees on the soil structure has also been reported by many workers (Sanchaz 1983, Nair, 1989)

Soil pH

Soil pH is the key soil factor which influences many soil properties especially the microbial activity (Tian et al 2013) and availability of many nutrients (Londo et al 2006).Data pertaining to effect of the investigating Agroforestry system on soil pH revealed that there was a general decrease in soil pH irrespective of treatments except the open field. The surface soil pH varied from 4.64 to 4.86 as compared to the original value of 4.85 with the open field having pH of 4.86. Highest decrease in pH was observed in the soil with pineapple intercrop under *Gmelina arborea* . Tree species significantly influence soil pH; lower pH under agroforestry ascribed to the increased accumulation of aboveground biomass, associated cation uptake and production of organic acids by the tree component of agroforestry systems (Tornquist *et al*

1999, Gupta and Sharma 2009, Sarvade et al 2014c).Rathore et al (2013) reported reduction in soil pH (12.12–15.62 per cent) in fruit based agrihorticultural model (mango + cowpea - toria) compared with the initial value recorded in 1995 before the establishment of orchard. There was more drop in pH with Melina arburea than Dalbergia sissoo. Intercropping further decreased the pH and among the intercrops highest decrease was measured with Pineapple and the four intercrops in terms of their effect on decreasing pH were in the order pine apple < turmeric< mango ginger < arrowroot (Table 3 and Fig 2).

Electrical Conductivity

Data in respect to soil EC presented in Table 2 revealed that the value varied from 0.107 dSm^{-1} to 0.129 dSm^{-1} at 0-15cm depth with the control Open field maintaining highest EC which was significantly higher than the cropped fields. Both the tree species were at par in influencing soil EC at surface layer. With intercropping there was drop in EC which might be due to removal of nutrients in large quantities by the intercrops. Among the intercrops lowest EC (0.110 dSm^{-1}) was measured with pineapple and highest (0,117 dSm^{-1}) with arrow root and intercrops were in the order Pineapple = Mango ginger < Turmeric < Arrow root (Table 3 and Fig 3)

Soil Organic Carbon (SOC)

Trees add organic matter to the soil system in various ways, whether in the form of roots or litterfall or as root exudates in the rhizosphere. Data on soil organic carbon presented in Table 2 and 3 , Fig.4) revealed that the surface soil organic carbon varied from 2.5 gkg^{-1} to 5.9 gkg^{-1} as compared to the initial value, 3.9 gkg^{-1}.Lowest and significantly much lower content(2.5 gkg^{-1}) than the initial(3.9 gkg^{-1}) and present content of all cropped soils (4.1-5. gkg^{-1}) was measured in the open field control plot which might be due to erosion loss of top soil and no contribution from trees. registered significant decrease in OC content. Soil with Agro forestry system whether with or without intercrops however registered significant increase in organic carbon content. Highest increase in SOC was observed in the soil with pineapple intercrop followed by mango ginger, turmeric and arrowroot under *Gmelina arborea* than *Dalbergia sissoo*. The *Gmelina arborea* caused significantly higher organic matter built up in surface soil than *Dalbergia sissoo*. Inclusion of intercropping also further enriched the soil with organic carbon which might be due to addition of crop residues , roots and root exudates.by the intercrops. Among the intercrops pine apple was most efficient in maintaining highest content of organic carbon (5.9 gkg^{-1}) followed by mango ginger and turmeric and arrowroot. Rizwan et al (2020) also reported increase in organic carbon under *Gmelina arborea* due to the decomposition of crop residues and leaf litter fall. In our experiment we have recorded 29.2% higher annual litter fall with *Gmelina arborea* than *Dalbergia sissoo* (Fig. 1) The annual Litter fall was 991kg ha^{-1} with the former as compared to 767kg ha^{-1} with the latter.

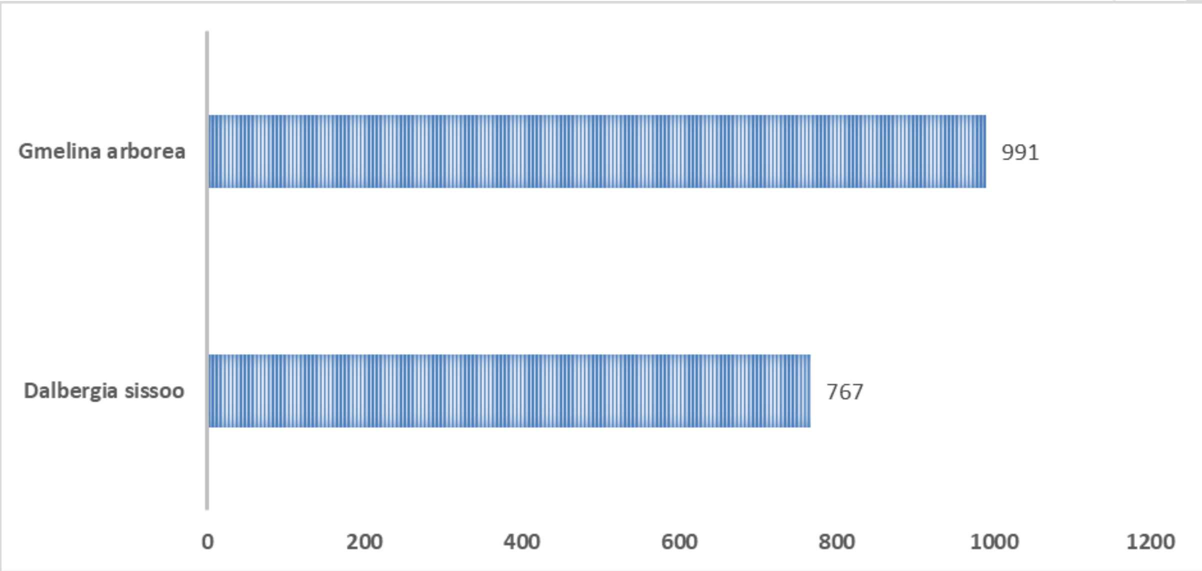

Fig 1. Annual Litter Fall by the two tree species in kg ha^{-1}

Ca and Mg

Data pertaining to effect on Ca and Mg recorded in Table 2 revealed that the content of these two cationic secondary nutrients varied from 1.61 to 1.89 cmol (p+) kg^{-1} and 0.67 to 0.86 cmol (p+)kg^{-1} at 0-15cm depth as compared to the initial values of 1.85 and 0.82 cmol (p+) kg^{-1} respectively. Results show that in the open field had highest content of both these nutrients which was more than the initial value and all cropped fields registered lower content of both the nutrients. This might have happened due to the uptake of Ca and Mg by the tree species by continuous planting with agroforestry system. Among the intercrops highest decrease in Ca and Mg content was observed with the pineapple intercrop under both the trees. The result of lowest Ca and Mg in pine apple planted plot and highest in control plot substantiated with their pH values.

CEC

Data on CEC presented in Table 2 and 3 and depicted in Fig 6 revealed that the CEC ranged between 4.20 and 5.29 cmol (p+) kg-1 at 0-15cm depth. There is fall in CEC in all cropped soil which is due to more uptake of basic cations ca and Mg by the perennial tree species in the agroforestry system irrespective of the treatments where as unplanted control maintained a higher CEC(5,29 cmol (p+) kg^{-1}). Among the treatments lowest CEC was measured in the soil under pineapple intercrop followed by mango ginger, turmeric and arrowroot under *Gmelina arborea* which is due to the same reason of uptake of basic cations and creation of more soil acidity. *Gmelina arborea* absorbed more Ca and Mg than *Dalbergia sissoo* and maintained lower CEC.

Available N

Results pertaining to available N presented in Table 2 and 3 and depicted in Fig 7 revealed that the mineralizable N ranged between 163.3 and 211.3 $kgha^{-1}$ at 0-15cm depth. The Agro forestry system had significant effect on available N. Data revealed that the decomposition of crop residues and leaf litter fall by continuous planting with agroforestry system resulted in increase in available N irrespective of the treatments where as unplanted open field registered a significant decrease the available N . Highest increase in available N was measured in the soil with pineapple intercrop followed by mango ginger, turmeric and arrowroot under both the tree species. Between the trees *Gmelina* *arborea* registered higher leaf fall, maintained higher organic carbon content and eventually more available N than *Dalbergia sissoo.* All the intercropped treatments also maintained higher available N content as there was accumulation of mor organic matter also, Among the intercrops , Pineapple planted soil recorded highest available N (mean of 208.5 $kgha^{-1}$) and arrowroot the lowest(mean of 197.3 $kgha^{-1}$). The additions organic matter by tree species form the chief substrate for a vast range of organisms involved in soil biological activity and interactions, with important effects on soil nutrients and fertility especially the mineralizable N.

Available P

Data pertaining to available P recorded in Table 2 and 3 and separately depicted in Fig 8 revealed that after 13 years of Agro Forestry the available (Bray's) P in the surface soil varied from 21.3 to 38.6 $kgha^{-1}$ and the treatments had significant effect on available P. Results revealed that the decomposition of crop residues and leaf litter fall by continuous planting with agroforestry system resulted in increase in available P irrespective of the treatments where as unplanted control field registered a decrease the available P(21.3 kg ha^{-1}) as compared to the initial status (27.5kg ha^{-1}). Between the trees *Gmelina arborea* maintained significantly higher content of available P than Dalbergia sissoo. Intercropping also registered higher content. Among the intercrops arrowroot intercrop registered highest available P followed by pineapple, mango ginger and turmeric.

Available K

Data pertaining to available K revealed that there was decrease in available K in the soil of the uncropped open field and increase in all cropped treatments. In the control the content measured 103kg ha^{-1} as compared to the initial 138.5kg ha^{-1} where as in all the cropped fields the value varied from 142.8 to 191.6 $kgha^{-1}$ at 0-15cm depth. The treatments had significant effect on available K status of the top soil. Between the two tree species *Gmelina arborea* registered significantly higher available K (mean 175.5 kg ha^{-1}) than *Dalbergia sissoo*(mean 156.1 kg ha^{-1}).Similarly intercropping on an average caused more available K (mean 169.4.1 kg ha^{-1}) than non intercropped system(mean 151.2 kg ha^{-1}). Among the intercrops highest mean available K measured was 182.5 kg ha^{-1} in the surface soil under pineapple intercrop which was followed by mango ginger (174.6 kg ha^{-1}), turmeric(167.3 kg ha^{-1}) and least in arrowroot(153.3 kg ha^{-1}).This has been depicted in Fig 9 separately to make it more clear.

These findings agree with a host of authors, who reported improvement in soil properties as the plantations advanced in age (Chijioke, 1980; Trouve et al.,1994; Mishra et al., 2003; Swamy et al., 2004). Trouve et al.(1994)found a progressive increase in organic matter under Eucalyptus spp. plantations in Congo DR Chijioke (1980)and Swamy et al. (2004) reported a significant improvement in soil nutrients status under *Gmelina arborea* plantations in Nigeria and India, respectively.

Table:1 Initial Physical and chemical properties of surface soil

Soil characteristics	0-15 cm
Sand (%)	74.8
Silt (%)	10.4
Clay (%)	14.8
Textural class	Sandy loam
BD (kgm^{-3})	1.54
pHw (1:2.5)	4.85
EC (dSm^{-1})	0.127
OC (gkg^{-1})	3.9
Ca [cmol (p+)kg-1]	1.85
Mg [cmol (p+)kg-1]	0.82
CEC [cmol (p+)kg-1]	1.85
Available N ($kgha^{-1}$)	181.6

Available P (kgha^{-1})	27.5
Available K (kgha^{-1})	138.5

Table.2 Soil properties influenced by agroforestry system at surface soil (0-15cm) during 2014-15

Treatments	BD (kgm^{-3})	Soil pH(1: 2.5)	EC (dSm^{-1})	OC (gkg^{-1})	Ca (cmol(p+)kg^{-1})	Mg (cmol(p+)kg^{-1})	CEC (cmol(p+)kg^{-1})	Avail. N (kgha^{-1})	Avail.P (kgha^{-1})	Avail. K (kgha^{-1})
T_1- Control (without tree and intercrop)	1.55_{a}	4.86_{a}	0.129_{a}	2.5_{g}	1.89_{a}	0.86_{a}	5.29_{a}	163.3_{i}	21.3_{h}	103.0_{h}
T_2-*Dalbergiasissoo* without intercrop	1.53_{ab}	4.84_{b}	0.126_{b}	4.1_{f} (39)	1.82_{b}	0.78_{b}	5.01_{b}	190.5_{h}	29.9_{g}	142.8_{g}
T_3-*Gmelinaarborea* without intercrop	1.52_{b}	4.81_{c}	0.123_{b}	4.4_{e} (43)	1.77_{c}	0.76_{c}	4.76_{c}	199.9_{e}	30.3_{g}	159.6_{ef}
T_4- Pine apple under *Dalbergiasissoo*	1.47_{e}	4.69_{f}	0.113_{de}	5.8_{a} (57)	1.62_{gh}	0.67_{gh}	4.41_{ef}	205.7_{bc}	33.7_{d}	173.4_{d}
T_5- Mango ginger under *Dalbergiasissoo*	1.49_{cd}	4.73_{e}	0.114_{d}	5.2_{c} (52)	1.65_{fg}	0.69_{fg}	4.44_{de}	197.3_{f}	32.7_{e}	161.6_{e}
T_6- Turmeric under *Dalbergiasissoo*	1.49_{cd}	4.74_{e}	0.115_{d}	5.0_{cd} (50)	1.66_{ef}	0.69_{ef}	4.46_{de}	196.8_{fg}	30.1_{f}	157.5_{f}
T_7- Arrowroot under *Dalbergiasissoo*	1.50_{c}	4.80_{c}	0.120_{c}	4.8_{d} (48)	1.71_{d}	0.71_{d}	4.57_{d}	192.9_{g}	35.1_{c}	144.9_{g}
T_8- Pine apple under *Gmelinaarborea*	1.47_{e}	4.64_{g}	0.107_{g}	5.9_{a} (58)	1.61_{h}	0.67_{h}	4.20_{g}	211.3_{a}	36.2_{b}	191.6_{a}
T_9- Mango ginger under *Gmelinaarborea*	1.47_{e}	4.67_{f}	0.108_{fg}	5.7_{ab} (56)	1.62_{gh}	0.67_{gh}	4.27_{fg}	206.5_{b}	34.9_{c}	187.6_{b}

T_{10}-Turmeric under *Gmelinaarborea*	1.48_{d}	4.69_{f}	0.110_{ef}	5.5_{b} (54)	1.65_{fg}	0.69_{fg}	4.33_{efg}	204.8_{c}	31.7_{ef}	177.0_{c}
T_{11}-Arrowroot under *Gmelinaarborea*	1.49_{cd}	4.78_{d}	0.114_{d}	5.1_{c} (51)	1.68_{de}	0.70_{de}	4.44_{de}	201.6_{d}	38.6_{a}	161.7_{e}
SEm(±)	0.01	0.01		0.08	0.01		0.05	1.69	0.56	1.16
CD $_{(0.05)}$	0.02	0.02	NS	0.23	0.03	0.01	0.14	3.52	1.64	3.41
Initial (May 2013)	1.54	4.85	0.127	3.9	1.85	0.82	5.21	181.6	27.5	138.5

Values in parenthesis are the percentage increase of organic carbon over control.

Table -3 Contrasting on soil properties at surface soil (0-15cm) influenced by agroforestry system during 2014-15

Contrasting on soil properties at surface soil (0-15cm) influenced by agroforestry system during 2014-15								
	BD (kgm^{-3})	Soil pH (1:2.5)	EC (dSm^{-1})	OC (gkg^{-1})	CEC ($cmol(p+)kg^{-1}$)	Avail.N ($kgha^{-1}$)	Avail.P ($kgha^{-1}$)	Avail.K ($kgha^{-1}$)
Control vs Planted Mean								
Control	1.55	4.86	0.129	2.5	5.29	163.3	21.3	103.0
Planted Mean	1.49	4.74	0.115	5.1	4.49	200.7	33.3	165.8
SEm(±)	0.01	0.01	0.001	0.08	0.05	1.25	0.58	1.21
CD $_{(0.05)}$	0.01	0.01	0.002	0.17	0.10	2.61	1.22	2.53
DalbergiasissoovsGmelinaarborea								
Dalbergiasissoo	1.50	4.76	0.118	5.0	4.58	196.6	32.3	156.1
Gmelinaarborea	1.49	4.72	0.113	5.3	4.40	204.8	34.3	175.5
SEm(±)			0.001	0.05	0.03	0.75	0.35	0.73
CD $_{(0.05)}$	0.01	0.01	0.001	0.11	0.06	1.57	0.73	1.53
Only Tree vs Tree + Intercrops								
Tree (-Intercrop)	1.53	4.83	0.124	4.3	4.89	195.2	30.1	151.2
Tree (+Intercrop)	1.48	4.72	0.113	5.4	4.39	202.1	34.1	169.4
SEm(±)	0.01	0.01	0.001	0.06	0.04	0.94	0.44	0.92
CD $_{(0.05)}$	0.01	0.01	0.002	0.13	0.08	1.97	0.92	1.91
Difference among intercrops (4)								

Pineapple	1.47	4.66	0.110	5.9	4.31	208.5	35.0	182.5
Mango ginger	1.48	4.70	0.111	5.5	4.36	201.9	33.8	174.6
Turmeric	1.49	4.72	0.113	5.3	4.40	200.8	30.9	167.3
Arrowroot	1.50	4.79	0.117	4.9	4.51	197.3	36.9	153.3
SEm(±)	0.01	0.01	0.001	0.08	0.05	1.19	0.56	1.16
CD $_{(0.05)}$	0.01	0.01	0.002	0.17	0.10	2.49	1.16	2.41

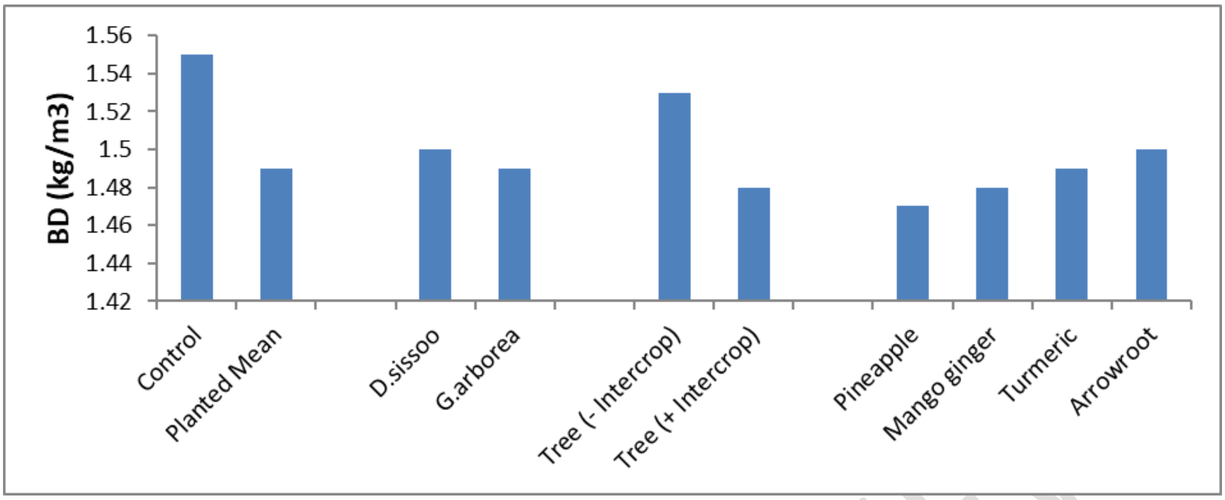

Fig.2. Contrasting of BD at surface soil (0-15cm)

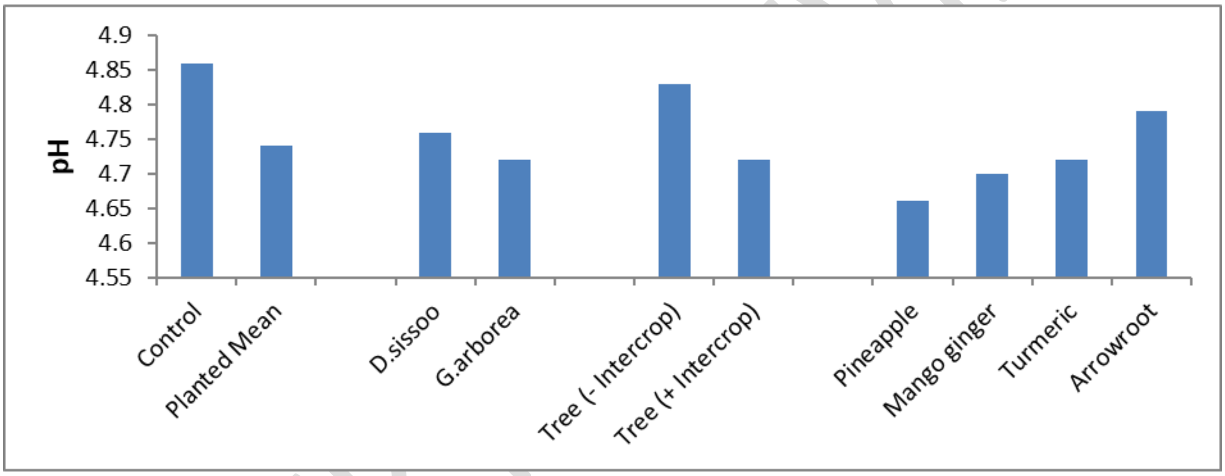

Fig.3. Contrasting of pH at surface soil (0-15cm)

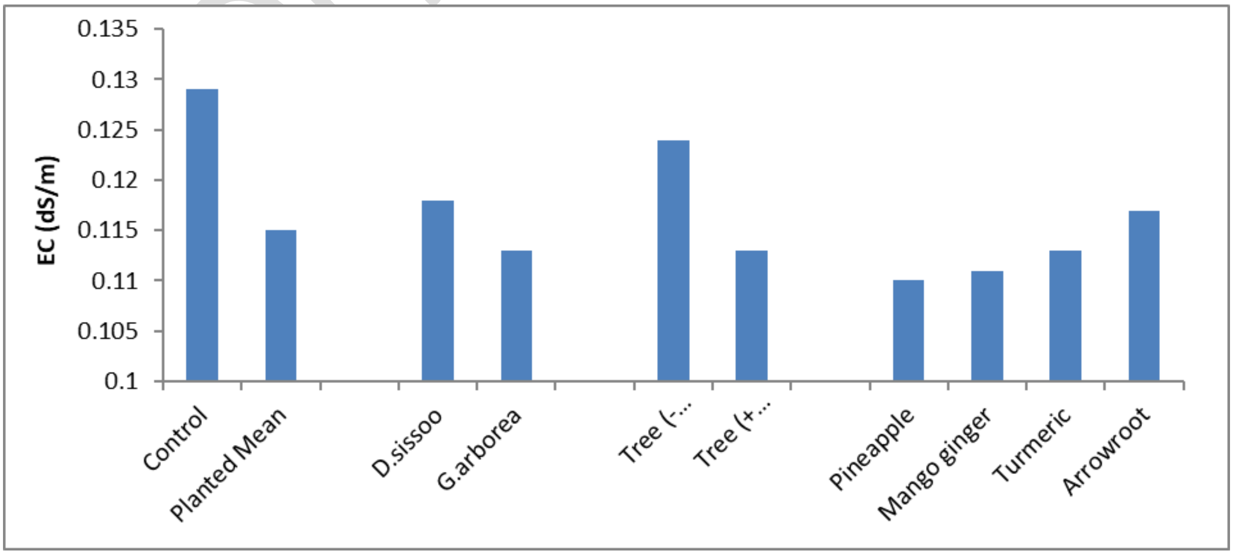

Fig.4. Contrasting of EC at surface soil (0-15cm)

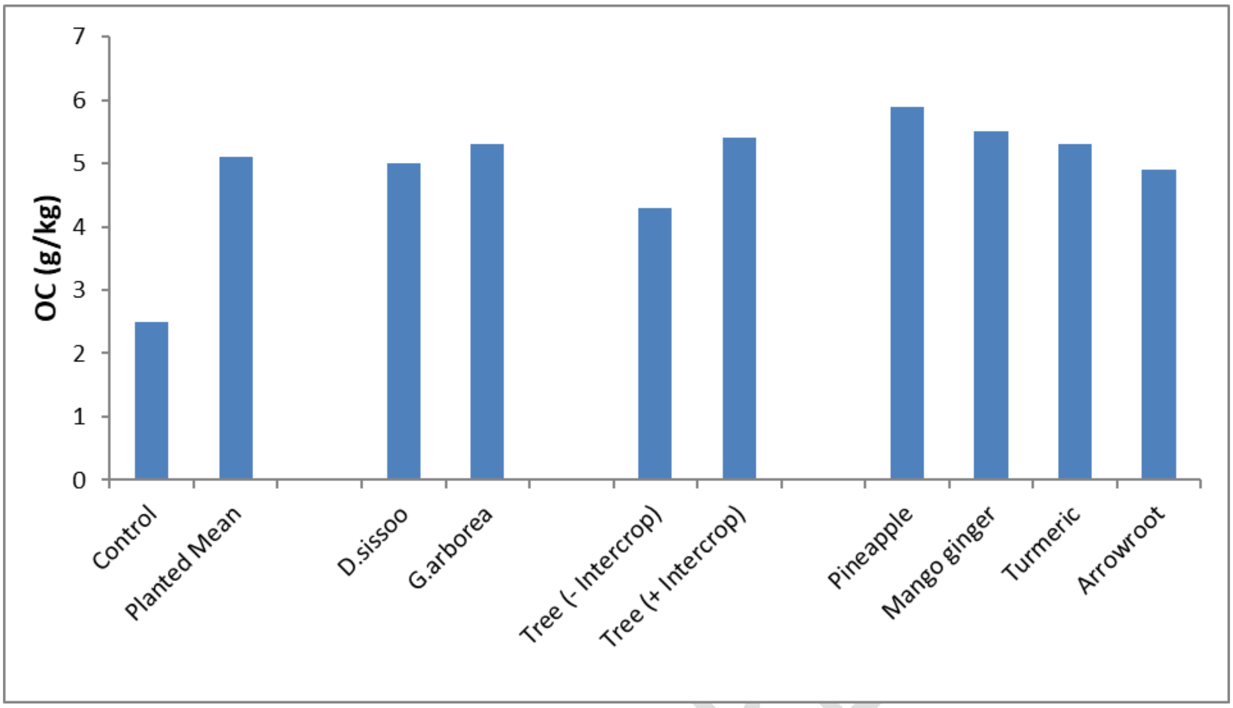

Fig.5. Contrasting of OC at surface soil (0-15cm)

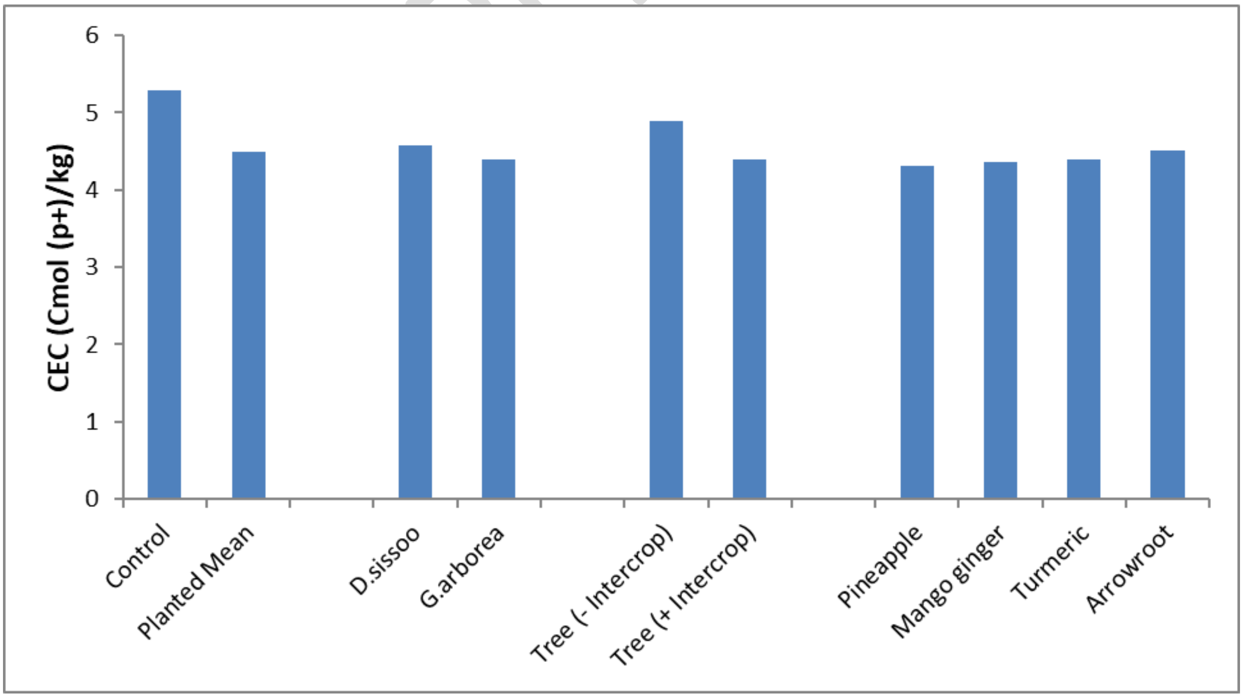

Fig.6. Contrasting of CEC at surface soil (0-15cm)

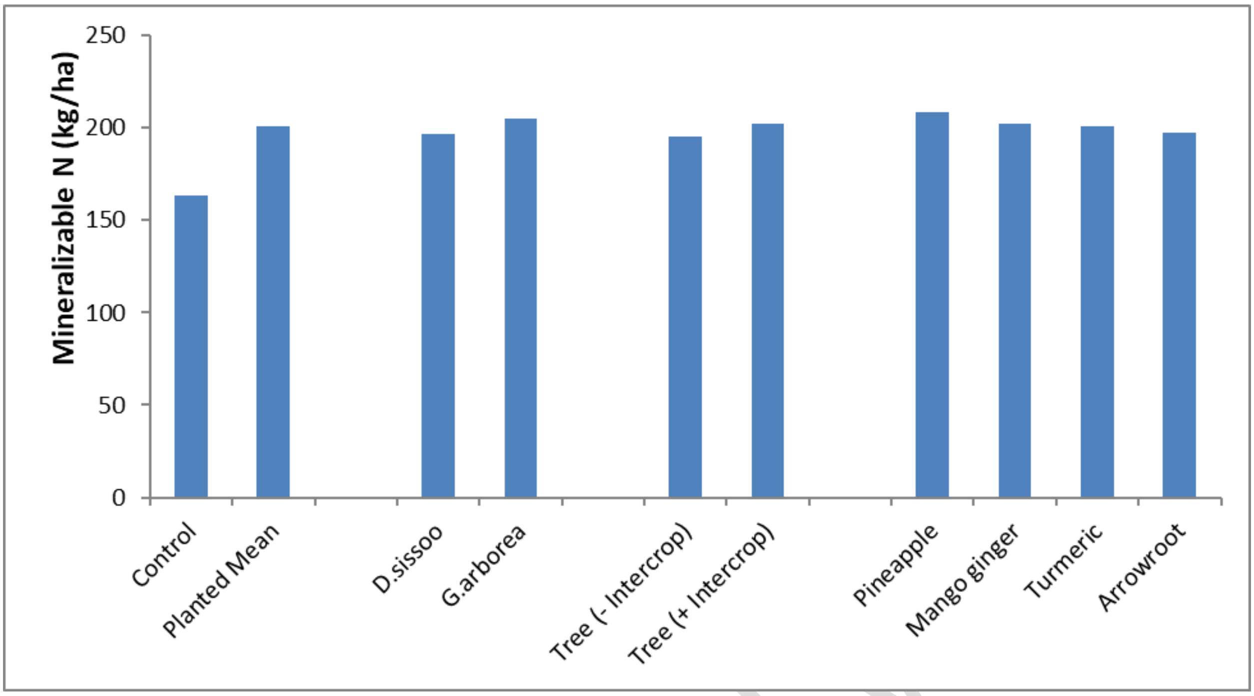

Fig.7. Contrasting of Mineralizable N at surface soil (0-15cm)

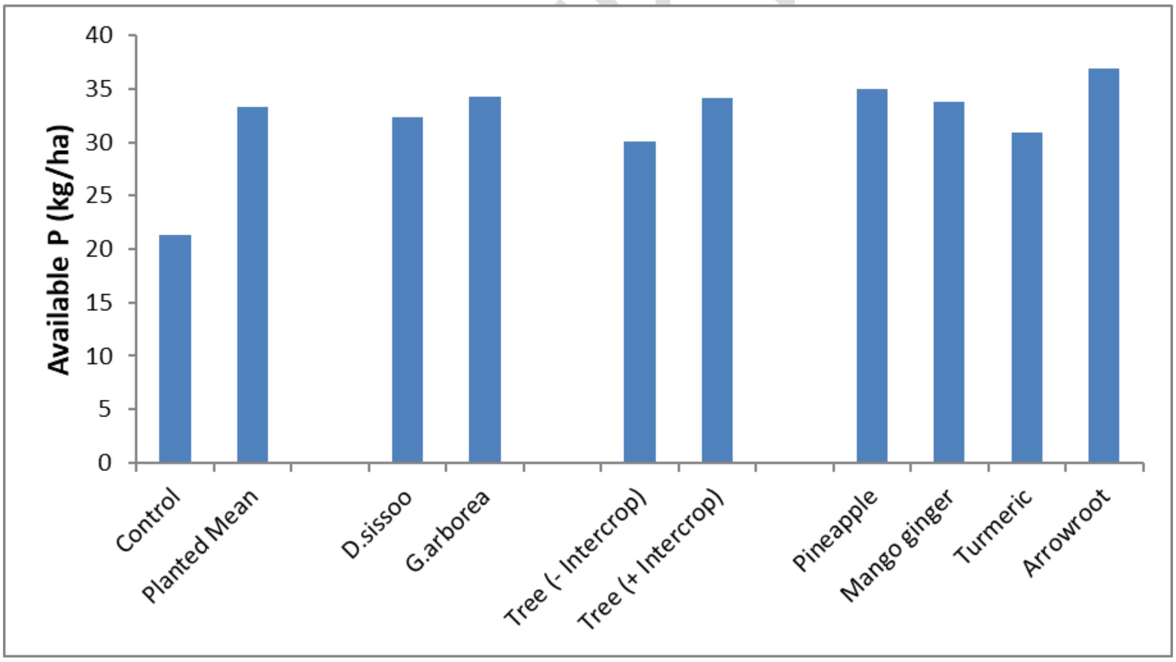

Fig.8. Contrasting of available P at surface soil (0-15cm)

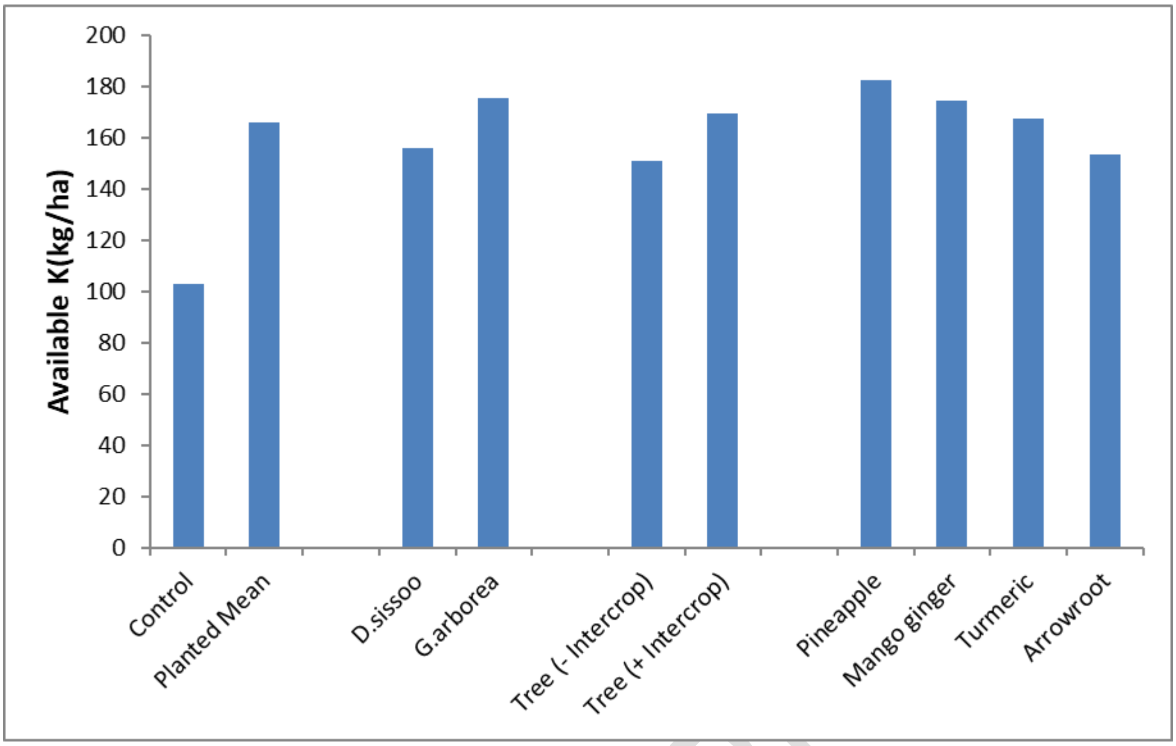

Fig.9. Contrasting of available K at surface soil (0-15cm)

Biomass accumulation by the Intercrops

Measurement of biomass of the intercrops presented in Table 6 revealed that at harvest, the stovers biomass varied from 6000 kg ha^{-1} to 9333 kg ha^{-1} and the economic harvested fruit or rhizome biomass varied from 2765 kg ha^{-1} to 7382 kg ha^{-1} . Among the intercrops highest biomass both in stover and economic part was measured in arrowroot and lowest in turmeric under both the tree species. Partitioning of Biomass into stover and economic part depicted in Fig 10 clearly demonstrates that the four intercrops in terms of mean biomass accumulated in stover, economic part and in the total above ground part , are in the order, Arrowroot > pine apple > mango ginger > turmeric. Between the two tree species, accumulation of biomass by the intercrops was more under *Dalbergia sissoo* than *Gmelina arborea* (Fig.11).

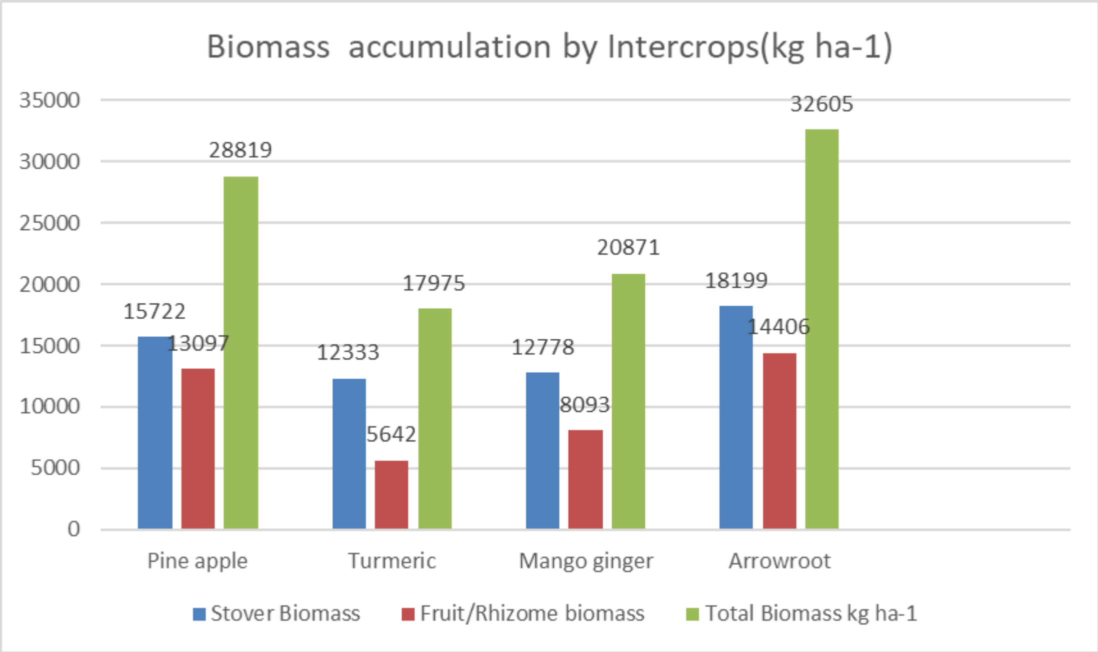

Fig.10 Mean Biomass accumulation by the Intercrops in the Tree based Agro forestry system

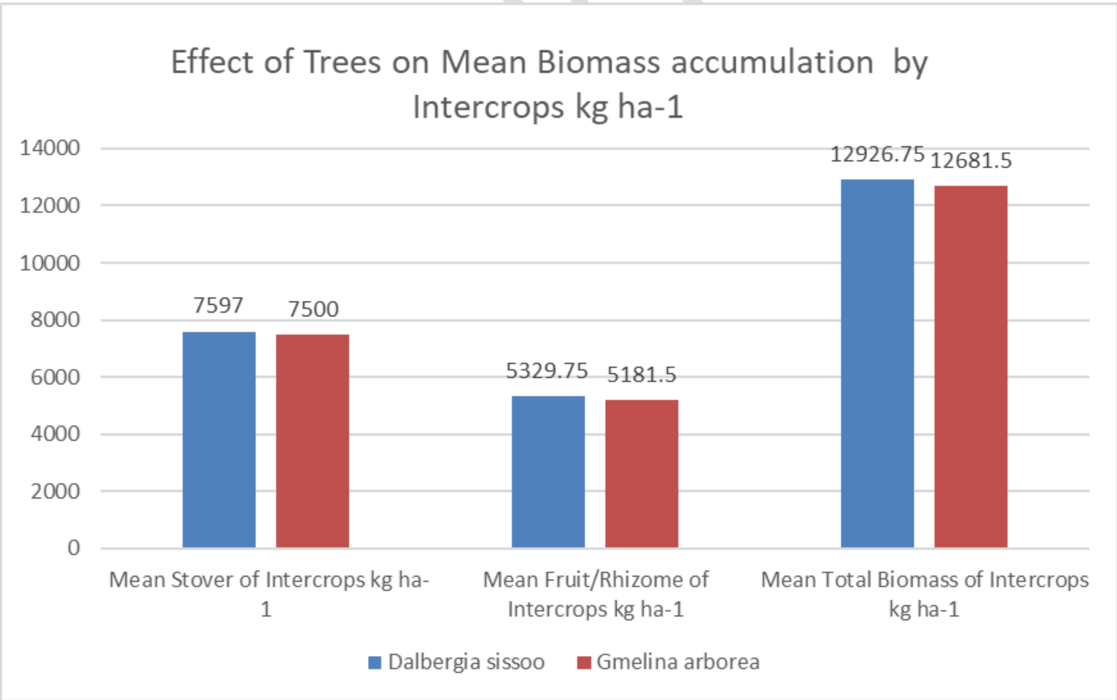

Fig.11 Effect of Trees on the mean Biomass accumulation (kg ha^{-1}) by the Intercrops in the Tree based Agro forestry system

Table: 4. Biomass of intercrops (kg ha^{-1}) during 2014-15

Treatments	Biomass of intercrops (dry) (kg ha^{-1})		Total above ground Biomass (kg ha^{-1})
	Stovers	Economic part	
T_4- Pine apple under *Dalbergia sissoo*	8055 $_c$	6845 $_c$	14900
T_5- Mango ginger under *Dalbergia sissoo*	6333 $_f$	2877 $_g$	9210
T_6- Turmeric under *Dalbergia sissoo*	6667 $_e$	4215 $_e$	10,882
T_7- Arrowroot under *Dalbergia sissoo*	9333 $_a$	7382 $_a$	16715
T_8- Pine apple under *Gmelina arborea*	7667 $_d$	6252 $_d$	13919
T_9- Mango ginger under *Gmelina arborea*	6000 $_h$	2765 $_h$	8265
T_{10}-Turmeric under *Gmelina arborea*	6111 $_g$	3878 $_f$	9989
T_{11}-Arrowroot under *Gmelina arborea*	8866 $_b$	7024 $_b$	15890
SEm(±)	0.60	9.21	-
CD $_{(0.05)}$	1.83	27.93	-

Relationship among soil and Plant parameters

Table 5. Relationship among soil and Plant parameters in terms of Linear Correlation Coefficient(r)

Sl Number	**Correlation between**	**Correlation Coefficient(r)**
1	pH vs SOC	0.887
2	pH vs Ca	0.918
3	pH vs. Mg	0.863
4	pH vs CEC	0.964
5	pH vs. Avail N	-0.766
6	pH vs Avail.P	-0.581
7	pH vs. Avail K	-0.899
8	SOC vs. Avail N	0.919
9	SOC vs Avail. P	0.845
10	SOC vs. Avail K	0.953
11	Biomass of Intercrop recycled vs. Avail N	0.398
12	Biomass of Intercrop recycled vs Avail. P	-0.395

14	Biomass of Intercrop recycled vs. Avail K	0.637
15	Biomass of Intercrop recycled vs Economic Yield	0.954

Results of Correlation study presented in Table 5 revealed that surface soil pH is strongly and positively correlated with SOC, Ca, Mg and CEC and negatively with Available N, P and K of surface soil. But SOC has stong and positive correlation with Available content of NPK. Similarly Intercrop biomass recycled has strong positive relationship with economic yield and available nutrients like available K.

Conclusion

With Agro forestry system there was improvement in soil bulk density, organic matter and available nutrients as compared to open field where there was loss of nutrients. Between the trees, *Gmelina arborea* maintained higher level of soil organic carbon ,available N, available P and available K on top soil than *Dalbergia sissoo*. Inclusion of intercrops maintained significantly higher organic carbon and available status of NPK on the surface soil than non inter cropped system. Among the intercrops highest soil organic carbon was maintained in the soil under pineapple followed by mango ginger , turmeric and least with arrowroot. Among the intercrops highest available N and K was maintained in pineapple followed by mango ginger , turmeric and least with arrowroot. But among the intercrops highest available P was maintained in arrowroot followed by pineapple ,mango ginger and least with turmeric. Pine apple crop recycled a major part of the absorbed N and K causing more accumulation of N and K in all the treated plots. Gmelina arborea +pine apple combination is considered the best agroforestry system for maintaining soil health and sustaining the system.

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