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Role of agroforestry in biomass production and soil moisture conservation in fruit based agrisilvihorticultural systems with legume intercrops in Odisha

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Abstract
This paper presents an experiment conducted at the experimental site of All India Co-Ordinated Research Project on Agroforestry, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, India, during July 2016 - January 2017 to determine the biomass and soil moisture content in fruit based agroforestry systems. The experiment was consisted of 16 treatment combinations including 12 agrisilvihorticultural systems comprised of combination of three fruit species such as mango, jack fruit & cashew and four legume crops i.e. arhar, groundnut, blackgram & cowpea and four sole crops. It was evident that among the fruit trees higher soil moisture was recorded with mango followed by jackfruit and cashewnut irrespective of the associated intercrops throughout the cropping season. The highest biomass of (7.66 t ha^{-1}) was recorded with cashewnut in cashewnut + blackgram system followed by jackfruit under jackfruit + groundnut system (7.06 t ha^{-1}) at 12 months respectively. The highest biomass of (11.79 t ha^{-1}) was recorded with jackfruit in jackfruit + blackgram system followed by cashewnut in cashewnut + blackgram systems of (11.33 t ha^{-1}) at 18 months respectively.

Keywords: Biomass, soil moisture, agroforestry, agrisilvihorticultural, legume, fruitbased, Odisha

Introduction
Agroforestry is a land use system that involves deliberate retention, introduction, or mixture of trees or other woody perennials in crop/animal production field to benefit from the resultant ecological and economical interactions (Chaturvedi and Krishnan, 2009) [9]. An efficient agroforestry system would aim at systematically developing integrated land use systems and practices where the positive interaction between trees and crops are encouraged and maximized. Agroforestry offers an economical and ecologically viable option for large scale diversification in agriculture on one hand and environmental amelioration on the other. Hence to save forests and meet the growing demands of wood, there is need for large scale plantations of fast growing tree species outside forests to make country self-reliant in its timber requirements. On-farm timber tree plantations can also benefit from the global environmental facilities like carbon trading (Pandey, 2007 and Dogra, 2007) [15, 18]. Therefore, there is a great need to identify the suitable agricultural and horticultural crops, which can grow well along with tree species with limited solar energy available underneath the trees. The tree based land-use agroforestry system is an ideal scientific approach in restoring soil fertility and improving its quality by several ways. The presence of tree component in agroforestry systems influence the physio-chemical properties of soil as physical (B.D., WHC, texture, structure, temperature) and chemical (pH, exchangeable bases, available N, P, K, soil organic carbon). Agroforestry systems have the potential to reduce erosion and runoff, and to maintain soil organic matter, improve soil physical properties and augment nitrogen fixation and promote efficient nutrient cycling (Nair, 1984) [14]. Improvement in soil fertility under agroforestry systems occurs mainly through addition of plant biomass and nutrient pumping from deeper layers. The fertility of soil improves under the tree cover, which checks soil erosion, adds soil organic matter, available nutrients and replenishes the nutrients through effective recycling mechanisms. Soil and water resources are better conserved under any trees including eucalyptus compared to keeping large tracts of land barren or even under grass cover. The objective of taking pulses as intercrops is to improve and maintain soil fertility besides complementing in growth and productivity of fruit based agrisilvihorticultural system.

2. Materials and Methods
The present investigation was carried out at the experimental site of All India Co-ordinated Research Project on Agroforestry,

Odisha University of Agriculture and Technology, Bhubaneswar during July 2016 to January 2017. The experiment was laid out in a randomized block design having sixteen (16) treatments with three (3) replications. The treatment includes twelve (12) agroforestry systems, namely, T1 = mango + arhar, T2 = mango+ groundnut, T3 = mango+ blackgram, T4 = mango + cowpea, T5 = jackfruit + *arhar*, T6 = jackfruit + groundnut, T7 = jackfruit+ blackgram, T8 = jackfruit + cowpea, T9 = cashewnut + arhar, T10 = cashewnut + groundnut, T11= cashewnut + blackgram, T 12 = cashewnut + cowpea and four sole crops i.e. T 13 = sole arhar, T 14 = sole groundnut, T 15 = sole blackgram and T 16 = sole cowpea. Four intercrops, *Cajanus cajan* (arhar), *Arachis hypogaea* (groundnut), *Vigna mungo* (blackgram), *Vigna unguiculata* (cowpea) were planted at spacing of 60 X 20 cm, 30 X 10 cm, 30 X 10 cm and 45 X 15 cm respectively. Fruit tree were planted at 8.0 m x 7.5 m during July 2015 and Eucalyptus tree was raised as filler tree in between two fruit trees in east-west direction at 8.0 m x 7.5 m. Soil pH, Organic carbon content, available nitrogen one at 0-15 cm and another at 15- 30 cm, soil moisture content (%), the biomass of standing trees (both below and above ground along with DBH) were recorded by using different instruments and formula.

3. Results and Discussion

i. Soil fertility changes under agrisilvihorticultural systems

Data on available nutrient status of soil *i.e.* pH, organic carbon, available nitrogen, available phosphorous and available potassium were recorded after the harvest of the crops, analysed in the laboratory and presented in Table 1. The organic carbon content, pH, available nitrogen, phosphorous and potassium content of soil differed significantly among various treatments at the end of cropping season.

pH in all the agrisilvihorticultural systems were higher compared to their initial values (5.3). The pH values in agrisilvihorticultural systems ranged from 5.44 to 5.62. Highest pH was found with blackgram in mango + blackgram (5.62) followed by jackfruit + blackgram (5.59). Lowest pH was recorded in cashewnut + groundnut system (5.44).

The organic carbon content from agrisilvihorticultural systems were higher as compared to the initial status (4.4 g kg^{-1}). The value ranged from 4.5 g kg^{-1} to 5.6 g kg^{-1} in different systems. The maximum organic carbon content of 5.6 g kg^{-1} was found in blackgram with mango + blackgram followed by jackfruit + blackgram (5.4 g kg^{-1}). Lowest organic carbon content was found in arhar with cashewnut + arhar (4.5 g kg^{-1}) and jackfruit + arhar (4.5 g kg^{-1}).The increase in soil pH in paddy field was also reported by Sae-Lee *et al.* (1992) [17] in Thailand with four tree species including *Samnea saman*.

The available nitrogen content from agrisilvihorticultural systems were higher as compared to the initial status (204.5 kg ha^{-1}). The value ranged from 205.6 kg ha^{-1} to 249.1 kg ha^{-1} in different systems. The maximum available nitrogen content of 249.1 kg ha^{-1} was found under mango + blackgram followed by jackfruit + cowpea (238.5 kg ha^{-1}) and the lowest available nitrogen content was found in cashewnut + arhar system (205.6 kg ha^{-1}). Bedse *et al.* (2015) [3] observed that maximum values of nitrogen content in intercropping treatment of cowpea. Similarly, Singh *et al.* (2004) [19] mentioned that the decomposition and release of nitrogen through litter fall and its decomposition was more in legume species

Similarly, it was observed that available phosphorous content from agrisilvihorticultural systems were comparatively higher than the initial status (42.5 kg ha^{-1}). The value ranged from 46.3 kg ha^{-1} to 63.1 kg ha^{-1} in different systems. The maximum available phosphorous content of 63.1 kg ha^{-1} was found in groundnut with mango + groundnut system followed by jackfruit + groundnut system (55.9 kg ha^{-1}) and the lowest available phosphorous content was recorded in cashewnut + blackgram system (46.3 kg ha^{-1}).The increase in availability of phosphorous content in the soil by intercropping might be due to increase in total microflora population particularly phosphorous solubilizer in the rhizopher of plant (Cardoso, 2002) [4].

The data pertaining to available potassium content from agrisilvihorticultural systems indicted higher values as compared to the initial status (140.8 kg ha^{-1}). The value ranged from 143.3 kg ha^{-1} to 163.9 kg ha^{-1} in different systems. The maximum available potassium content of 163.9 kg ha^{-1} was found under mango + cowpea system followed by jackfruit + cowpea (159.1 kg ha^{-1}) system and the lowest available potassium content was found in cashewnut + arhar system (143.3 kg ha^{-1}). Animon *et al.* (1999) [1] resulted improving trend with respect to the available nitrogen, phosphorus and potassium content of the soil under acacia and eucalyptus plantations. The pH of the surface soil was reduced by growing acacia and eucalyptus species.

Table 1: Soil fertility status as influenced by trees and crops in agrisilvihorticulturalsystems

Treatment	pH	Organic carbon (g kg^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1 (Mango +Arhar)	5.50	4.9	221.5	54.8	146.5
T_2 (Mango + Groundnut)	5.51	5.2	232.7	63.1	151.3
T_3 (Mango + Blackgram)	5.62	5.6	249.1	49.7	154.8
T_4 (Mango + Cowpea)	5.57	5.2	238.5	52.3	163.9
T_5 (Jackfruit + Arhar)	5.47	4.5	208.6	51.2	144.8
T_6 (Jackfruit + Groundnut)	5.51	4.9	211.9	55.9	150.2
T_7 (Jackfruit + Blackgram)	5.59	5.4	226.7	46.8	152.6
T_8 (Jackfruit + Cowpea)	5.53	5.0	215.3	48.5	159.1
T_9 (Cashewnut + Arhar)	5.45	4.5	205.6	47.7	143.3
T_{10} (Cashewnut + Groundnut)	5.44	4.7	207.7	51.8	146.9
T_{11} (Cashewnut + Blackgram)	5.55	4.9	220.3	46.3	149.3
T_{12} (Cashewnut + Cowpea)	5.47	4.8	212.8	46.9	154.7
Initial soil status	5.43	4.4	204.5	42.5	140.8

ii. Soil moisture content (%)

The soil moisture content under different treatments were observed and presented in Table 2. The data revealed that the soil moisture content under different treatments varied in different depths. It was observed that with the increasing in soil depth soil moisture increased. Soil moisture content in agrisilvihorticultural system is dependent on the type of soil, rooting characteristics of the pulse crops, canopy diameter of fruit species, availability of solar radiation, amount of leaf litter and their timely decomposition (Annual report of AICRP on Agroforestry, 2008).

The intercrops higher soil moisture content was observed with groundnut followed by arhar, blackgram and cowpea irrespective of fruit tree associated. This might be due to dense foliage of groundnut compared to other legume crops and though cowpea had dense foliage the low soil moisture content was attributed to its higher yield by which there was more soil moisture utilization. Avinash *et al.* (2013) [2] reported that agrihorti system recorded higher soil moisture as compared to sole mango plantation. The moisture retention under different agrihorti system was in the order of cowpea (13.32 cm)>black gram (13.29 cm)>pigeon pea (13.27 cm)>okra (12.42 cm)>sesame (12.17 cm) and > sole mango (11.62 cm). The soil moisture content also found to increase from July to August and decline slowly from September onwards and minimum soil moisture content was recorded in October in all the sole crops as well as agrisilvihorticultural systems due to crop uptake with increase in crop growth and less rainfall in subsequent months. There was also higher moisture in lower depth compared to surface soil layer in all the systems during entire crop growth period. The higher available soil moisture content was observed with sole intercrops grown in open condition in from July to October but after that in November the higher available soil moisture content was observed in all the agrisilvihorticultural systems compared to the open field conditions irrespective of the fruit trees associated. This may be attributed to less evaporation loss under the tree canopy towards the end of kharif season when the soil moisture was limiting. Ghanbari *et al.* (2010) [9] reported that the intercropping of maize with cowpea resulted in higher soil moisture conservation compared to maize alone.

Table 2: Soil moisture content (%) at different depth (cm) in agrisilvihorticultura systems

Treatments	July		Aug		Sep		Oct		Mean	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1 (Mango +Arhar)	9.47	10.61	10.32	11.58	8.62	10.44	7.25	9.71	8.91	10.58
T_2 (Mango + Groundnut)	9.68	10.79	10.55	11.73	8.71	10.53	7.32	9.85	9.06	10.72
T_3 (Mango + Blackgram)	9.36	10.47	10.23	11.44	8.49	10.32	7.18	9.65	8.79	10.47
T_4 (Mango + Cowpea)	9.16	10.29	10.08	11.21	7.89	10.18	6.79	9.57	8.48	10.31
T_5 (Jackfruit + Arhar)	9.42	10.48	10.25	11.50	8.38	10.35	7.12	9.64	8.79	10.49
T_6 (Jackfruit + Groundnut)	9.53	10.64	10.41	11.62	8.47	10.47	7.20	9.78	8.90	10.62
T_7 (Jackfruit + Blackgram)	9.21	10.41	10.09	11.31	8.06	10.13	6.83	9.41	8.54	10.31
T_8 (Jackfruit + Cowpea)	9.07	10.27	9.86	11.11	7.63	9.92	6.57	9.05	8.28	10.08
T_9 (Cashewnut + Arhar)	9.29	10.33	10.01	11.23	8.13	10.18	7.08	9.32	8.62	10.26
T_{10} (Cashewnut + Groundnut)	9.40	10.61	10.28	11.47	8.28	10.23	7.14	9.65	8.77	10.49
T_{11} (Cashewnut + Blackgram)	9.05	10.26	9.89	11.02	7.85	10.04	6.80	9.08	8.39	10.1
T_{12} (Cashewnut + Cowpea)	8.92	10.12	9.55	10.96	7.47	9.97	6.21	8.53	8.03	9.89
T_{13} (Sole Arhar)	9.53	10.82	10.50	11.71	8.85	10.64	7.30	9.81	9.04	10.74
T_{14} (Sole Groundnut)	9.71	10.90	10.62	11.85	8.92	10.71	7.38	9.88	9.15	10.83
T_{15} (Sole Blackgram)	9.40	10.58	10.41	11.53	8.71	10.47	7.25	9.70	8.94	10.57
T_{16} (Sole Cowpea)	9.22	10.37	10.24	11.47	8.02	10.25	6.95	9.64	8.60	10.43
Rainfall (mm)	222.2		247.8		238.0		132.8		132.8	

iii. Biomass of tree species in agrisilvihorticultural systems

The biomass of trees was recorded at two times i.e. at 12 months & 18 months after planting. The highest tree biomass of (7.66 t ha^{-1}) was recorded with cashewnut in cashewnut + blackgram system followed by jackfruit in jackfruit + groundnut and jackfruit + blackgram system of (7.06 t ha^{-1}) and (6.91 t ha^{-1}) at 12 months respectively. The lowest biomass of (1.52 t ha^{-1}) was found with in mango + arhar system at 12 months. Similarly, the highest biomass of (11.79 t ha^{-1}) was recorded with jackfruit in jackfruit + blackgram system followed by cashewnut in cashewnut +blackgram system and jackfruit in jackfruit +groundnut system of (11.33 t ha^{-1}) and (9.42 t ha^{-1}) at 18 months respectively. The lowest biomass of (2.33 t ha^{-1}) found in mango + arhar at 18 months. Agroforestry systems can store large amount of carbon below ground compared to sole cropping because of its well-developed root system. The incorporation of trees on farms can increase the amount of carbon sequestered compared to a monoculture field (Sharrow and Ismail (2004) [18]. Watson *et al.* (2000) [21] also observed that transformation of low productivity crop plants in agroforestry can increased triple carbon stock from 23-70 t ha^{-1} in 25 years. Cardinael *et al.* (2012) [5] examined short rotation willow production in alley cropping and found that willow biomass yield was significantly higher in agroforestry field in compared to conventionally field.

Table 3: Biomass of fruit trees under agrisilvihorticulturalsystems

Treatments	12 months (t ha^{-1})			18 months (t ha^{-1})		
	Below ground	Above ground	Total	Below Ground	Above Ground	Total
T_1 (Mango +Arhar)	1.04	0.48	1.52	1.52	0.81	2.33
T_2 (Mango + Groundnut)	1.19	0.58	1.77	1.61	0.88	2.49
T_3 (Mango + Blackgram)	1.34	0.68	2.02	1.56	0.84	2.40
T_4 (Mango + Cowpea)	1.22	0.60	1.82	2.16	1.31	3.47
T_5 (Jackfruit + Arhar)	3.05	2.08	5.13	3.81	2.80	6.61
T_6 (Jackfruit + Groundnut)	4.03	3.03	7.06	5.18	4.24	9.42
T_7 (Jackfruit + Blackgram)	3.96	2.95	6.91	6.28	5.51	11.79
T_8 (Jackfruit + Cowpea)	1.49	0.79	2.28	1.88	1.08	2.96
T_9 (Cashewnut + Arhar)	3.12	2.14	5.26	4.13	3.13	7.26
T_{10} (Cashewnut + Groundnut)	3.47	2.48	5.95	4.45	3.46	7.91
T_{11} (Cashewnut + Blackgram)	4.33	3.33	7.66	6.07	5.26	11.33
T_{12} (Cashewnut + Cowpea)	3.31	2.32	5.63	4.94	3.99	8.93

4. Conclusion
The findings of this study indicate that all the legume intercrops improved the soil physico- chemical properties irrespective of the fruit trees associated compared to their initial status. Overall fruit based agrisilvihorticultural system seems to be more beneficial (both in biomass production and soil moisture conservation aspect) in comparison to conventional sole cropping.

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