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Research Article

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Stabilizing crop productivity returns and soil improvement by agroforestry practices under marginal lands in semi-arid tropics of Telangana state, India

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Summary

Different agroforestry trials conducted in Agroforestry Research blocks, Professor Jayashankar Telangana State Agricultural University, Hyderabad has showed higher economic gain in marginal lands. Sunflower grown when inter cropped in *Hardwickia binata* after stylo recorded higher seed yield (342 kg ha^{-1}) than grown after fallow in *Hardwickia binata* (248 kg ha^{-1}). The net returns from tree and crop were considerably higher when sunflower grown as inter crop in *Hardwickia binata* Rs. 6593 ha^{-1}. The *Faidherbia albida* (13 years age old) trial revealed that seed yield of maize + soybean when grown as inter crop was higher (2.94 t ha^{-1}) when compared to sole cropped maize without trees (1.7 t ha^{-1}). Due to shade effect of tamarind, after 8 years the same system was converted to horti-horti system for better land utilization by planting economic demand plants such as henna. The higher fresh biomass production of henna (640 kg ha^{-1}) recorded in double row planting when compared to single row. The soil productivity and fertility was improved in degraded marginal lands by different agroforestry practices. Pertaining to soil improvement over initial in different agroforestry practices the influence of different land use systems on soil properties and nutrient status revealed that bulk density reduced in surface and sub-surface soil in all tree based systems as compared to fallow (1.65 and 1.68 mg m^{-3}) and agricultural lands. The water holding capacity and infiltration rate was maximum in agri-horti system 30.0 and 30.0 per cent at 0-15 and 15-30 cm depth, respectively. Nutrient status and organic carbon was more in soils with tree plantation. Soil enrichment found in marginal lands in different agroforestry practices such as *Melia azedarach* based agri-silvi system, the conjoint use of 75% RD N + 25% N poultry manure showed significant effect on OC (0.59%) and available NPK (150.0, 24.95, 210.0 kg ha^{-1}) followed by 100% RDF (0.55% and 147.0,24.00,216.0 kg ha^{-1}). In case of *Melia dubia* based silvi-pasture system, the OC and available N and P significantly affected by type of fodders and nutrient management over farmers practice *i.e.* FYM 10 t ha^{-1}. But there is no significant effect by interactions. The highest OC content recorded in fodder maize (0.52%) than sorghum (0.46%). In case of available N and P the significant effect found with fodder sorghum (152.0 and 51.00 kg ha^{-1}) than maize (109 and 22.42 kg ha^{-1}).

Key words : Agroforestry practices, Soil improvement, Tree crop relation

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Introduction

In semi-arid regions of India, stability of crop yields and returns is very difficult due to abnormal weather condition. Growing tree alone or seasonal crops will not give optimum yields from the system. Under such situation, integration of trees with arable crops, legumes, grasses under land capability and help farmers of dry regions for establishing the cropping system. It aims at utilizing the land, resources in optimum condition by intensifying crops in temporal and spatial terms through efficient utilization. The main aim of agroforstry practices in dry lands is to improve the existing land to optimize productivity of component crops in tree intercrop system. These practices will improve the primary output like food, fodder, fuel and small timber etc., and also yield additional benefits in terms of intercrop yield, fertility improvement, water conservation in most efficient way. Over 120 m ha have been declared degraded and problem soils mainly under arid and semi-arid tropics (NAAS, 2010). In general the productivity and fertility status of degraded marginal lands is very low to low. There are many ways to increase the productivity and fertility status of degraded marginal soils. Among them adapting the agroforestry practices are the best choice to improve and enrich the soil (Aariff Khan and Krishna, 2017).

Resource and Research Methods

Different agroforestry systems like agri-silvi, agri-horti culture, silvi-pasture systems and block plantations were tested in red sandy loams and marginal lands of student farm and agroforestry research blocks of PJTS Agricultural University campus, Rajendranagar, Hyderabad, T.S were utilized for present evaluation. In agri-silvi culture system, *Hardwickia binata* (8 years age old) with sunflower, cowpea, field bean, soybean, groundnut as *Kharif* crops and *Faidherbia albida* (13 years age old) with maize as *Rabi* crop was grown. The experiment was conducted from 2006-2008 with field crops as intercrops in between trees. In another experiment (Agri-horti system) guava + curry leaf with soybean as intercrop in *Kharif* and another with tamarind + curry leaf + custard apple with sorghum, cowpea, redgram were grown as intercrops in *Kharif* (8 years age old) followed by tamarind + henna (1 or 2 rows) were tested in marginal lands of Hyderabad during 2008-2015. The *Melia azedarach* based agri-silvi experiment was laid in Randomized Block Design with three replications and seven treatments. Whereas, *Melia dubia* based silvi-pasture experiment was laid in Split plot design with four replications and six treatments during 2013-14. The initial and final soil samples were analyzed for soil properties and nutrient status as per standard procedures (AOAC, 1980 and Wilde *et al.*, 1972). The crop yields (kg ha^{-1}) and net returns (Rs. ha^{-1}) evaluated as per local market and deducting cost of cultivation from the system for calculating net returns and economics.

Research Findings and Discussion

The results obtained from different cropping systems have been presented in the following heads.

Agroforestry practice for crop improvement with legumes and non legumes in various cropping systems:

Hardwickia binata based system:

Sunflower grown in *Hardwickia binata* (10 years age old) after stylo for a period of three years recorded higher seed yield than sunflower inter cropped after fallow in *Hardwickia binata.* The net returns from tree and crop found higher in intercropped sunflower grown in *Hardwickia* when compared to sole crop sunflower. This was due to inclusion of leguminous fodder like stylo and considering the expected returns from the tree at that particular age from the value added products like fuel, fodder etc from trees (Table 1) and sunflower returns.

Faidherbia albida based system:

Maize grown in *Faidherbia albida* (13 years age old) trees produced higher seed yield with intercropped system when compared to sole crop. However, maize equivalent yield with soybean, field bean grown in *Faidherbia albida* were higher than sole crop maize (Table 2). The net returns from the system (tree + crop) were increased considerably when maize was grown in combination with legume crops in *Faidherbia albida* over

maize grown in sole crop. The increased net returns in maize + legume system was mainly due to complementary effect of trees for crop growth coupled with beneficial effect of legume intercrop. This shows that nitrogen fixing trees like *Hardwickia binata* and *Faidherbia albida* etc., would be beneficial in poor soils under dry land conditions for crop productivity improvement and realizing higher net returns from the system.

Agroforestry practice for economic gain in marginal land:

A field trial on agri-silvi-horti system was conducted from 2003 to 2008 (Table 3) reported that higher fruit yield of tamarind recorded (2.21 t ha^{-1}) in tamarind + curry leaf (filler plant) + sorghum cropping system which was followed by tamarind + curry leaf (filler plant) + cowpea (2.17 t ha^{-1}) and tamarind + custard apple (filler plant) + sorghum 2.17 t ha^{-1} cropping system. Maximum and minimum returns were recorded with tamarind + custard apple + redgram (Rs. 29972 ha^{-1}) and tamarind + curry leaf + cluster been (Rs. 23764 ha^{-1}), respectively. Similar results were reported by Kundu *et al*. (2010) with maize growth in tamarind.

In the same system, when tamarind trees were become 8 years age old, they were shading the filler plants, hence, they were removed and in its place shade loving hardy species like henna was planted in one or two rows in between tamarind trees. The performance was tested between 2008 to 2015 (8 to14 years age old trees). The growth of henna with double rows produced significantly higher biomass 640 kg ha^{-1} and height (2.8 m) than single row (520 kg ha^{-1} and 2.4 m). This shows that increasing planting intensity has beneficial effect in biomass production. Among the organic manure treatment, application of *Neem* cake 2 kg $plant^{-1}$ (2 t ha^{-1}) produced significantly higher biomass 580 kg ha^{-1} and height 3.0 m (Table 4). The spread of henna plants from NS and EW directions was also recorded. Higher spread recorded at NS direction (120 cm) and EW (110 cm) in single row of henna compared to 2 rows of henna (100 and 90 cm). Similarly the spread of henna was higher in *Neem* cake applied treatment towards NS direction (124 cm) when compared with EW (102 cm). This shows that on per plant basis, the utility of height and nutrients was better in single row of henna. But total biomass was higher in 2 rows of henna because of more number of plants.

Agroforestry practices for soil improvement in degraded marginal lands:

Different land use systems:

The effect of land use systems with different

Table 1: Seed yield and total net returns from sunflower intercropped with *Hardwickia binata*

Cropping system	Seed yield (kg ha^{-1})	Net returns (Rs. ha^{-1})
Sole cropping of sunflower	636	4134
Inter cropping of sunflower after stylo in *Hardwickia binata*	342	6593
Inter cropping of sunflower after fallow in *Hardwickia binata*	248	5287

Table 2 : Maize equivalent yield and total net returns from the system in *Faidherbia albida* based agri-silvi culture system

Cropping system	Maize equivalent yield (t ha^{-1})	Total net returns (Rs. ha^{-1})
Maize alone with trees	2.66	10301
Maize + Cowpea with trees	2.56	8891
Maize + Field bean with trees	2.92	10126
Maize + Soybean with trees	2.94	11276
Maize + Groundnut with trees	2.10	6715
Sole maize without trees	1.7	3764

Table 3 : Seed yield of soyabean and total net returns from the system in guava and curry leaf based agri-horti culture system

Cropping system	Seed yield (kg ha^{-1})	Total net returns (Rs. ha^{-1})
Sole cropping of soyabean	800	3269
Inter cropping of soybean in guava	739	8021
Inter cropping of soybean in curry leaf	740	4845

agroforestry systems on soil physical properties and nutrient status at 0-15 and 15-30 cm depth (Table 5) revealed that bulk density of soil reduced in surface and subsurface soils in tree based cropping system compared to fallow (1.65 and 1.68 mg m^{-3}) and agricultural land (1.62 and 1.67 mg m^{-3}), lowest being in eucalyptus system (1.38 and 1.42 mg m^{-3}) (Swarnam *et al.*, 2004 and Thyagaraj *et al.*,2010).This might be due to better spread and penetration of root system as well as porous nature of soil in rhizosphere. Whereas, maximum and minimum water holding capacity recorded in tamarind based agri-horti system (30.0 and 30.0% at 0-15 and 15-30 cm) and in fallow land (15.0 and 10.0%), respectively. In case of infiltration rate the maximum and minimum found in agricultural land and in eucalyptus and *Faiderbia albida* plantation (1.6 cm ha^{-1} at 30 cm depth), respectively (Sathyavathi and Reddy, 2004 and Nagender Rao *et al.*, 2009). This is attributed to better soil aggregates and improvement in soil structure which coincides with low bulk density values in corresponding system. The total N percentage and carbon was increased considerably in soil covered with tree plantation when compared to fallow and agricultural lands. Maximum total N (0.076 and 0.071%) and total carbon 0.89 and 0.76 per cent at

Table 4: Growth and biomass of henna in tamarind based horti-horti system

Treatments	Height (m)	Biomass (kg ha^{-1})	Spread (cm)		Main branches
			NS	EW	
Planting density					
One row of Henna	2.4	520	120	110	2.5
Two rows of Henna	2.8	640	100	90	2.0
C.D. (P=0.05)	NS	68	16	12	NS
Organic manures					
M1 FYM 2 kg $plant^{-1}$	2.2	490	108	100	2.0
M2 Vermi 2 kg $plant^{-1}$	2.8	510	110	102	2.0
M3 *Neem* cake 2 kg $plant^{-1}$	3.0	580	124	102	2.2
M4 FYM + *Neem* cake 1 kg each (2 kg $plant^{-1}$)	2.2	540	110	100	1.8
M5 Vermicompost + *Neem* cake 1 kg each (2 kg $plant^{-1}$)	2.4	500	104	90	2.0
M6 FYM +Vermicompost1 kg each (2 kg $plant^{-1}$)	2.8	480	108	92	1.9
C.D. (P=0.05)	0.6	62	14	10	NS
Interaction					
C.D. (P=0.05)	NS	NS	18	14	NS

NS= Non-significant

Table 5: Influence of different land use systems on soil properties and nutrient status

Land use system	(Age/ year)	Bulk density (mg m^{-3})		Water holding capacity (%)		Infiltration rate (cm hr^{-1})	Total nitrogen (%)		Total carbon (%)		C:N ratio	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Fallow land	--	1.65	1.68	15.0	10.0	2.8	0.021	0.017	0.21	0.20	10.1	12.1
Agricultural land	--	1.62	1.67	18.0	20.0	2.9	0.039	0.036	0.42	0.38	11.1	11.1
Albizia lebbeck based Agri-silvi system	9	1.51	1.70	25.0	20.0	2.3	0.042	0.034	0.51	0.40	12.2	11.8
Acacia nilotica based Silvi-pasture system	9	1.42	1.60	30.0	28.0	1.8	0.067	0.064	0.76	0.71	11.1	11.1
Tamarindus indica based Agri-horti system	13	1.48	1.59	30.0	30.0	2.1	0.076	0.071	0.89	0.76	12.1	10.1
Eucalyptus camalundensis	13	1.38	1.42	30.0	21.0	1.6	0.051	0.042	0.59	0.49	11.1	11.1
Faiderbia albida	13	1.55	1.62	27.0	19.0	1.6	0.054	0.049	0.68	0.58	12.1	12.1
Leucenia leucocephala	13	1.50	1.54	28.0	20.0	1.8	0.062	0.056	0.68	0.66	10.9	11.8
Mean	-	1.51	1.60	25.4	21.1	2.1	0.050	0.040	0.59	0.52	11.4	11.2
C.D. (P=0.05)	-	--	---	--	---	---	0.008	0.01	0.1	0.09	--	--

both soil depths, respectively resulted in agri-horti system followed by silvi-pasture system 0.067, 0.064 per cent and 0.76 and 0.71 per cent. This might be due to better decomposition of leaf litter as well as availability of nutrients from the system (Sanjeeva Reddy *et al.*, 2009).

Agri-silvi system *i.e. Melia azedarach* + foxtail millet:

There was no significant effect by different treatments on pH and EC (Table 6). But there was significant effect on OC and available NPK content. The conjoint use of 75% RD N + 25% N poultry manure showed significant effect on OC (0.59%) and available NPK (150.0, 24.95, 219.0 kg ha^{-1}) followed by 100% RDF (0.55% and 147.0,24.00,216.0 kg ha^{-1}). The higher availability of nutrients may be attributed due to addition of mineral fertilizer NPK along with organic sources reduced the C:N ratio and thus, increased the rate of decomposition resulting the faster availability of nutrients from organic manures (Nandal and Ravikumar, 2010).

Silvi-pasture system - *Melia dubia* + fodder maize and sorghum:

The soil OC and available N and P contents was significantly affected by type of fodders and nutrient management over farmers practice *i.e.* FYM 10 t ha^{-1} (Table 7). But there was no significant effect by interactions. The highest OC content recorded in fodder maize (0.52%) than sorghum (0.46%). This is due to addition of tree litter and decomposition of roots of weeds

Table 6 : Soil properties and available nutrients of foxtail millet as influenced by nutrient management in *Melia azedarach* in agri-silvi system

Treatments	pH	EC (dSm^{-1})	OC (%)	Available nutrient (kg ha^{-1})		
				N	P	K
T_1 FYM 10 t ha^{-1}	6.85	0.019	0.42	134	19.75	209
T_2 100% RDF	6.92	0.022	0.55	147	24.00	216
T_3 75%N + 25% N FYM	6.78	0.029	0.50	140	22.95	212
T_4 75% RD N + 25% N VC	6.90	0.018	0.46	139	21.78	207
T_5 75% RD N + 25% N PM	7.03	0.028	0.59	150	24.95	219
T_6 75% RD N + *Azospirillum* + PSB 5 each kg ha^{-1}	6.88	0.032	0.49	139	23.00	212
T_9 Sole crop without trees	6.79	0.025	0.51	143	24.15	217
S.E. ±	0.07	0.004	0.03	1.7	0.86	1.6
C.D. (P=0.05)	NS	NS	0.09	5.2	2.65	5.0
Initial soil	6.97	0.024	0.38	139	18.80	211

NS= Non-significant

Table 7: Soil properties and available nutrients of cereal fodders as influenced by nutrient management in *Melia dubia* based silvi-pasture system

Treatments (Main)	Type of fodder								
Nutrient management (Sub)	OC (%)			Available nutrient (kg ha^{-1})					
				N			P		
	M1 Maize	M2 Sorghum	Mean	M1 Maize	M2 Sorghum	Mean	M1 Maize	M2 Sorghum	Mean
S_1 FYM 10 t ha^{-1}	0.42	0.38	0.40	104	151	127	16.85	47.50	32.17
S_2 100% RDF	0.54	0.46	0.50	108	149	128	19.90	51.85	35.87
S_3 75% RD N + 25% N FYM	0.51	0.43	0.47	106	153	129	23.70	49.30	36.50
S_4 50% RD N + 50% N FYM	059	0.52	0.55	110	156	133	26.00	52.75	39.37
S_5 75% RD N + 25% N PM	0.58	0.50	0.48	114	151	132	27.30	53.90	40.60
S_6 Sole fodder crop	0.48	0.47	0.47	111	151	131	20.75	50.70	35.72
Mean	0.52	0.46	-	109	152	-	22.42	51.00	-
-	S.E. ±	C.D. (P=0.05)	-	S.E. ±	C.D. (P=0.05)	-	S.E. ±	C.D. (P=0.05)	-
Main	0.003	0.013	-	0.24	1.1	-	0.26	1.18	-
Sub	0.024	0.070	-	2.52	7.27	-	1.10	3.17	-
Interaction	-	NS	-	-	NS	-	-	NS	-
Initial soil		0.42			105			15.50	

NS= Non-significant

in the rhizosphere (Devarana Vadgi *et al*.,2003). In case of available N and P the significant effect found with fodder sorghum (152.0 and 51.00 kg ha^{-1}) than maize (109 and 22.42 kg ha^{-1}). The reason may be due to short duration of sorghum and the applied mineral fertilizer was less utilized than maize comparatively utilized more effectively (Singh *et al*. 2008).

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