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Economic viability of agri-silvi-horticultural system

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ABSTRACT

An experiment was conducted from 2006-2016 to study the economic viability of sapota timber based agroforestry system at University of Agricultural Sciences, Dharwad on medium black soils under rainfed conditions. The experiment consisted of sapota as major fruit tree species and five timber tree species, viz. *Pterocarpus marsupium, Tectona grandis, Terminalia paniculata, Lagerstroemia lanceolata* and *Terminalia alata* which were planted in between two sapota trees. Field crops, viz. soybean and safflower were sown ever year in alleys of sapota + timber trees in *kharif* and *rabi* seasons respectively. Recommended package of practices were followed for field crops and sapota trees and all the silviculture practices were followed for better growth of the timber trees. Height, diameter, marketable timber were higher in *Tectona grandis* with sapota and *Lagerstroemia lanceolata* with sapota as compared to other tree species. Both net returns, B:C ratio and IRR were higher in the field crops + Sapota + *Tectona grandis* (₹ 67129/, 3.84, 123% respectively) followed by field crops + sapota + *Pterocarpus marsupium* (₹ 64688, 3.74, 120% respectively) as compared to other tree species.

Key words: Agroforestry, Benefit cost ratio, Economic viability, Internal rate of returns

Agroforestry has established itself as one of the most promising land management system helping in the expeditious enhancement of productivity per unit area on sustainable basis. This technology has dual role in supporting socio-economic status of the farmer on one hand and mitigating the adverse climatic effects of deforestation to greater extent by increasing the green cover of the others. Timber species selection should strongly depend on the amount of shade they provide to crops during their development and once they reach their productive age. In India, nearly 1600 species are considered as capable of yielding timber or wood of commercial value.

Agroforestry systems have incorporated timber species of high commercial value and successful examples of this practice are reported in several tropical countries of Central and South America (Somarriba and Beer 1987, Heuveldop *et al.* 1988, Musaack and Laarman 1989, Jardim *et al.* 2004, Orozco *et al.* 2008). Nevertheless, despite all the benefits derived from these agroforestry systems, selection criteria for native timber species and their management are lacking. Timber trees constitute a potential capital saving over time, which could eventually reduce financial losses caused by sudden drops in marketing prices of agricultural crops (Tscharntke *et al.* 2011).

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Tree has a special role in the ethos of the people of India. There are several sacred trees and sacred groves valued (Bawa 2004). Agroforestry systems in India include tree in farms, community forestry and ethone forestry practices (Pandey 1996). Agroforestry system have been presented as solution for rising fuel wood/small timber in India resulting increase in demand and decrease in supply of fuel wood from natural forest.

Overall India is estimated to have 14224 million (Ravindranath and Hall 1995) to 24602 million (Prasad *et al.* 2000) trees outside forests spread over an area of 17 million ha (Anon. 1999) supplying 49% of 201 million tonnes of fuel wood and 48% of the 64 million m^3 of timber consumed annually by the country (Rai and Chakrabarti 2001). The report of Kumar *et al.* (1998) indicated that the biological yield was higher under trees in the open area and the productivity of *Hordeum vulgare* (Barley) was positive with tree species. *Prosopis cineraria* enhanced grain yield by 86.6%, *T. induulata* by 48.8%, *Acacia albida* by 57.9% and *Azadirachta indica* by 16.8% over the control (Kumar *et al.* 1998).

Fruit tree based agroforestry system involves intentional, simultaneous association of annual or perennial crops with perennial fruit producing trees on the same farm unit. Because of the relatively short pre-production phase of fruit trees, high market value of their products and the contribution of fruits to household dietary needs, fruit tree based agroforestry enjoys high popularity among resource limited producers worldwide (Bellow 2004). The land use systems in the state are in the process of transformations due to the rapid changes in the socio-economic status of farmers, industrialization and climate change as well as government policies due to which shortage of cultivable land has become very common.

Agroforestry systems have complementary or competitive effect which results in increase or reduction of yield of field crops. Soybean is a valuable crop graining importance due to its industrial value. The present study was initiated to find out the ideal timber with sapota and field crops for economic viability of agroforestry model under rainfed conditions in northern Karnataka.

MATERIALS AND METHODS

An experiment was initiated to know compatibility of sapota–timber based agroforestry system at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad under rainfed conditions in 2006-2016. The experiment consisted of sapota fruit tree species planted at 8 m × 8 m spacing on medium black soil. One timber tree was planted in between two sapota trees. The timber tree species, viz. *Pterocarpus marsupium, Tectona grandis, Terminalia paniculata, Lagerstroemia lanceolata, Terminalia alata* of uniform rotation were selected for evaluations. Field crops, viz. soybean (JS-335) and safflower (A-1) were sown in the inter space of sapota – timber alleys. The experiment was randomized block design with four replications.

The experiment site had medium black soil with pH 6.85 and available nitrogen 245 kg/ha, phosphorous 19.6 kg/ha and potassium 285 kg/ha. The mean annual rainfall was 779.4 mm received in 57 rainy days and average mean maximum temperature and minimum temperature were 34.7ºC in April and 14.6ºC in January respectively with relative humidity of 50 to 85%.

The recommended package of practices was followed for raising soybean. Soybean variety JS-335 was sown in *kharif*. Seeds were treated with *Rhizobium* culture, phosphorus solubilizing bacteria (PSB) and bavistin. Seeds of 62.5 kg/ha were sown at 30 cm × 5 cm apart. Recommended fertilizer of 35:50:35 kg/ha NPK was applied as basal dose. Suitable plant protection measures were taken up to control pests and diseases. Safflower variety A-1 was grown in rabi. Seeds were treated with bavistin and about 6 kg/ha seeds were sown in 45 cm × 5 cm apart. Recommended fertilizer application of 40 : 40 : 20 kg/ha NPK was applied as basal dose. Suitable plant protection measures were taken up to control pests and diseases.

Silvicultural operation for timber trees, viz. pruning the branches in bottom 2/3 height and soil working were done every year before onset of monsoon. Pruning of branches of trees and climber control were done at later stages. Root pruning was made by deep ploughing every year along the tree rows. Observations like height, spread, diameter at breast height and clear bole height were recorded. Grain and haulm yield of field crops were recorded every year. At the end of experimentation standing tree value was assessed based on poles and biomass. The income from sapota, field crops was worked out based on prevailing market price. Economic analysis was made based on income from field crops, sapota fruits and trees in agroforestry systems and is presented in tables.

RESULTS AND DISCUSSION

Productivity of field crops: Soybean grain yield (Table 1) was significantly reduced in sapota timber based agri-silvi-horticulture system as compared to sole field crops. The mean reduction yield was 29% in *Terminalia paniculata* + sapota, 26.2% in *Pterocarpus marsupium* + sapota, and 27% in *Terminalia alata* + sapota as compared to sole soybean. Among the timber trees, the minimum reduction of soybean yield was recorded in *Tectona grandis* + sapota (26%) and *Lagerstroemia lanceolata* + sapota (23.2%) as compared to the other timber tree species.

Grain yield of safflower was higher in sole safflower followed by safflower with sapota and was reduced when safflower grown with timber tree species (Table 2). The yield reduction of safflower with tree species was higher as compared to *kharif* (Soybean) crops. The reduction yield was increased with age of tree advanced. Among tree species both sapota with *Tectona grandis* (23.9%) and *Pterocarpus marsupium* (24.8%) has lower reduction of yield as compared to *Terminalia paniculata* + sapota (30.3%) and *Terminalia alata* + sapota (28.1%) and *Lagerstroemia lanceolata* + sapota (25.2%). The poor growth of safflower

Table 1 Soybean grain yield (kg/ha) as influenced by agri-silvi-horti system

Agroforestry system	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average yield
Sapota + *Pterocarpus marsupium* + FC	1360.0	1185.0	767.5	625.5	584.6	597.2	636.3	568.8	475.6	755.6
Sapota + *Tectona grandis* + FC	1325.0	1237.0	789.2	635.6	563.8	530.1	623.8	581.3	460.4	749.6
Sapota + *Terminalia paniculata* + FC	1331.0	1250.0	762.5	639.4	538.6	513.4	575.0	506.3	425.0	726.8
Sapota + *Lagerstroemia lanceolata* + FC	1381.2	1275.0	770.5	642.4	548.6	605.4	633.3	625.0	495.6	775.2
Sapota + *Terminalia alata* + FC	1387.5	1281.5	738.7	631.5	538.6	505.4	558.8	581.3	415.0	737.6
Sapota + FC	1425.0	1369.0	759.2	682.5	590.2	667.3	677.3	696.9	575.5	827.0
Field crops (FC)	1466.2	1437.5	1085.0	885.6	785.6	962.3	827.3	916.3	652.4	1002.0
SEm±	96.5	30.6	30.3	32.6	30.4	38.5	11.6	15.6	13.4	-
CD (P=0.05)	286.5	90.8	90.0	96.8	89.9	114.5	34.5	46.4	39.8	-

Table 2 Safflower grain yield (kg/ha) as influenced by agri-silvi-horti system

Agroforestry system	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average yield
Sapota + *Pterocarpus marsupium* + FC	1193.7	1050.0	697.5	512.5	432.5	385.4	482.5	0.0	120.6	541.6
Sapota + *Tectona grandis* + FC	1100.0	1105.0	769.7	578.0	478.2	298.6	466.3	0.0	135.2	547.9
Sapota + *Terminalia paniculata* + FC	1037.5	1000.0	717.5	527.6	427.6	276.2	388.8	0.0	146.4	502.4
Sapota + *Lagerstroemia lanceolata* + FC	1125.0	1077.5	700.0	532.2	432.2	364.8	456.8	0.0	158.2	538.5
Sapota + *Terminalia alata* + FC	1025.0	1055.6	712.5	546.6	446.6	314.4	383.8	0.0	174.4	517.7
Sapota + FC	1268.7	1210.0	720.0	530.0	430.4	390.8	506.3	0.0	220.6	586.3
Field crops (FC)	1562.5	1405.0	870.0	682.4	536.2	494.2	603.8	0.0	328.5	720.3
SEm±	45.0	35.01	27.9	29.8	26.8	25.6	8.7	-	10.6	-
CD (P=0.05)	133.7	103.9	83.1	88.5	79.3	76.1	26.1	-	31.4	-

may be due to higher tree crop competition for moisture as it limits factors in *rabi* crops.

Field crop yield significantly reduced when grown in agroforestry system. Both crops, soybean and safflower were recorded significantly higher when they are grown solely. Soybean grain and haulm yield was significantly higher with sapota + field crops (575.5 kg/ha and 460.2 kg/ha respectively) followed by Sapota + *Lagerstroemia lanceolata* (495.6 kg/ha and 392.6 kg/ha). Safflower yield was significantly higher when grown with sapota (220.6 kg/ha) followed by sapota + *Terminalia alata* (174.4 kg/ha) when compared to other systems. This may be due to the lower leaf area, total dry matter production and grain yield. Similar reports were reported by Mishra and Puri (2004). The decrease was minimum in barseem and maximum in wheat as reported by Nandal and Hooda (2005) in popular based agroforestry system. Swamy and Puri (2008) also reported significant variation in grain and straw yield of wheat due to *Gmelina* tree spacing.

Growth of timber trees: The growth and diameter at breast height (Table 3) was significantly higher in the *Pterocarpus marsupium* + sapota (9.25 m and 25.08 cm) and lowest in the *Lagerstroemia lanceolata* + sapota (8.25 m and 19. 42 cm) when compared to other tree species. Whereas maximum crown area was recorded in the *Terminalia alata* + sapota (32.70 m^2/plant) followed by *Terminalia paniculata* + sapota (31.39 m^2/plant) as compared to other tree species. Marketable timber volume was significantly higher in sapota + *Tectona grandis* followed by sapota + *Terminalia paniculata* as compared to other tree species.

Growth of sapota: Sapota growth was higher when grown alone (Table 3). Height of sapota was significantly higher in association with sapota + *Lagerstroemia lanceolata* (4.42 m) followed by sapota + *Pterocarpus marsupium* (4.24 m). Collar diameter and crown area of sapota was significantly higher in association with sapota + *Pterocarpus marsupium* (12.55 cm and 12.92 m^2/plant respectively) as compared to sapota with other tree species. Fruit yield of sapota was significantly higher when sapota grown alone (1578 kg/ha) followed by sapota + *Pterocarpus marsupium* (1135 kg/ha) and sapota + *Tectona grandis* (1106 kg/ha) and lowest in sapota + *Terminalia alata* 712 kg/ha).

Economic analysis of agroforestry system: Economic viability is one of the essential considerations for adaption of any technology by the farmers. At the end of experiment, economic analysis was made based on estimated income from timber trees, income from sapota, soybean and safflower yield.

Table 3 Growth of tree species and sapota and fruit yield of sapota in different agroforestry systems (2015-16)

Agroforestry system	Tree species				Sapota			
	Height (m)	DBH (cm)	Crown area (m^2/pl)	Marketable timber volume (m^3/ha)	Height (m)	Collar diameter(cm)	Crown area (m^2/pl)	Fruit yield (kg/pl)
S + *P. marsupium* + FC	9.25	25.08	23.10	27.57	4.24	12.55	12.92	1135.0
S + *T. grandis* + FC	8.97	23.61	28.30	31.48	4.14	11.53	10.00	1106.3
S + *T. paniculata* + FC	8.63	21.29	31.39	25.66	4.15	11.74	10.19	647.5
S + *L. lanceolata* + FC	8.25	19.42	21.90	21.32	4.42	12.22	11.37	1097.5
S + *T. alata* + FC	8.54	20.02	32.70	22.60	4.19	12.46	10.18	712.5
Sapota + FC					4.75	13.75	15.24	1578.8
Field crops (FC)								
SEm±	0.31	1.33	1.45		0.16	0.46	0.72	8.1
CD (P=0.05)	0.95	4.11	6.02		0.48	1.38	2.16	24.4

Field crops (FC): Soybean - Safflower

Table 4 Economic analysis of agri-silvi-horti system

Agroforestry system	Gross return (₹/ha/yr)	Cost of cultivation (₹/ha/yr)	Net return (₹/ha/yr)	Discounted @ 12% interest			BCR	IRR (%)
				Gross returns (₹/ha/yr)	Cost of cultivation (₹/ha/yr)	Net returns (₹/ha/yr)		
Sapota + *Pterocarpus marsupium* + FC	80063	15375	64688	28029	7492	20537	3. 74	120
Sapota + *Tectona grandis* + FC	82504	15375	67129	28766	7492	21274	3. 84	123
Sapota + *Terminalia paniculata* + FC	67943	15375	52568	24397	7492	16906	3. 26	107
Sapota + *Lagerstroemia lanceolata* + FC	62579	15375	47203	23204	7492	15712	3. 1	98
Sapota + *Terminalia alata* + FC	63163	15375	47788	23146	7492	15654	3. 09	98
Sapota + FC	31570	14925	17008	14907	7177	7835	2. 08	80
Field crops (FC)	26751	13231	13520	13561	6176	7385	2. 2	-

Field crops (FC): Soybean - safflower

Gross returns was significantly higher with sapota + *Tectona grandis* + field crops followed by sapota + *Pterocarpus marsupium* + field crops as compared to sapota with other timber tree species.

Net returns were higher in sapota – timber in agroforestry system as compared to sole field crops or sole sapota. The net returns was higher in sapota + *Tectona grandis* + field crop (67129 ₹/ha/yr) followed by sapota + *Pterocarpus marsupium* + field crop (64688 ₹/ha/yr) as compared to other timber tree species. Benefit cost ratio and internal rate returns were higher in sapota + *Tectona grandis*+ field crop (3.84 and 123% respectively) followed by sapota + *Pterocarpus marsupium* + field crop (3.74 and 120% respectively) as compared to other timber tree species.

Similarly, Kaushik *et al.* (2002) also reported that horti-silvicultural system showed maximum returns in association with field crops. Similar results were reported by Nadal and Ravikumar (2010). Similarly a agroforestry system with *Acacia auriculiformis* and rice had a benefit cost ratio of 1.47:1 and with an internal rate of returns of 33% at 12% annual discount rate during ten years period (Vishwanath *et al.* 2000). Higher net returns from poplar and mango based agroforestry is also reported by Naugaria and Jaspal Singh (2004) and Awasthi *et al.* (2005) respectively compared to mono cropping of poplar or mango.

The comparative economics of exclusive poplar (*P. deltoids*) and Eucalyptus based systems with the average population maintained per ha, the B:C was worked out. The farmers preferred the bund system due to its less detrimental impact on the grain/commercial crop patterns (Kareemulla *et al.* 2003). Karemulla *et al.* (2002) has estimated the economics of introduction of silvi-pasture system in the degraded lands both for conservation and livelihood. The results indicated that in an eighth year rotation on one ha with *Albizzia amara* + *D. cinerea* + *Leucaena leucocephala* with *Chrysopogon fulvus* + *Stylosanthes hamata* + *S. scabra*, the B:C ratio worked out to 1.52 at a 12% discount factor. Aonla based agroforestry from third year onwards produced much higher yield (108 kg/plant) in aonla + chrysopogon as compared to pure stand (104 kg/plant) and lowest (92 kg/plant) in aonla + napier combination (Prasad *et al.* 2005). Similar results of highest benefit cost ratio were obtained from brinjal intercropped with *B. vulgaris* (Nithya Kalyani 2010).

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