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Bio-economic assessment of silviagriculture systems for sustainable productivity

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Abstract
Field trials were conducted in agroforestry system involving short rotation tree species and cereal, legume, oilseed and vegetable intercrops to assess the biomass production in silviagriculture system. The results revealed that in pungam and simaruba based silviagriculture system, red gram recorded the highest grain yield and net returns. Under *Eucalyptus tereticornis*, cow pea and black gram recorded the lowest grain yields of 282 and 193 kg ha^{-1}. Under rain fed ecosystem, *Ailanthus excelsa* based silviagricultural system was found to profitable. Legume crops were found to be the compatible and profitable intercrop under silviagricultural systems.

Keywords: Economics, grain yield, land equivalent ratio, silviagriculture

Introduction
Agroforestry systems in the different combinations of agrisilviculture, agrisilvipasture and silvipasture are agro-ecological options which include in their concepts the main components of sustainability that is economical, the social and the environmental. Generally, the overall productivity in agro forestry systems is higher than that in sole cropping systems (Chaturvedi, 1981) [3]. The trees in agro forestry practices generally fulfill multiple purposes, involving the improvement of soil fertility as well as production of one or more products (Cooper *et al*., 1996) [4]. Concept of domesticating indigenous plants (Leakey and Newton, 1994) [5] and incorporating them in agroforestry systems (Sanchez, 1995) [6] primarily for the benefit of the resource poor farmers is new paradigm providing an array of products for consumption and trade. Land equivalent ratio (LER) provides an accurate assessment of the competitive relationship between the components, the best usage of land as well as the overall productivity of the system. Experiments were conducted to study the productivity of various silviagricultural systemsandtoexplorethesustainablesystemforenhancingtheproductivityofagroforestry system.

Materials and Methods
Field trials were conducted in the existing plantations of various tree species as follows and the grain yields were recorded.
Recorded.

Silvi-agriculture systems	Intercrops
Pongamia glabra	Black gram, Green gram, Red gram, Cow pea, Ground nut, Soybean, Sunflower
Bambusa vulgaris	Green gram, Black gram, Cow pea, Gingelly, Bhendi, Brinjal
Simaruba glauca	Black gram, Green gram, Cow pea, Red gram
Silver oak, *Eucalyptus tereticornis, Tectno grandis, Simaruba glauca*	Cow pea
Silver oak, *Eucalyptus tereticornis, Tectno grandis, Simaruba glauca*	Black gram
Grevillea robusta, Tectona grandis, Gmelina arborea	Cow pea
Grevillea robusta, Tectona grandis, Gmelina arborea	Ground nut
Acacia holosericea, Acacia nilotica, Azadirachta indica, Ailanthus excelsa,	Cow pea
Acacia holosericea, Acacia nilotica, Azadirachta indica, Ailanthus excelsa	Sesame
Acacia holosericea, Acacia nilotica, Azadirachta indica, Ailanthus excelsa	Sorghum

For these silviagriculture systems, land equivalent ratio (LER) (Willey, 1979) [8] and net returns from the system were computed.

Results and Discussion

Pungam based silviagriculture system

In this Silviagriculture system, green gram recorded the highest LER 1.01 followed by cow pea (0.95). Leguminous intercrops recorded recorded higher LER values ranged from 0.89 to 1.01. (Table 1). *Pongamia grabra* + green gram gave the highest LER of 1.01 implying the best usage of land as well as the overall productivity of the intercrop system. LER increased due to efficient use of resources (Banik *et al*., 2006) [6]. When LER values are higher than one, there is an advantage of intercropping in terms of the use of resources for the plant growth compared to sole cropping (Sullivan, 1998; Adetiloye *et al*., 1983) [1]. Among the intercrops, red gram recorded the highest grain yield of 1120 kg ha^{-1} with the net returns of Rs. 64147/-.

Table 1: Grain yield and LER of intercrops in Pungam based silviagriculture system

Intercrops	Grain yield (kg ha^{-1})		Net returns (Rs.)		LER
	IC	PC	IC	PC	
Black gram	710	800	50072	56966	0.89
Green gram	505	550	44280	48600	1.01
Red gram	1120	1200	64147	69000	0.93
Cow pea	570	600	30200	36000	0.95
Ground nut	900	970	44288	47963	0.93
Soybean	310	400	9090	12600	0.78
Sunflower	380	450	12200	15000	0.84
CD (P:0.05)	31				

IC: Intercropping; PC: Pure cropping

Bambusa vulgaris based silviagriculture system

Brinjal recorded the highest yield of 3486 kg ha^{-1} with LER Value of 0.98. The LER value ranged from 0.88 to 0.98 (Table.2).

Table 2: Grain yield and LER of intercrops in *Bambusa vulgaris* based silviagriculture system

Intercrops	Grain yield (kg ha^{-1})		Net returns (Rs.)		LER
	IC	PC	IC	PC	
Green gram	970	1085	88920	99960	0.89
Black gram	1335	1420	97947	104458	0.94
Cow pea	893	995	49580	55700	0.90
Gingelly	612	690	54626	62239	0.88
Bhendi	1842	1920	69920	74600	0.96
Brinjal	3486	3570	72010	74950	0.98
CD (P:0.05)	45				

IC: Intercropping; PC: Pure cropping

Simaruba glauca based silviagriculture system

Red gram recorded the highest grain yield with a LER value of 0.98 (Table.3). Under *Simaruba glauca* plantations, red gram is compatible and profitable crop. In this system, LER value ranged from 0.92 to 0.98.

Table 3: Grain yield and LER of intercrops in *Simaruba glauca* based silviagriculture system

Intercrops	Grain yield (kg ha^{-1})		Net returns (Rs.)		LER
	IC	PC	IC	PC	
Black gram	1054	1134	76422	82550	0.92
Green gram	1107	1172	102072	108312	0.94
Cow pea	902	970	50120	54200	0.93
Red gram	1226	1256	70613	72443	0.98
CD (P:0.05)	20				

IC: Intercropping; PC: Pure cropping

Silviagriculture system with legumes as intercrops

Cow pea and black gram were raised as intercrops in Silver oak, *Eucalyptus tereticornis Tectno grandis* and Simaruba *glauca* plantations. Cow pea recorded higher grain yields irrespective of the tree species. Grain yield of cow pea ranged from 282 kg ha^{-1} under *Eucalyptus tereticornis* to 457 kg ha^{-1} under Silver oak plantation. Under *Eucalyptus tereticornis*, cow pea and black gram recorded the lowest grain yields of 282 and 193 kg ha^{-1}. LER ranged from 0.48 to 0.79 with regard to cow pea and 0.46 to 0.90 with black gram (Table.4).

Table 4: Grain yield and LER of intercrops

Tree component	Cow pea			Black gram		
	Grain yield (kg ha^{-1})					
	IC	Net returns	LER	IC	Net returns	LER
Silver oak	457	23420	0.79	378	24640	0.90
Eucalyptus tereticornis	282	12920	0.48	193	10470	0.46

Tectno grandis	367	18020	0.63	202	11159	0.48
Simaruba *glauca*	417	21020	0.72	263	15832	0.63
Pure cropping	580	30800		420	27858	
CD (P:0.05)	80			55		

IC: Intercropping

Silviagriculture system for rainfed ecosystem

Under rain fed ecosystem, *Ailanthus excelsa* + Cow pea recorded the highest grain yield of 376 kg ha^{-1}, LER 0.89 and net returns of Rs. 18560. *Ailanthus excelsa* + Sesame recorded the highest grain yield of 379 kg ha^{-1}, LER 0.84 and Net returns of Rs. 31885 while *Ailanthus excelsa* + Sorghum recorded the highest grain yield of 1880 kg ha^{-1}, LER 0.84 and net returns of Rs. 57142. Under rain fed ecosystem, *Ailanthus excelsa* based silviagricultural system was found to profitable (Table 5). When LER values are lower than one, sole cropping use the resources more efficiently in comparison with intercropping (Sullivan, 1998) [7]

Maximum net returns from *Pongamia glabra* + Red gram (Rs. 64147 ha^{-1}), *Bambusa vulgaris* + Black gram (Rs. 97947 ha^{-1}), *Simaruba glauca*+ Green gram (Rs. 102072 ha^{-1}), Silver oak+ Black gram (Rs. 24640 ha^{-1}), *Tectona grandis* + Cow pea (Rs.48500 ha^{-1}) and *Ailanthus excelsa*+ Sorghum (Rs. 57142 ha^{-1}) were recorded. Among the various crops, legume crops were found to be the compatible and profitable intercrop under silvi agricultural systems (Table 5).

Table 5: Grain yield and LER of intercrops under rainfed ecosystem

Tree component	Cow pea			Sesame			Sorghum		
	Grain yield (kg ha^{-1})								
	IC	**LER**	**Net returns**	**IC**	**LER**	**Net returns**	**IC**	**LER**	**Net returns**
Acacia holosericea	369	0.87	18140	363	0.81	30323	1805	0.81	54817
Acacia nilotica	340	0.80	16400	336	0.75	27688	1708	0.76	51810
Azadirachta indica	359	0.85	17540	359	0.80	29933	1793	0.80	54445
Ailanthus excelsa	376	0.89	18560	379	0.84	31885	1880	0.84	57142
Pure cropping	423	-	21380	448	-	38620	2238	-	68240
CD (P:0.05)	20			36			115		

IC: Intercropping

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