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Proceedings of the Symposium on "Statistical Methodology for Agroforestry Research"

Agroforestry refers to a system of land use that combines growing or raising of herbaceous crops (and/or livestock) with woody species. A good agroforestry system should be able to increase production of food, fodder and timber and at the same time be able to improve the conservation and rehabilitation of the soil resources needed for future production. Statistical methodologies relating to agroforestry research still seems to be in the early stage of its development. So in order to take stock of the existing situation Indian Society of Agricultural Statistics decided to conduct a symposium on Statistical Methodology for Agroforestry Research at its 53rd Annual Conference which was held at Tiruchirappalli from 2nd to 4th December, 1999. The symposium on the said topic was organised on 3rd of December at 2.30 p.m.

Dr. S. Varadarajan, Director, School of Economics, Coimbatore chaired the session. Dr. V.K. Sharma and Dr. Seema Jaggi of IASRI acted as the convenors. The session started with a brief introduction of the topic by Dr. V.K. Sharma. The following three papers were presented and discussed at length during this session.

(1) Using appropriate experimental design is an important aspect of agroforestry research. Dr. Seema Jaggi of IASRI, New Delhi reviewed various designs suitable for the research and also described some new techniques for the analysis of data from such experiments. Conventional approach to agroforestry experimentation is difficult because of too many combinations of factors and the requirement of large plot for trees. Several characteristics of trees like slow growth of trees, long term effects that trees have on the surroundings, age of trees etc. compound experimental problems and complicate the issue of experimental design, it was emphasised that there cannot be a general solution for any problem related to agroforestry experimentation. The choice of a particular design requires location specific factors to be taken into account as the performance of agroforestry systems widely differs between locations. It was also highlighted that the analyses of data generated from these experiments are also complex since it involves multiple outputs.

(2) Sh. Ajit of National Research Centre for Agroforestry (NRCAF), Jhansi presented the paper entitled 'The study of root distribution pattern through prediction model in Dalbergia Sissoo based agroforestry system' in which he emphasised the tree-crop interaction that drew attention to the tree root distribution pattern. On the basis of his empirical study, he demonstrated the use of residual diagnostics and validation tests in understanding tree-crop interaction mechanism. The discussion at the end of the presentation led to the suggestion that in the method used, it would be necessary to measure root density in different directions. It was also pointed out that the developed model may be validated on the data generated from the experiment in the subsequent years.

(3) Dr. Anil Rai of IASRI, New Delhi in his presentation explained the findings of a diagnostic survey in agroforestry research. The main objective of the survey was to study the impact and constraints of agroforestry/social forestry program in relation to socio-economic structure of the region. The study was undertaken in Chhachroli block of Yamuna Nagar District by selecting a sample of 400 households. The study revealed that size of farms and size of farm farmilies had influence on adoption of agroforestry and its income benefits while the level of education of the farmers did not. In all categories farms, agroforestry contributed to the rise in income of the farmers. To make a precise measure of the benefit of agroforestry, incremental benefit/cost ratio would be appropriate as tree crops yield income over a number of years.

Finally Dr. S. Varadarajan, chairman of session in his conclusive remarks pleaded for a system's approach to evaluate the contribution of agroforestry to farm income. He drew special attention to the shade effect of the trees on crops which should be taken care of while planning the experiments. He also emphasis the role of uncertainty in return to the investment in agroforestry system. Specifically, he suggested bench mark surveys, case studies of agroforestry in different conditions, experimental research for analysing tree-crop interactions and simulation studies need to be undertaken.

Recommendations of the Symposium

- Efforts should be made to develop strong interaction between All India Co-ordinated Research Project on Agroforestry and IASRI.
- Monographs/manuals should be prepared on the Statistical Methodologies related to Agroforestry for the benefit of the agroforestry research workers.
- There is a need to develop efficient designs for agroforestry experiments and modelling of Agroforestry systems.

Design and Analysis of Agroforestry Experiments: An Overview

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Agroforestry is an integrated system of growing more than one component (crop, trees etc.) together on the same piece of land. Conventional approach to agroforestry experimentation is difficult because of too many combinations of factors and the requirement of large plots for trees. The arrangement of components in relation to one another within the plot is an important consideration in agroforestry experiments, especially in interaction studies. An understanding of the nature of tree and crop interactions at the tree-crop interfaces can provide an important step for designing agroforestry systems. Several characteristics of the trees compound experimental problems and complicate the issue of experimental design, like slow growth of trees, long term effects that trees have on their surroundings, long-lived nature of trees, age of trees and the area over which the influence of trees extends. Using appropriate design is a very important aspect of agroforestry experimentation. A general recommendation or solution cannot be suggested since these problems are specific to site or experiment.

This paper gives an overview of some of the designs used in agroforestry experimentation along with illustrations where-ever possible. Other than the conventional design, the designs that have been discussed in detail are Y-design [Huxley (1985a)], Star design [Rao *et al* (1991)], Systematic design [Huxley, (1985b), Nelder (1962)], Augmented design [Pinney (1991)] and Beehive design [Martin (1973)]. Some analytical techniques, other than the usual analysis of the design adopted, have also been described. These techniques included Covariance analysis, Principal Component analysis, Stability analysis etc.

The Study of Root Distribution Pattern Through Prediction Model in Dalbergia Sissoo Based Agroforestry System

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The prime aim of agroforestry systems is to produce more biological yield than either pure crop or pure tree systems. It only can be achieved by a thorough

understanding of tree-crop interaction mechanism. This in turn requires the trees root distribution pattern in the upper zone of the soil, and modelling is one of the tools to describe/predict the interaction behaviour of the tree-crop system. A study was initiated at NRC- Agroforestry, Jhansi during 1994, on different agronomic and physiological root management practices (deep ploughing, root barrier polythene sheet, deep basin, pruning-up to 40% of height, growth regulator - GA3100 ppm, control) in Dalbergia Sissoo based agroforestry systems. Blackgram-mustard crop sequence was taken as intercrop. To describe the pattern of root length density (Y) distribution at different places from tree base (X), the model $Y = 0.346^{*}$ [exp(–0.706^{*}X)] has been proposed. It was assessed using residual diagnostics and validation tests for fulfillment of underlying assumptions. Preliminary predictive results of the model revealed that out of the six treatments considered in the experiment, 'deep basin' and 'deep ploughing' leads to minimum values (0.164 and 0.212 respectively) of root length density adjacent to the tree base and hence would result in minimum competition for moisture and nutrients between tree and crop under D. *sissoo* based agroforestry systems.

Digonostic Surveys in Agroforestry Research

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Presently there is no option except to develop a scientific plant-animal man food chain policy for each agro-ecological area based on long term consideration. Hence, the importance of agroforestry as well as social forestry is evident. The available literature clearly indicates that the planning and management scene in forestry has never been more demanding then at present. The planning and management strategies should be socio-economically viable, market responsive, solve increasingly complex problem with speed and accuracy. Apart from this, planning should be aimed to promote sustainable forest resource utilization alongwith sustainable development of other natural resources like land, water and its environment.

The agroforestry/social forestry is comparatively a recent system adopted by the forest department, but due to its multidisciplinary nature and relevance in the present context research worker in different areas have developed interest in it and number of research papers have appeared in this area recently. Rao,

E.V. (1967) studied the economics of plantation particularly of Casurina and Eucalyptus with special reference to the sandy soil of Nellore South Division of Andhra Pradesh. Mann and Lahire (1969), Medina and Jamson (1980), Ahuja and Mann (1975), Bhimaya and Kaul (1960), Deb Roy and Pathak (1974), Muthana (1980) conducted studies for planning management, development and constraints in the field of agro-forestry/social forestry. Singh and Pazo (1981) discussed the need of agro-forestry in eastern Himalayas. Mathur (1981) discussed the socio economic aspects of agro-forestry specially with reference to shifting cultivation in North-Eastern part of the country. Singh (1981) discussed the scope of agro-forestry in Punjab and Himachal. Unfortunately, the socio-economic aspects have been ignored and only few studies have been taken up in this field. Keeping in view the above facts a study has been taken up in Yamuna Nagar district of Haryana State on the initiative of the State Forest Department of Haryana.

The main objective of this study was to study the impact and constraints of agroforestry/social forestry program in relation to socio-economic structure of the region. This study was undertaken in Chhachroli block of Yamuna Nagar district. The study block consists of 166 villages which were divided into two groups according to their distance from the natural forest/reserve forest/protected forest. First group (common boundary wih forest) consists of 87 villages whereas 79 villages belongs to second group (away from the forest boundary). A sample of 20 villages, 10 from each group has been selected by SRSWOR. Each of the selected villages was completely enumerated and divided into four category on the basis of holding size i.e. landless, small (less than 1.0 ha), medium (1 to 2.0 ha) and large (more than 2.0 ha) households. From each village 20 household was selected from four different categories proportionally again by SRSWOR. Hence, final sample consists of 400 household for detail surveys. Some of important tables of the study are given along with important results, which are follows.

- The agroforestry is more popular in the villages, which are far away from the forest area. Around 61% households of the villages away from the forest received income from the trees of agroforestry where as it is only 35% households in the villages near the natural forest.
- The maximum benefit of the agroforestry in the form of labour generation goes to the landless category of households. 73% households of land less category in the villages which are away from the forest and 35% households of same category in the villages near the forest boundaries received the income from agroforestry by engaging in agroforestry operations.

- The economic dependence on the income of trees from agroforestry increases with increasing the family size and number of animals in both groups of villages.
- Around 48% of the households are benefited by agroforestry for getting wood as a source of cooking.
- The rate of adoption of agroforestry system in farmers households are more i.e. 85% in the villages which are far away from the forest boundaries as compared to the households of the villages near the forest boundaries (80%).
- The overall annual income from the trees of those households adopted agroforestry increases with increasing holding size whereas the average income from trees of the households not adopted agroforestry decreases with increasing holding size (Table-1).
- Most of the large and medium farmers adopted agroforestry as their source of income.
- The overall annual income from the trees of agroforestry is Rs. 8337 for adopted households, whereas corresponding income for non-adopted households are comparatively less i.e. Rs. 2638 (Table-1).
- In case households adopted agroforestry, the overall income from agriculture, livestock products, service, trees of agroforestry, labour, self employment and natural forest are 61%, 14%, 8%, 7%, 6%, 3% and 1.0% respectively. However, the percentage contributions from agroforestry in the total income of the household increases as the holding size increase. It is 56%, 83% and 90% for small, medium and large farmers respectively (Table- 1).
- The major source of income for all categories of farmers i.e. small (31%), medium (58%) and large (71%) is agricultural. In case of landless families, labour (51%) followed by service (16%) are the major sources of their income. The income from the trees of agroforestry contributes marginally to the overall income of the household's i.e. between 3% to 8%. However, the overall income from agroforestry contributes 52% , 82%, 90% and 15% of the income of households for small, medium, large and landless households (Table-2).
- The levels of education play no role as far as income from agroforestry is concern. The contributions of income of the total income households from overall agroforestry system are 80% and 79% for educated and illiterate respectively. This may be due to the fact that technology related to agroforestry perforate from farmers to farmers (Table-3).

These results clearly indicate that the agroforestry has important role to play in social and economic development of the region.

Table 1 Contribution of income from different according to adoption of agroforestry under different holding size.

Holding size	Status of Agro forestry	No. of house holds		Income								
				Agroforestry				Natural Forest	Self Emp.	Service	Labour	Overall
				Agri.	Forestry	Livestock	Total					
Small	Adoption	77	Av.	12521	3235	7540	20641	2742	14388	28230	15450	36651
			%	33.72	3.9	18.7	56.62	2.53	8.16	10.00	22.99	
	Non Adoption	30	Av.	7377	3050	6981	14270	2160	27500	73500	11889	34117
			%	21.62	1.79	18.42	42.03	3.17	5.37	28.72	20.9	
Medium	Adoption	55	Av.	35660	6062	10811	50549	2613	14500	84850	19500	61164
			%	58.3	6.67	17.68	82.65	0.62	2.59	10.09	25.3	
	Non Adoption	5	Av.	22200	1400	12060	34820	900	15000	–	8000	42780
			%	51.89	1.30	28.19	81.38	0.84	14.04	–	3.74	
Large	Adoption	71	Av.	92694	13020	14986	117343	3144	26000	67778	28000	130137
			%	71.25	7.75	11.19	90.19	0.30	1.40	6.60	1.51	
	Non Adoption	0	Av.	–	–	–	–	–	–	–	–	–
			%	–	–	–	–	–	–	–	–	
Total	Adoption	203	Av.	47001	8337	11115	62588	2802	16563	53552	17137	75989
			%	61.54	6.80	14.05	82.39	0.78	2.89	7.98	5.99	
	Non Adoption	35	Av.	9494	2638	7775	17206	2012	21250	73500	11684	35354
			%	26.85	1.70	20.10	48.65	2.77	6.87	23.75	17.96	

Co-efficient of variance ranges between 5 to 14%

Table 2 Contribution of income from different sources according to holding size.

Holding size	No. of house holds		Income								
			Agroforestry				Natural Forest	Self Emp.	Service	Labour	Overall
			Agri.	Forestry	Livestock	Total					
Small	107	Av.	11065	3208	7385	18856	2529	15844	41164	14382	35940
		%	30.5	3.34	18.63	52.47	2.70	7.42	14.99	22.44	
Medium	60	Av.	34538	5823	10915	49238	2270	14625	84850	18063	59632
		%	57.92	6.35	18.30	82.57	0.63	3.27	9.49	4.04	
Large	71	Av.	92694	13020	14986	117343	3144	26000	67778	28000	130137
		%	71.23	7.75	11.20	90.18	0.30	1.40	6.6	1.52	
Land less	162	Av.		1322	4928	4111	1648	19471	55623	16463	27133
		%		2.71	12.44	15.15	2.02	15.06	16.45	51.31	
Total	400	Av.	41462	5315	8760	34923	2138	18372	56220	16204	52647
		%	46.66	5.65	14.02	66.33	1.16	5.67	10.68	16.16	

Co-efficient of variance ranges between 5 to 9%

Table 3 Contribution of income from different sources according to the level of education of farmers.

Level of education	No. of house holds		Income								
			Agroforestry				Natural Forest	Self Emp.	Service	Labour	Overall
			Agri.	Forestry	Livestock	Total					
Educated	75	Av.	68381	13766	14298	90160	2163	15539	65873	17854	112215
		%	60.13	8.33	11.89	80.35	0.21	2.40	14.87	1.91	
Illiterate	163	Av.	29099	4451	9014	39992	2642	18344	34263	15419	50596
		%	57.51	4.47	17.04	79.02	1.66	4.00	3.32	11.96	
Total	238	Av.	41462	7996	10643	55896	2578	17168	56507	15718	70013
		%	58.97	6.43	14.43	79.83	0.92	3.19	9.31	6.88	

Co-efficient of variance ranges between 5 to 19%