

**A RESOURCE ECONOMIC STUDY ON TREE DIVERSITY IN
COFFEE BASED PLANTATIONS IN THE WESTERN GHATS
REGION OF KARNATAKA**

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**DEPARTMENT OF AGRICULTURAL ECONOMICS
UNIVERSITY OF AGRICULTURAL SCIENCES
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**A RESOURCE ECONOMIC STUDY ON TREE DIVERSITY IN
COFFEE BASED PLANTATIONS IN THE WESTERN GHATS
REGION OF KARNATAKA**

MUTHAPPA, P. P.

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University of Agricultural Sciences, Bangalore
in partial fulfilment of the requirements
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CERTIFICATE

This is to certify that the thesis entitled “A RESOUCCE ECONOMIC STUDY ON TREE SPECIES DIVERSITY IN COFFEE BASED PLANTATIONS IN THE WESTERN GHATS REGION OF KARNATAKA” submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRICULTURAL ECONOMICS** to the **University of Agricultural Sciences, Bangalore**, is a record of research work carried out by Mr. P. P. MUTHAPPA under my guidance and supervision and that no part of the thesis has been submitted for the award of any other degree, diploma, associateship, fellowship or other similar titles.

Bangalore

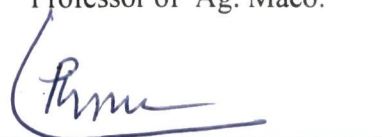
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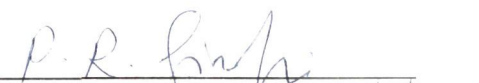
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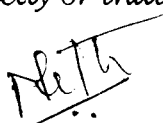
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INTRODUCTION

CHAPTER I

INTRODUCTION

Forests in tropical countries are one of the richest biomes in the world. However, high population density of men and cattle has resulted in excessive utilisation of this valuable resource. Consequently, deforestation is a major global concern. There have been attempts to prevent this irreparable damage through strict protection against all human disturbances. It is evident now that the effort has not yielded the desired results. The failure is largely due to local and more so regional – global demands for forest utilisation. The forests are threatened from people-government conflicts as well as ever mounting commercial pressures (Kushalappa and Kushalappa 1998b).

India has diverse climatic and topographic conditions, which has contributed to a wide variety of ecosystems and life forms. The different ecosystems and their biological diversity have contributed to make India one among the 12 mega diversity regions in the world. The Western Ghats and the northeastern region are two of the most biological rich areas within India. Western Ghats is a 1500 Km long, 5 to 15 km. wide and 2 to 5 Km. high mountain range running parallel to the west coast of India. Bio-geo graphically Western Ghats is a relict pocket of ancient biota, which is cut off from the rest of the Southeast Asian humid forest tract and is one of the best representatives of non-equatorial tropical forest in the world. The rich bio-diversity and its high endemism have resulted in declaring this region as one of the 18 global hot spots of biodiversity (Olson and Dinerstein, 1998).

1.1 Trees as natural resource and the economic dimension.

Forests in general and tree diversity in particular are very crucial from the point of environmental conservation and maintaining ecological balance in addition to the several use and non-use values that the trees provide. However, economic valuation of tree diversity is difficult in theory and even more difficult in practice. The total economic value in the tropical context are use and non-use value (Table 1.1). The importance of trees both at global as well at the local context should be viewed in terms of its total economic value.

1.2 Forestry and plantations in Western Ghats.

The Western Ghat area is a chain of high lands running along the western edge of India. This hill range contains some of the most important tropical forest in the sub-continent covering an area of 160 thousand sq. km. Western Ghats has overall effect on the southwestern monsoon which has resulted in very distinct and unique biological diversity in this area. The Western Ghats have 3500 floral species, which accounts for 1/3rd of the flowering plants of India which means this hill range is a outstanding eco-region where conservation effort is of utmost priority. The Western Ghats also produces coffee, tea, pepper, cardamom and rubber besides minerals like iron ore, manganese and bauxite. Forests have been cleared for these developmental needs. Forests in Western Ghats have been worked systematically with the advent of British rule (around 1886) by means of approved working plans. The forests were worked later based on selection felling system mainly for plywood industries. In the

Table 1.1: Total economic value

Use value			+ Non-use value
(1)	(2)	(3)	(4)
Direct value	+ Indirect value	+ Option value	+ Existence value
Timber			
Non-timber products	Nutrient cycling	Future uses as per (1) and (2)	Forests as object of intrinsic value, as bequest, as a gift to others, as a responsibility (stewardship).
Recreation	Watershed protection		Includes cultural and heritage values
Medicine	Air-pollution reduction		
Plant genetics	Micro-climate		
Education			
Human habitat			

process, large areas were leased out for working where selected soft wood species have been removed (Kushalappa and Kushalappa, 1998a).

With this backdrop of the Western Ghats as a hot spot of biodiversity, commercial production of plantation crop such as; coffee, cardamom, pepper, tea, etc., were introduced. Introduction of coffee in the Western Ghats region has a long history. It all began four centuries ago, when Saint Baba Budan an Arab mystic, returned from Mecca with seven seeds of the wonder bean **Coffee**. He planted them in the Chandragiri Hills in Chickmangalore district of Karnataka State which lies in the Western Ghats region whose conducive climate and altitude proved ideal for coffee cultivation.

The East India Company with its relentless spirit of exploration for harnessing commercial avenues in India, discovered a gold mine in coffee cultivation and developed it into a viable plantation crop. By the end of the 19th century, the green hills of Karnataka, Tamil Nadu and Kerala were covered with thriving coffee plantations. However, Karnataka State, the home of Indian coffee remains the largest producer of finest varieties of coffee even today. Kodagu district in Karnataka was found to have the best suited agro-climatic conditions for the production of quality coffee. Till date, coffee beans produced in this part of the Western Ghats are known all over the globe for its high quality.

India is one of the very few countries which produce Arabica and Robusta coffee varieties in more or less equal quantities. An average of two hundred thousand tonnes of coffee equivalent to 3.3 million bags is produced a year in an area of about

three hundred thousand hectares. India exports 70 per cent of its coffee production to various countries all over the world earning about Rs.900 crores per year.

Contrary to this enormous developmental benefit, it is often complained that plantation crops have detrimental effect on forestry in general and forest tree diversity in particular. For instance, a report (Anonymous 1999) indicates that the loss of forests to a large extent in Chickmangalore and Kodagu districts where coffee plantations dominate (Table 1.2).

It has always been a challenge to the researchers particularly natural resource economists and planners to address this conflict between development and conservation.

1.3 Trees within the plantations

Unlike other forms of intervention in the nature through agriculture, growing plantation crops like coffee, pepper, cardamom and cocoa, have many elements of conservation of trees such as shade, support, wind break, soil and water conservation, improving the water table, carbon sink in mitigating the global warming problem, etc. As per the observations made by Central Coffee Research Institute in Chickmangalore district of Karnataka, coffee planters maintain standard tree density in their coffee plantations. This dimension of agronomic association of plantation crops with trees must be emphasised in order to address the issue of the harmony between development and conservation. In addition, growing trees in coffee estates possess

Table 1.2: Loss of forests in Western Ghats (Area in Sq. km.)

District	Area	Extent of forest				Forest loss due to (% to total loss)		
		1920		1990		Agri	Tea or coffee	Reservoirs
		area	% to total	area	% to total			
Chickmangalore	7184	5068	71	2500	35	55.8	42.2	2.2
Hassan	6816	2205	32	721	11	81.0	18.3	0.7
Kodagu	4098	3622	88	1464	36	28.0	71.5	0.5
Shimoga	10556	6330	60	4637	44	93.1	0.0	6.9
Uttar Kannada	10251	9034	89	7806	76	92.6	0.0	7.4

Anon, Economic and Political Weekly, 1999

another crucial dimension of conservation i.e., conservation of the much needed tree species diversity.

In this backdrop, the present study makes a modest attempt to study the resource economics of forest trees maintained in coffee based plantations in the Western Ghats region of Karnataka.

1.4 Kodagu district – an overview

Though the erstwhile kingdom of Coorg (later christened as Kodagu) headed by Haleri rulers was in existence for more than two centuries, there were no towns or big settlements except the town of Madikeri as the capital. The people of Kodagu being agriculturists basically chose to live in the villages and hamlets.

The forests of Kodagu are naturally divided into deciduous and evergreen. The deciduous belt lies within 10-12 miles of the eastern boundary, while finest evergreen forests are met with on the southwestern slopes and in the valleys of the Western Ghats. The most valuable trees in the deciduous forests are teak, honne (*Pterocarpus marsupium*), beeti (*Dalbergia latifolia*), nandi (*Lagerstromia microcarpa*) and matti (*Terminalia coriacea*). The evergreen forests on the Western Ghats contain poot (*Callophillum augustifolium*), Ebony ironwood (*Mesuaiferrea*), Cedar (*Cedrella toona*) and Sampige (*Michielia champaka*).

The farmers in south Kodagu have “bane” lands (uplands) granted to them for servicing their holdings of rice. These are held free of revenue for grazing, leaf

manure, firewood and timber for their own use. The farmers of north Kodagu have lands allotted to each holding as in south Kodagu, but village forests are also assigned to each village. Besides 799 “*Devarakadus*” (sacred forests) varying in extent from an acre or two to several hundreds. These are carefully preserved and some of them are considered so sacred that the villagers not even venture into these forests.

1.5 Land Tenure

The whole of the arable lands are held direct from the government on the following tenures:

Jumma: The Jumma ryots hold their lands on a tenure at half assessment of rupees 5 per annum per 100 “butties” (varies from 1.96 to 5.88 acres according to the structure and description of the soil) of wet land with its accompanying bane and barike (low swampy description of land adjacent to, or below the paddy fields used for grazing purposes). The then Jumma holders were liable to be called out to repulse outward aggression or internal disturbances as and when required by the ruler.

Sagu: Lands of sagu tenure are held at full assessment of Rs. 10 per 100 butties. Sagu lands are classified as redeemed or unredeemed according to the timber rights that have been paid for by the occupants or not.

Oombli: The “Oombli” lands were granted for services which are held at three different rates viz., Rs. 3, Rs. 2.5 and Rs. 1 per annum for 100 butties.

1.6 Need for the study

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Currently, the development of tropical forest cover under Western Ghat region is under attention of the planners due to its local, regional and global environmental impacts. In this region, the trees are grown and maintained by the planters in the coffee plantations as shade trees for coffee, support for pepper, timber, fuel wood, and other indirect benefits which includes ergonomics. These coffee plantations in a way under various tenure systems have contributed to conservation of tree species. The trees are effective means to improve the environment and ecological balance. In this back drop, coffee estates that house wide variety of trees will have opportunity to avail the “Green box” provisions in WTO Agreement on Agriculture (Appendix I). For instance, Brazil has already initiated the debate on the ‘multifunctionality’ role such as positive externality and environmental functions from agriculture in the World Trade Committee on “Trade and Environment” (WTO 1999). The present study makes an attempt to strengthen this issue of multifunctionality role including environmental benefit from trees and diversity provided by coffee plantations. The study mainly is an attempt to analyse the contribution of coffee plantation in conserving tree diversity.

The objectives of the study are as under:

1. Analysis of tree species diversity in different land tenure systems of coffee plantations.

2. Assessment of stumpage value, direct and indirect benefits of trees in coffee plantations.
3. To study the problems and prospects of maintaining tree diversity in coffee plantations.

1.7 Hypotheses relating to the study

Objective 1:

- a) Age of the plantation has positive relationship with tree diversity.
- b) Arabica coffee plantation requires more shade and hence more tree diversity is found in such plantation.
- c) Larger the size of the individual holding greater is the diversity of tree species.
- d) Plantations under unredeem land tenure system have higher tree species diversity.

Objective 2:

- a) Stumpage value of standing timber stock is more in case of unredeemed land tenure.
- b) Stumpage value of trees is more in case of larger plantations.

Objective 3:

- a) Small growers face difficulty in maintaining tree diversity.
- b) Lack of incentives to grow traditional trees is a cause for reduced tree diversity.
- c) Restriction on felling of traditional tree species acts as a disincentive to the planters.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

In this chapter an effort is made to review the studies done in the past which are pertinent to the present study and are presented under following headings:

- 2.1 Agroforestry in general
- 2.2 Coffee and agroforestry
- 2.3 Benefits from trees
- 2.4 Tools for measuring diversity
- 2.5 Diversity and management
- 2.6 Western Ghats and diversity

2.1 Agroforestry in general

Bhaskar and Swami Rao (1985) indicated that farm forestry is synonymous with organic farming and it will not only help to prevent further desertification which is taking place today but also assist in producing more foodgrains, milk and meat for people.

Dixit (1988) analysing the impact of social forestry identified certain economic and technical problems. These related to lack of capital (48%), delay in realising profits (47per cent), limited land for growing trees (27%) and difficulty in the supply of seedlings (24%).

Aulokh (1990) found a strong resistance from the farmers for adoption of farm forestry. The resistance was mainly due to their perception relating to (a) shade trees have adverse effect on the crops (b) birds damage the crop (c) roots of trees interfere with field crops and (d) the water regime in the soil will be adversely affected. As a result, even nursery plants supplied at nominal prices were not acceptable to farmers and were not planted by them.

Sharma (1992) reported the current status of agroforestry practices and highlighted interaction between the components of agroforestry. There is a lack of quantitative information about the complex interactions although qualitative and judgmental information is available from villages, ever since they are protected in the traditional agroforestry system.

Ahmed (1994) observed that environmental decay and destruction has arisen from rapid growth and population. It was pointed that the remedy to these environmental problems calls for long term planning and legislative measures to control and reduce the human population and enforce laws for reducing emission from vehicles. With regard to the natural resources deforestation was stated as the most serious threat.

Manjul Bajaj (1994) suggested the need to re – examine the present policy of restricting the sale of timber in private lands. It was suggested that forest timber be allowed to gravitate to its highest value usage and that there should be some sort of steady supply of timber from forests because if we do not allow it legally, it will

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happen illegally. It was also felt that if the present system of subsidy is removed the system will work itself out.

Nadkarni (1994) outlined the significance of forests apart from their ecological role in supporting the local economy, particularly the relatively poor groups who derive their biomass requirement outside the framework of the market.

Verma (1994) recorded that about 36 per cent of the sample farmers did not intend to plant seedlings on account of lack of space. Among them, marginal farmers constituted 76 per cent. Another major reason was damage to the seedlings due to unattended rainfed farms for major part of the year.

Chaun and Sanjeev (1995) observed that due to developmental activities like road construction, building of hydel projects, increase in horticultural activities coupled with the enormous biotic pressures, the forest genetic resources have been on the decline for many decades. Exploitation of these resources for economic gains and day to day use by the community in the absence of suitable measures for their protection, propagation and conservation has caused danger to the survival of many valuable species. The elements of environment conservation should necessarily form a component of the school, college and university curricula.

Anil Kumar *et. al.* (1999) found that many of the farmers were neutral or undecided in their attitude towards the agro-forestry programme. The study indicated non-availability of water, desired plant species, and smaller size of land holding as the important constraints as perceived by the farmers. Likewise, the important constraints

perceived by agro-forestry personnel related to the inadequacy of staff, counter propaganda by certain organizations, inadequacy of publicity and extension work.

2.2 Coffee and agroforestry

Abdul (1991) showed that inter cropping of coffee with *P. merkusii* and *A. hunsteinii*. The results indicated low coffee production as compared to that under coconut. It was suggested that forest tree species having light canopy, especially leguminous trees have the ability to fix nitrogen so as to improve crop yield should be selected and introduced in coffee plantations.

Eduardo (1995) observed that five out of eight coffee agroforestry systems in the Venezuelan Andes were important as they increased diversity in coffee plots. This type of diversity of systems has also been found in Mexico and Costa Rica. The diversity of the culture of coffee in the area was found to depend first on agroecological conditions (altitude and precipitation), secondly on the demand for specific products and thirdly on local infrastructure – good roads and access to markets.

2.3 Benefits from trees

Tirath Gupta and Deepinder Mohan (1982) stated that besides the higher financial returns from tree crops, certain societal benefits eg., the development of a more efficient system of energy transfer, soil and water conservation, improvement in soil textures and nutrient contents, moderating influences on the climate and

enhancement of wildlife and outdoor recreation facilities were also expected to emerge out of the proposed shift in land use for tree crops.

Reddy and Korwar (1985) worked out the economics of agroforestry, silvi agriculture and silvi – pastoral systems and found them to be economically viable. The annuity value was Rs. 799 in case of agroforestry, Rs. 598 for silvi-agriculture and Rs. 142 for silvi pastoral systems. The corresponding benefit cost ratios were 1.45, 1.29 and 2.25 respectively. The agroforestry and silvi agriculture provided foodgrain, firewood and fodder. These systems also yielded a number of indirect or intangible benefits like reduction of soil erosion, stabilization of foodgrain prices and improvement of environment.

Sara (1992) was of the opinion that agroforestry programs and policies would gain both clarity and direction from more comprehensive programmes of agroforestry economics research. It was pointed out that economists can play a critical role in explaining and predicting regional and household agroforestry production and consumption, assessing the economic performance and potential of agroforestry systems and initiating regular data collection on agroforestry.

Gurmel Singh *et al.* (1993) concluded that agroforestry measure particularly silvipastoral system offers great potential for the management of degraded and problematic soils in India. Under denuded and degraded conditions mechanical measures although expensive have to be adopted in conjunction with agroforestry measures. Agroforestry measures were found not only ameliorating productivity of degraded lands but also arresting soil, water and nutrient losses.

Punjab Singh and Roy (1993) viewed that silvipastoral technologies offer possibilities for ameliorating productivity of degraded lands in a variety of situations. However, a better understanding of such systems is required for large scale adoption.

Prathiban and Vinaya Rai (1994) compared the sites where bamboo, cassia, casurina, eucalyptus, teak, subabul and silk cotton trees have been grown for the past 15 years in terms of soil fertility with cultivated field in the proximity. Nutrients N, P and K registered an increase under tree cover compared to barren soil. Higher N content was noted in the sites of silk cotton, higher phosphorous in bamboo, cassia and teak.

Chauhan *et al.* (1995) observed the effect of tree spacing on wheat yield and found that in case of siris, subabool and control, the ten and eight meter distances gave higher wheat yield, whereas, six, four, and two meter distances showed low yield in that order. Mulberry and poplar showed reduced yield upto four meter distance. However six meter and higher distances indicated negligible effect on wheat yield.

Chauhan *et al.* (1997) in another study evaluated the growth and productivity of an agri-horti-silvicultural system of agroforestry by planting kinow-mandarin, subabool and cultivating agricultural crops between woody perennials under irrigated conditions of subtropical low hills of Himachal Pradesh. Maximum fruit, fodder, and fuelwood yield were obtained from treatment consisting of 36 trees of kinow-mandarin plus 15 trees of subabul and agricultural crops. Investigations also revealed

that 45 per cent subabul tree could be interplanted beneficially in kinow-mandarine orchards.

Vincent Favrichon (1998) developed a quantitative model to describe and simulate the dynamics of an undisturbed stand as well as a logged uneven – aged, multispecies stand in French Guyana. It was a management oriented matrix model that takes into account three main characteristics of the forest dynamics. First, the density dependence was estimated considering factors such as growth, mortality and ingrowth. Second, a site effect was introduced on the assumption that the stand density in a natural stand is an approximate site characteristic. Third, the very high species diversity was reduced by combining species into five groups on growth behaviour basis with reference to shade tolerance and maximum potential size.

Kushalappa, (1998) opined that forest is a dynamic resource and hence the ecosystem has to be managed properly to provide goods and services to people. Harvesting of mature, over-mature and dead trees would improve the hygiene of forest ecosystem and at the same time provide some revenue to the exchequer.

2.4 Tools for measuring diversity

Cao Min (1992) observed that *Shorea chinensis* forest in Xishuangbanna is more diversified in tree species composition than the insular forest in Micronesia, Thailand and Equatorial Amazon. The diversity indices such as Shannon's H, the complement of Simpson's index, d, and Fisher's alpha were applied in this study.

Parresol (1999) indicated ratio type and difference sampling estimates being appropriate if one needs only the estimates of the total woody biomass of the tree. Similarly, if one wants to develop weight-ratio or density-integral type of models, a more intensive sampling would be more appropriate. Under short-rotation woody biomass programs, trees typically do not attain a large size, so development of weight-ratio or density-integral models is probably not labor efficient or cost effective.

Nath *et al.* (2000) described the tree stocks and species diversity in four different compartments of Sitaphar forest reserve. Individual tree stems per hectare was higher in some blocks, whereas, basal area per hectare was higher in other blocks. The Shannon-Weiner diversity index, species diversity index, Richness index and evenness index was highest in compartment No. 51 but index of dominance was lowest in compartment No. 51. Trends of diversity indices show that vegetation community in compartment No. 51 is highly stable in comparison to remaining three compartments. The overall tree diversity in Sitaphar forest reserve is comparable to the tropical forests and emphasis has been given to conserve the area.

Arun and Singh (2000) observed higher insect species richness in West Himalayan region, Shannon diversity and Pielou's evenness indices in plot I (*P. smithiana*) as compared to plot II (*A. pindrow*) for both living and dead trees.

Shannon-diversity index (H') was calculated using the species abundance (P_i), and species richness (S) in natural logarithm ($\log_e$) form:

$$H' = -\sum P_i \log_e P_i$$

The Pielou's evenness index (J) was then calculated using Shannon-diversity index (H') and species richness (S) through the formula:

$$J = H' / \log_e S$$

5.5 Diversity and management

Prasad (1993) observed that the plantation in Gaya district predominantly consisted of *Acacia auriculaeformis* plants. When the plantation was departmentally exploited it was found that only 14,109 trees of acacia species was surviving out of the total of 69,600 trees of acacia planted. Thus, the survival rate was only 27 per cent. In spite of the internal rate of returns for the plantation worked to 12.82 per cent. Acacia species is not very economical since it has very limited timber value. Even with low survival percentage and timber value the plantation with Acacia species was found to be economically viable.

Sekar and Karunakaran (1994) estimated the average life span of cashew to be around 25 to 30 years. It gives economic returns from the third year of planting, gets stabilised at the seventh year, produces economic yield upto the twentieth year and then onwards starts declining. In the study area, cashew plantations are felled after 25 years of age. On an average, a population of 175 trees is maintained per hectare, generating about 200 to 250 kg of cashew nuts per year.

Joseph *et al.* (1995) suggested light management in terms of shade regulation to improve tree diversity relative to natural stand growth. Maximum economic efficiency would require a substantial reduction in basal area and average size of

trees. Obviously, this would lead to low tree diversity. Maximizing unconstrained tree diversity would be costly. Management that conciliated diversity and economic efficiency required a decrease in the basal area of stand relative to their current state.

Pathak (1997) favoured taking up appropriate agroforestry practices to rehabilitate the natural ecosystem, replacing by one managed for subsistence of economic purposes which in turn are more vulnerable to drought, erosion, pests and all the uncertainties of agriculture. Appropriate agroforestry practices offer a practical means of protecting environment by approximating the natural three-dimensional structure of a mixed tree/crop system and by maintaining or even increasing the number of plant species. Thus, agroforestry was found to meet the joint criteria of productivity, sustainability and practicability.

Shrivastava and Siaguru (1997) viewed that sustainable management of forest, normal growing stock, normal age gradations and normal increments as pre – requisites to bring the forests to normalcy. Concentrated regeneration felling with artificial regeneration will ensure the restocking of felled areas in shortest possible time. A period of 120 years is required to convert the entire forest to normal age gradation. The normal growing stock can be achieved by proper yield regulations and stocking improvement.

Siani *et al.* (1997) studied the effect of pruning intensity on the canopy dynamics of Gutel (*Trewia nudiflora* L.) in an agroforestry system under Terai conditions of Uttar Pradesh. Pruning was found effective in regulating the leaf fall

and canopy development. *Trewia* species tolerates heavy pruning and was found most suitable in sequencing its phenophases in relation to wheat inter crop in an agroforestry system.

Panth *et al.* (1998) compared the productivity of urd bean – wheat cropping sequence under *Populus deltoides*, Eucalyptus hybrid, *Syzygium cumini* and *Trewia nudiflora* to sole cropping system. The vegetative (straw) yield suffered more than grain yield when grown under all species. The grain yield did not vary significantly under trees as compared to sole crops. The reduction (21 to 38 per cent) in photosynthetically active radiation (PAR) availability during rabi season reduced grain yield of wheat by 17.4 per cent. Whereas, 25 to 75 per cent reduction in PAR during Kharif season lowered urd grain yield by 38 per cent. The marginal reduction in grain yield and 38 per cent reduction in straw yield were well compensated in economic terms by the tree increments attained during the period of experimentation.

Sudhir and Paramatma (1999) observed that inter cultivation of compatible seasonal crops in the inter spaces between Poplars is essential not only for generating continuous supplementary income but also for compensating the loss of land to tree plantations. Wheat, sugarcane and vegetables with Poplar provided higher supplementary income in the early stages. Besides, wheat also gave some income in the later stages. Selection of proper inter crops and their varieties suitable to Poplar and reduction in the tree intensity in the later stage increased the income from inter cropping.

Srivastava (1994) observed that the casuarina trees grown under irrigated condition fared better achieving more girth and height within the timeframe and at close spacing. The profitability depended upon the prevailing market price at the time of harvest.

5.6 Western ghats and diversity

Shyam sunder *et al.* (1986) attributed ecological decline in the Western Ghats to conversion of forest lands for cultivation of coffee, cardamom, rubber and unauthorised cultivation. Steps to prevent deterioration and revival of the Ghats' ecology *inter alia* include, legislative measure such as moratorium on further expansion of non forestry crops in thick evergreen forests under private ownership and nationalization of timber trade in Western Ghats.

Kushalappa (1998) undertook a study in ecologically fragile high altitudinal Western Ghat forest area in Kodagu district. The relevance of working system in managing these forests has been stressed in this study. The government owned reserve forests which were worked under selection system has not modified the forest with respect to its structure, composition and improved regeneration and diversity. The private forests called "coffee saguali malais" have been clean felled and replaced with plantation crops like coffee, cardamom and cashew. This kind of unscientific working has resulted in conversion of the ecologically rich and economically valuable tropical moist evergreen forests to degraded semi evergreen forests.

✓ Kushalappa and Kushalappa (1998b) emphatically stated that Kodagu district in Western Ghats is a treasure of biodiversity. The forests that covered the entire district earlier have been either converted to plantations of coffee, cardamom and other plantation crops or worked for timber. The study outlined the working in reserve forests and “jamma malais” which have not affected the growing stock, regeneration and diversity. Accordingly, it was concluded that the structure and composition have not altered in those forests. However, the working undertaken in private coffee “saguvali malais” had drastically reduced the growing stock and altered the regeneration and diversity.

METHODOLOGY

CHAPTER III

METHODOLOGY

The chapter on methodology describes the general features of the study area, the sampling scheme, data base, the analytical concepts and tools employed.

3.1 The study region

The study was conducted in Kodagu district which lies in the Western Ghats region of Karnataka. The district of Kodagu occupies the summits and the eastern and Western slopes of the Western Ghats within the degrees of North latitude 11°14'. It has an area of 158.66 sq. miles. Its greatest length from North to South being 60 and from East to West is 40 miles. The district is bounded on the north by Dakshina Kannada district and Sakleshpur taluk of Hassan district and on the south by the Vynad taluk belonging to Kerala. On the west, it is bounded by Dakshina Kannada district and Malabar region in Kerala state and on the east by Hassan and Mysore Districts. The west, northwest, and southwest boundary runs along the foot of the Western Ghats that overlooks the low lands of Dakshina Kannada and Malabar. On the North and East for a short way the Cauvery and the Hemavathy rivers mark the boundary between Mysore and Kodagu. On the south, the Brahmagiri range of hills forms the line of division from the Kerala state.

3.2 Demographic features

Kodagu is a very small district in the state of Karnataka, with an area of 4104 sq. km. The entire district is under Western Ghats. Forest occupy 1346 sq. km. accounting for 33 per cent of the total geographical area. The district has large area under plantation crops like coffee, cardamom, pepper, etc, which support diverse tree species and are classified as private forests. The present land use pattern of the district is provided in Table 3.1

3.3 Climate and rainfall

The climate of Kodagu district is temperate and humid. The capital of the district, Madikeri, is located at 3809 feet above the mean sea level. The average annual rainfall of the district during the last 5 years is 122.58 inches. The mean temperature, humidity, and rainfall during each month of the year 1994 are presented in Table 3.2

The rainfall registered at Madikeri during the 13 years is presented in Table 3.3

3.4 Sampling scheme and data base

Kodagu district is purposively selected for this study because of the fact that it is the major coffee producing area in the country. Moreover, the district lies in the Western Ghats region of Karnataka, which is one of the hot spots of diversity in the world. In the

Table 3.1: Land use pattern in Kodagu district (1995).

Sl. No.	Land Use	Area in ha.	Percent of land use
1.	Forest area	134597	32.76
2.	Land put to other use	2369	3.78
3.	Uncultivated land	31010	7.55
4.	Permanent pasture	17404	4.23
5.	Miscellaneous	37878	9.22
6.	Fallow lands	5699	1.39
7.	Cultivable waste	11915	2.90
8.	Net sown area	148581	36.17
	Total	410775	100.00

Source: Kushalappa. 1998a

Table 3.2 Mean temperature, humidity and rainfall during the year 1994

Months	Temperature (°F)	Humidity (per cent)	Rainfall
			inches
January	66.6	57	-
February	70.0	62	-
March	72.9	61	-
April	72.3	79	3
May	70.1	82	10
June	67.7	90	9
July	64.7	94	53
August	64.2	94	25
September	64.2	92	11
October	67.4	84	7
November	66.9	72	-
December	65.7	66	-
Mean	67.7	78	16.8

Table 3.3: Rainfall registered at Madikeri during the fifteen years

Years	Inches
1980 – 81	137
1981 – 82	109
1982 – 83	205
1983 – 84	149
1984 – 85	126
1985 – 86	124
1986 – 87	127
1987 – 88	136
1988 – 89	126
1989 – 90	142
1990 – 91	107
1991 – 92	107
1992 – 93	120

coffee plantations many indigenous/ multipurpose tree species are maintained as shade for coffee plants.

The selection of the sample area and the sample planter respondents was largely determined by the nature and kind of data to be collected for the present study. The sampling design adopted for the present study is described below:

All the three taluks in the district viz., Madikeri, Virajpet and Somwarpet were considered. One village from each taluka which are adjoining to each other was selected because the vegetation and the altitude are almost the same which would facilitate in comparing the tree diversity in different coffee estates coming under the selected study area. Thus, the sample consisted of three adjoining villages representing three different taluks.

A list comprising of coffee planters holding land under jamma, sagu redeemed and sagu unredeemed land tenure was prepared from the revenue offices of the three villages. From this, three small (less than 25 acres) and three large planters (25 acres and above) were selected at random representing each of the three land tenures respectively. Thus, six planters under each tenure were selected in all the three villages. Accordingly, the sample comprised 54 planter respondents chosen at random.

The researcher using pre-tested schedule interviewed the respondents personally. The data collected pertained to the year 1999-2000.

The data collected include the following details:

1. General information of the respondents.
2. Information regarding coffee plantation-variety, area, output, age and altitude.
3. Information on tree species in coffee plantation.
4. Opinion from the respondents regarding tree farming within the coffee plantation.

3.5 Sampling design

A reference line was chosen in each sampling locality which often ran along a natural or man made linear feature, e. g. a cart track, path, fence, boundary, stream, etc. across the extent of the sampling locality. The direction of the reference line was either north south or east west. The vegetation transects were established exactly along the north-south direction if the reference line was roughly east west and *vice-versa*. In each locality, one reference line and several transect lines running perpendicular to it provided the needed framework for sampling (Fig 3.1). The transects in coffee plantations were typically of 50 meter length and 10 meter breadth (Fig 3.2). However, in places where the extent of sampling locality was less than 50 meter on either side of reference line, the length of transect line was as short as 20 meters. The sampling locality was selected using random numbers (Shonil, 1999). In coffee plantations the understorey is cleared for planting coffee and only shade trees are retained. All individual trees greater than or equal to 10 cm. Diameter at Breast Height (DBH) in belt transects were enumerated and

Fig. 3.1 Sampling Design

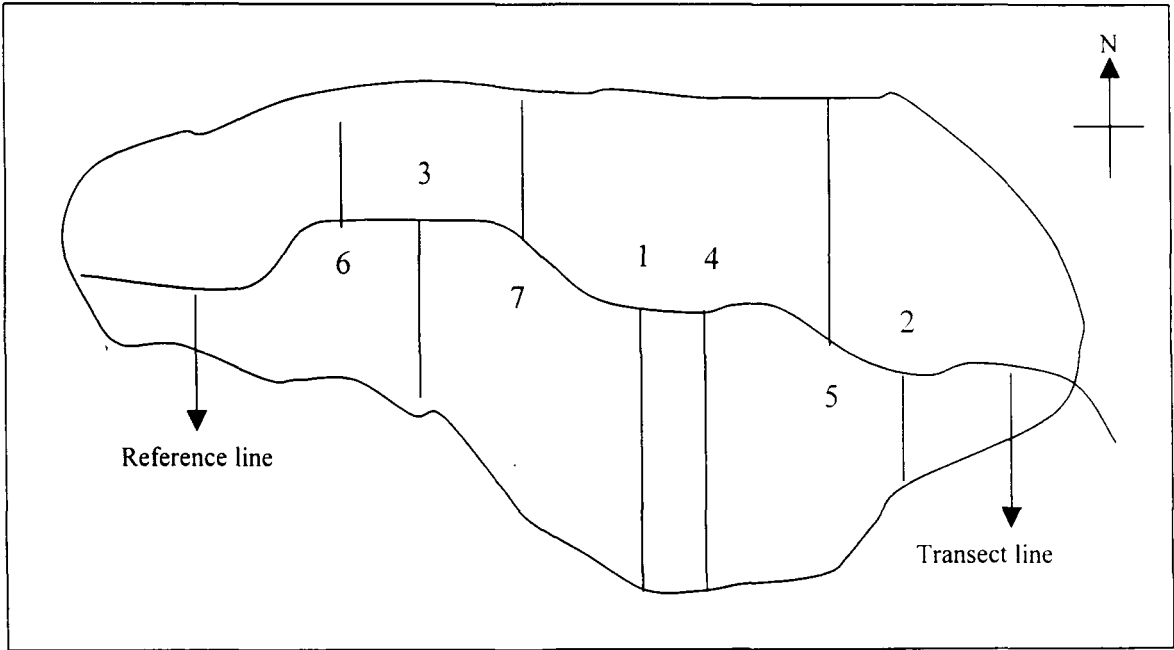
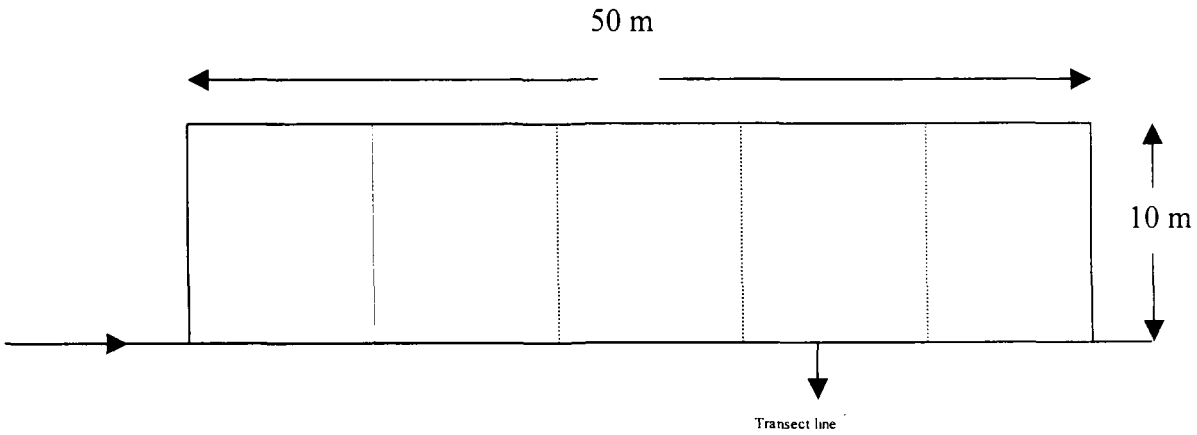


Fig. 3.2 Belt transect in coffee plantations



identified at species level. The diameter was measured using a measuring tape at a standard height of 130 cm. from the base of the tree (following the centre for tropical forest studies convention). The height of individual trees was measured using an instrument called multimeter.

3.6 Economic concepts and analytical tools

The methods of analysis followed in the study are presented under the following headings:

3.6.1 Tree species diversity

Conservation of tree species is of major concern all around the globe. Coffee plantations have diverse tree species within it, as shade trees which is a must for realizing better yields from coffee plants. Tree species diversity tends to differ from one plantation to another and also from one region to another. At this backdrop, it would be relevant to assess the tree species diversity under different plantations.

Simpson's tree diversity index (λ) was used in the present study. The index is arrived by using the formula;

$$\lambda = \sum_{i=1}^s p_i^2$$

where p_i is the proportional abundance of the i^{th} species, given by

$$p_i = n_i / N' , \quad i = 1, 2, 3, \dots, S$$

where n_i is the number of individuals of the i^{th} species and N is the known total number of individuals for all species in the population. Simpson's index, varies from 0 (maximum diversity) to 1 (no diversity) and gives the probability of two individuals drawn at random from a population belonging to the same species. Simply stated, if the probability is high that both individuals belong to the same species, then the diversity of the community species is low Simpson's diversity index.

λ applies only to finite communities where all of the members have been counted i.e., $n = N$, where n is the total number of individuals in the sample and N is the total number of individuals in the population. Since, the sample in the current study was drawn from a infinite population Simpson's unbiased estimator (λ) for infinite population was used.

$$\lambda = \sum_{i=1}^s \frac{n_i(n_i - 1)}{n(n - 1)}$$

To get the direct tree diversity values, λ is subtracted from 1.

Simpson's diversity index was used to calculate the tree species diversity in different class of estates after post stratification of the data into coffee estate under different taluks, sizes, tenure and age groups.

Further, tree diversity index (Y) was considered as the dependent variable and was regressed against independent variables like variety of coffee (X_1), altitude (X_2) and

land tenure (X_3). Variety of coffee and land tenure was taken as dummy variables. In case of variety of coffee, robusta and arabica were given the value of 0 and 1 respectively. Regarding land tenure for better interpretation, jamma and redeem land tenure were clubbed together and given a value of 0, while, unredeem land tenure was assigned a value of 1.

To suppress the effect of intercept, deviations of each observation from the mean was considered and the regression was run using the function given below:

$$(Y - \bar{Y}) = f(X_1 - \bar{X}_1, X_2 - \bar{X}_2, X_3 - \bar{X}_3)$$

3.6.2 Stumpage value of standing timber stock

Trees in coffee plantations play very important role by influencing the coffee yield. Trees generally have very high commercial values but usually it is undervalued. In the study, an effort was made to know the current value of the standing timber stock. For this purpose, girth and height of individual trees were measured using a measuring tape and multimeter respectively as explained in sampling design (3.5). The volume (V) of the trees in cubic meter was calculated using the formula as below:

$$V = \pi \frac{D^2}{4} \times H \times F.F$$

Where, $\pi \frac{D^2}{4}$ = basal area

$$D = g / \pi$$

$$g = \text{girth}$$

$$\pi = 22/7$$

H = height

F.F = Form factor which varies from 0.6 to 0.8. This is considered to correct the uneven girth of the trees along its height. In the current study F. F = 0.7 was considered.

3.6.3 Benefits from trees and problems and prospects of maintaining tree diversity in coffee plantations

Tabular analysis was used for assessing the various benefits that could accrue from trees. These were classified into two broad groups viz., direct benefits (timber, fuel wood, shade, support for pepper and food) and indirect benefits (soil and water conservation, windbreak, religious purpose and others).

Tabular analysis was also used to analyse the problems and prospects of maintaining tree diversity in coffee plantations for the data obtained through opinion survey.

RESULTS

CHAPTER IV

RESULTS

The results of the study are presented in this chapter under the following headings:

- 4.1 General information about the sample.
- 4.2 Tree density in coffee plantation.
- 4.3 Tree species diversity in coffee plantation.
- 4.4 Stumpage value of standing stock of trees in coffee plantation.
- 4.5 Benefits from trees to the planter and to the coffee plantation.
- 4.6 Opinion of the respondents regarding trees in coffee plantation.
- 4.7 Problems and prospects of maintaining tree diversity in coffee plantation.

4.1 General information about the sample.

The sample size of 54 coffee planters that was selected for the present study comprised equal number of large and small growers. There were 18 planters representing each of the three land tenure systems Viz., Jamma, redeem and unredeem. Under each of these three land tenure systems, 9 planters belonged to small and large growers category respectively. Further, twenty planters had Arabica coffee plantation and the remaining 34 had Robusta plantation.

As observed from the table 4.1 the area under coffee plantation ranged between six and 300 acres with the average area of 41 acres. The average size of the plantation was highest in Somwarpet taluk (51 acres) followed by Virajpet taluk (47 acres) and Madikeri taluk (24 acres). The age of the sample plantations ranged between 15 to eighty years with a mean age of 43 years.

The plantations in Virajpet taluk were older (48 years) as compared to Somwarpet (44 years) and Madikeri taluks (37 years). The yield of coffee recorded in sample plantations ranged between 1250 kgs to 1800 kgs per acre. The yields were higher in Virajpet taluk (1600 kg/acre), followed by Somwarpet (1450 kg/acre) and it was lowest in Madikeri taluk (1400 kg/acre).

Plantations in the selected sample came under different altitudes, wherein the maximum altitude was 910 m and the minimum altitude was 850 m. The mean altitude was 880 m. The average altitude of the plantations in Virajpet taluka was 880 m, Madikeri 878 m and Somwarpet 883 m.

4.2 Tree density in coffee plantation

Tree density is a crucial factor that has a bearing on coffee yield. Thus, it would be worthwhile to understand the tree density maintained in sample coffee plantations. The number of plots surveyed to get 250 trees in each plantation ranged between seven to

Table 4.1: General information about the sample

SI no	Taluk	Village	Average				Average Number of	
			Age of the plantation	Size of holding (acres)	Altitude (mt)	Coffee output (kg./acre)	trees/plot	trees/acre
1	Madikeri	Arekad	37	24	878	1400	29	230
2	Virajpet	Karadigod	48	47	880	1600	26	209
3	Somwarpet	Nellihudikri	44	51	883	1450	29	230
Range		Minimum	15	6	850	1250	23	120
		Maximum	80	300	910	1800	36	288
Average			43	41	880	1483	28	223

eleven. Totally, 482 plots were surveyed. The average number of plots surveyed per plantation worked to nine.

Number of trees per plot (50m X 10m) varied from a minimum of 23 trees to a maximum of 36 trees. The average number of trees per plot was 28. Number of trees per acre varied with a minimum of 120 trees in robusta plantation to a maximum of 288 trees in arabica plantation.

During the survey 65 tree species were identified (Appendix II) which were post-stratified into three groups viz., traditional tree species, commercial tree species and those which belong to both traditional and commercial tree species, wherein, the number of trees under each of the above mentioned three groups were 50 (78 per cent), 8 (12 per cent) and 7 (10 per cent) respectively.

Of the total (13,500) individual trees enumerated, silver oak formed the most predominant tree species with 3,794 trees (31.85 per cent) followed by ponwal with 1850 trees (14.83 per cent) and third in the order was balanji with 1,607 trees (12.88 per cent). All the dominant species belonged to commercial tree species group (Appendix III).

The tree per acre was higher in large plantation (247 trees) as compared to small plantation (215 trees). In large plantations silver oak was found (Appendix IV) to be the major tree species with 72 trees per acre (29 per cent) followed by ponwal (14 per cent) and balanji (13 per cent). Similar trend was found in case of small plantations with silver

oak (35 per cent), ponwal (34 per cent) and balanji (28 per cent) forming the major tree species composition.

The analysis of tree density under different tenure system showed that the plantations under redeem land tenure had higher tree density with an average of 242 trees per acre followed by plantations under jamma (232 trees per acre) and unredeem land tenure (219 trees per acre). The species composition was almost similar under all the three tenure systems but the number of tree species per acre differed. Under jamma tenure, silver oak formed 36 per cent of trees averaging 84 trees per acre. Nearly, 17 per cent of trees belonged to ponwal and 14 per cent to balanji species.

Under redeem tenure, silver oak accounted for 34 per cent of the trees with an average of 82 trees per acre followed by ponwal and balanji averaging 36 (15 per cent) and 34 (14 per cent) trees per acre respectively (Appendix IV). In plantations under jamma tenure 74 per cent of the trees were identified as commercial trees, 22 per cent as traditional and four per cent of the trees as both commercial and traditional species. Similarly, 73 per cent of the trees in plantations under redeem land tenure is considered as commercial trees, 22 per cent as traditional species and five per cent as both commercial and traditional. Plantations under unredeem land tenure had 58 per cent of the trees belonging to commercial tree species, 35 per cent to traditional species and 7 per cent to both traditional and commercial tree species (Table 4.2).

Considering the plantations in terms of variety, Arabica plantation had 281 trees per acre and in these plantations silver oak formed the major species with 94 trees per acre (34 per cent). Similarly, in robusta plantations, silver oak formed the major species with an average of 31 trees per acre (26 per cent). However, the number of trees was relatively low in robusta plantations (120 trees/acre) when compared to arabica (Appendix IV). Ponwal and balanji variety of trees formed second and third dominant species in both varieties (arabica and robusta) of coffee plantations.

**Table 4.2: Traditional and commercial trees under different tenure systems
(per cent)**

Tree type	Tenure			Sample
	Jamma	Redeem	Unredeem	total
Traditional	22	22	35	12
Commercial	74	73	58	78
Both	4	5	7	10

4.3 Tree species diversity in coffee plantations

Tree diversity index (TDI) gives the direct measure of tree species diversity in coffee plantations. TDI was calculated by subtracting Simpson's diversity index (λ) from one.

The tree diversity was found to be relatively high in all the plantations. The large coffee plantations showed higher diversity in tree species with an average TDI value of 0.8586. The average value of TDI in small plantations worked out to 0.8221 (Table 4.3). The TDI values ranged from 0.7566 to 0.9550 in large plantations and from 0.7220 to 0.9403 in small plantations.

Tree diversity in plantations under unredeem land tenure system was found to be highest with an average TDI value of 0.8916. The tree species diversity was next higher in plantations under redeem land tenure with an average TDI value of 0.8227. The average TDI value in plantations under jamma tenure was relatively low at 0.8068. The TDI values ranged from 0.7243 to 0.9048 in jamma tenure and from 0.7221 to 0.9054 in redeem tenure (Table 4.3).

The talukwise classification of the plantations indicated that plantations in Somwarpet taluk had higher TDI with an average value of 0.8885. The TDI value ranged from 0.8154 to 0.9550 in Somwarpet taluk, from 0.7703 to 0.9180 in Virajpet taluk and from 0.7221 to 0.9276 in Madikeri taluk.

The coffee plantations were post stratified into different age groups viz., young (15-40 years), middle (41-60 years) and old (61-80 years). On an average the proportion (56 per cent) of young plantations was higher when compared to middle aged (35 per cent) and old (9 per cent) plantations. It was observed that old plantations had relatively higher tree diversity with an average TDI value of 0.8431. This group had a minimum

Table 4.3:Tree diversty index in different types of plantations

	TYPE OF PLANTATION	TDI	Range	
			Minimum	Maximum
SIZE	Large	0.8586	0.7566	0.9550
	Small	0.8221	0.7220	0.9403
TENURE	Jamma	0.8068	0.7243	0.9048
	Redeem	0.8227	0.7221	0.9054
	Unredeem	0.8916	0.7722	0.9550
AGE	Young(15-40years)	0.8392	0.7243	0.9502
	Middle(41-60years)	0.8416	0.7221	0.9132
	Old(61-80years)	0.8431	0.7567	0.9550
ALTITUDE	Low(850-870m)	0.8521	0.7703	0.9552
	Medium(871-890m)	0.8428	0.7221	0.9502
	High(891-910m)	0.7983	0.7368	0.9008
TALUK	Madikeri	0.7894	0.7221	0.9276
	Virajpet	0.8429	0.7703	0.9180
	Somwarpet	0.8885	0.8154	0.9550

TDI value of 0.7567 and the maximum was 0.9550 (Table 4.3). The middle age plantations had an average TDI value of 0.8416 and it ranged from 0.7221 to 0.9132. The TDI value ranged from 0.7243 to 0.9502 in young plantations with an average TDI of 0.8391.

The sample was post stratified into 3 groups based on altitude viz., low (850-870m), medium (871-890m) and high (891-910m) altitude plantations. It was observed that 19 (35 per cent) plantations came under low altitude group, 28 (52 per cent) plantations were under medium altitude and 7 (13 per cent) plantations belonged to high altitude group (Table 4.3). The tree diversity index values showed higher tree species diversity at lower altitude with an average TDI value of 0.8521 where the minimum and maximum TDI values were 0.7703 and 0.9550 respectively. Under medium altitude, the average TDI value was founded to be 0.8428, which was relatively lower than the TDI at lower altitude. Under this group of estates the maximum TDI value was 0.9502 and the minimum was 0.7221. The average TDI under higher altitude was found to be 0.7983, which was lower than the TDI values under the other two classes of estates.

Further, when TDI (dependent variable) was regressed with variety of coffee (X_1), altitude (X_2) and tenure system (X_3), as independent variables, the results showed that tenure system and altitude were significant. Altitude had a negative effect on TDI (Table 4.4). The equation obtained from regression is as follows:

$$\text{TDI} = 0.02 X_1 - 0.0001 X_2 + 0.086 X_3$$

(1.38) (-2.89) (5.69)

Note: Figures in parentheses represent t values.

**Table 4.4: Influence of various factors on tree
diversity - Regression analysis**

SI no	Explanatory variables	Coefficients	t statistic
1	Variety of coffee	0.02	1.389
2	Altitude	(-)0.001*	(-)2.893
3	Tenure	0.086*	5.695

$R^2 = 0.42$

Note

* Significant at one per cent

Dummy variables:

Variety of coffee: Robusta = 0; Arabica = 1

Land tenure: Unredeem =1; (jamma and redeem) = 0

4.4 Stumpage value of standing stock of trees in coffee plantation

Trees have very high timber value in addition to the other direct and indirect values. Taking into consideration the market value of timber (Rs/m³) and the volume of the trees, the stumpage value of standing timber stock was calculated. The average stumpage value of trees for the entire sample was calculated at Rs 6.4 lakh per acre. The maximum value amounted to Rs 12.4 lakh per acre and the minimum value recorded was Rs 3.4 lakh per acre.

The volume and stumpage value of timber stock was classified into three groups, viz., low (less than mean minus standard deviation), medium (between mean minus standard deviation and mean plus standard deviation) and high (greater than mean plus standard deviation) as shown in table 4.5. It was observed that in case of volume of timber stock, five (9 per cent) plantations were under low category, 39 (72 per cent) plantations were under medium category and 10 (19 per cent) of the plantations were under high volume category. The respective figures for low, medium and high stumpage value categories were, seven (13 per cent), thirty-nine (72 per cent) and eight (15 per cent) plantations.

Table 4.6 presents the number of plantations, average volume of trees and stumpage value under different categories of plantations. It is observed that the average volume of trees was highest (44 cubic meter) in unredeem and lowest (21 cubic meter) in redeem land tenure system. Similarly, the average stumpage value of timber was highest

Table 4.5: Volume and stumpage value of standing stock of timber

Category	Volume (cubic m)	Number of plantations	Value (Rs in Lakh)	Number of plantations
Low	<14.14	5	<4.2	7
Medium	14.14 - 47.15	39	4.2 - 8.6	39
High	>47.15	10	>8.6	8

Note:
Low = < mean minus standard deviation
Medium = between mean minus standard deviation and mean plus standard deviation
High = > mean plus standard deviation

Table 4.6: Number of plantations in different Volume (cu.m) of timber and stumpage value (Rs in Lakh) categories under different types of plantations (per/ac)

Category		Volume(cu.m)						Stumpage value (Rs in lakh)					
		Number of Plantation			Volume range			Number of Plantations			Stumpage value range		
		Low	Medium	High				Low	Medium	High			
		<14.14	14.14to47.15	>47.15	Maximum	Minimum	Average	<4.2	4.2 to 8.6	>8.6	Minimum	Maximum	Average
Tenure	Jamma	2	14	2	11	51	27	3	13	2	3.4	9.8	5.9
	Redeem	3	15	0	13	38	21	4	14	0	3.7	7.1	5.2
	Unredeem	0	10	8	21	89	44	0	12	6	5.3	12.4	8
Variety	Arabica	0	27	6	16	89	38	6	23	4	4.1	12.4	7.6
	Robusta	5	12	4	11	59	26	1	16	4	4.05	9.6	5.6
Size	Large	0	17	10	16	89	39	0	19	8	4.6	12.4	7.7
	Small	5	22	0	11	42	23	7	20	0	4.1	7.1	5.1
Altitude	Low	2	14	3	14	59	28	2	12	5	3.5	12.4	6.8
	Medium	2	19	7	12	69	32	4	22	2	3.7	9.6	6
	High	1	6	0	11	89	32	1	5	1	4.1	9.6	5.8

Note:
Low = < mean minus standard deviation
Medium = between mean minus standard deviation and mean plus standard deviation
High = > mean plus standard deviation

(Rs 8 lakh per acre) in plantations under unredeem land tenure and lowest in plantations under redeem land tenure system (Rs 5.2 lakh per acre). Size wise classification of the plantations indicated that large plantations had higher volume of trees (39 cubic meters) than small plantations (23 cubic meter). This is reflected by the higher stumpage value (Rs 7.7 lakh/acre) in large plantations compared to small plantations (Rs 5.1 lakh/acre). A comparison in terms of altitude indicated that plantations at lower altitude had lower volume (28 cubic meter) than those at medium (32 cubic meter) and high altitudes (32 cubic meter). It was observed that the plantations at low altitude had higher (Rs 6.8 lakh/acre) stumpage value of timber while the plantations under medium (Rs 6 lakh per acre) and high altitude (Rs 5.8 lakh/acre) had lower value. This is expected since the number of trees per unit area was higher in plantations at lower altitude (Table 4.6). Arabica plantations had higher volume (38 cubic meter) and stumpage value (Rs 7.6 lakh per acre) when compared to robusta plantations where the volume and stumpage value per acre were 26 cubic meter and Rs 5.6 lakh/acre respectively.

The tenure wise classification of plantations revealed that value of tree stock in plantations under unredeem land tenure was very high averaging at Rs 8 lakh per acre. In these plantations the minimum value was Rs 5.3 lakh per acre and the maximum value was estimated at Rs 12.4 lakh per acre (Table 4.6). Plantations under jamma system of land tenure were placed second in terms of value per acre. The estimated value of tree stock under this category ranged from Rs 3.4 to Rs 9.8 lakh per acre. Under redeem land tenure system the tree stock was estimated between Rs. 3.7 to Rs 7.1 lakh per acre with an average value of Rs 5.2 lakh per acre.

Under the size wise classification, large plantations showed higher value at Rs 7.7 lakh per acre, where the minimum value was Rs 4.6 lakh per acre and the maximum value was Rs 12.4 lakh per acre. However, the value of tree stock in small plantations was estimated at Rs 5.1 lakh per acre (Table 4.6).

Plantations when classified according to variety of coffee planted showed that the average estimated value of trees under arabica plantation was Rs 7.6 lakh per acre. The maximum value of tree stock in arabica plantations was estimated at Rs 12.4 lakh per acre and the minimum value at Rs 4.1 lakh per acre (Table 4.6). In robusta plantation the average value was found to be lower at Rs 5.6 lakh per acre and ranged from Rs 4.05 to Rs 9.6 lakh per acre.

Further, the stumpage value of standing timber stock (Y) was regressed with variety of coffee (X_1), age of the coffee plantation (X_2), tenure system (X_3) and size of the coffee plantation (X_4). The variables such as variety of coffee, tenure system and size of plantations were found to be significant (Table 4.7). The equation obtained is as under:

$$Y = 2.16 + 1.92X_1 + 0.00067X_2 + 1.19X_3 + 0.011X_4$$

(1.93) (4.03) (0.04) (3.85) (2.09)

(Note: Figures in the parentheses indicated t values)

Table 4.7:Factors influencing stumpage value of tree stock per acre (Regression analysis)

SI No	Explanatory variables	Coefficients	t statistic
1	Intercept	2.16	1.93
2	Variety of coffee	1.92*	4.03
3	Age of coffee plantation	0.00067	0.04
4	tenure	1.19*	3.85
5	Size of the holding	0.011**	2.09

$R^2 = 0.46$

Note

* Indicates significance at one per cent level

** significant at 5% level

4.5 Benefits from trees to the planter and the plantation

Trees provide a wide variety of direct and indirect benefits most of which are unaccounted. The direct benefits consist of providing shade for coffee, support for pepper, use as fuel wood and timber. The indirect benefits could be visualised through plants acting as wind breaks, preventing soil erosion and water conservation. The benefits from traditional and commercial species were assessed separately.

Most respondents opined that they derived direct benefits from traditional and commercial trees in the form of shade for coffee and support for pepper. In addition seventy six per cent of the farmers indicated that they obtained food (fruits) from traditional trees which is a direct benefit (Table 4.8). All the respondents agreed to the fact that both traditional and commercial trees provide indirect benefit by way of conserving soil and water. Similarly, most respondents revealed that trees act as a windbreak and some traditional trees have religious value. It is interesting to note that sixty eight percent of the respondents were of the opinion that they derived other benefits (medicinal, religious, environmental, etc) from traditional tree species. A vast majority of respondents indicated timber and fuel wood as the direct benefit from commercial tree species.

4.6 Preference for tree types in coffee plantation

The opinion survey on the type of tree grown indicated that 98 per cent of the respondents preferred growing of commercial tree species (Table 4.9). The reasons for

Table 4.8: Benefits from trees

		Tree type	
		Traditional	Commercial
B E N E F I T S	Direct benefits	Per cent	Per cent
	Shade	100	100
	Fuel wood	100	100
	Suppor for pepper	98	70
	Timber	98	98
	Food	76	0
	Indirect benefits		
	Soil conservation	100	100
	Water conservation	100	100
	Wind break	96	96
	Religious	96	4
	Others	69	0

Table 4.9: Reasons for growing commercial species over traditional species in coffee plantations

SI No	Reasons	Per cent of respondents
1	Profitability	100
2	Non-profitability of other species	94
3	Multiple use	91
4	Shade for coffee	87
5	Support for pepper	87
6	Timber yielding	50
7	Fast growing	19
8	Others	37

this were attributed to profitability of commercial species (100 per cent), non profitability of traditional species (94 per cent), support for pepper (87 per cent), multiple use (91 per cent), shade for coffee (87 per cent), fast growth (19 per cent), timber yielding (37 per cent) and others (37 per cent).

It is interesting to note that most of the large growers opined that they received help from the forest department while only a few small growers endorsed the same. The type of help received by both the large and small growers related to supply of seedling and providing seedlings at discounted price. All the respondents opined that they received reasonable revenue from trees grown in their plantations.

Density of trees in coffee plantations is a crucial factor that determines the coffee yield. More than half (57 per cent) of the respondents opined that it is less desirable to have more trees. During the survey, it emerged that a optimal density could be achieved with 200 tree per acre in arabica plantation and 100 trees per acre in robusta plantations.

All the respondents preferred to grow more trees, wherein, 94 per cent preferred to grow more trees by purchasing additional land and 25 per cent by having more tree density in the existing plantations.

Assessment of technology information required by planters regarding tree plants 63 per cent of the respondents wanted information on appropriate combination of trees suited for coffee plantation. Nearly half (48 per cent) of the respondents required

information on fast growing species that are good for both coffee and pepper. Besides, 31 per cent of the respondents sought information regarding latest tree species available. Few of the respondents required information on mechanical pruning, timber yielding, multiple use tree species and density of trees in coffee plantation (Table 4.10).

4.7 Problems and prospects of maintaining tree diversity in coffee plantation.

The opinions elicited on problems and prospects of maintaining tree diversity in coffee plantations are presented in Table 4.11. The slow growth of certain tree species and competition of some species with coffee were expressed as the major problems (87 per cent) in maintaining tree diversity in coffee plantation. In addition, non-profitability of some species (54 per cent), higher incidence of pest and diseases (54 per cent) and restriction on felling (35 per cent) were expressed as the other major problems in maintaining tree diversity.

The factors such as religious value (76 per cent), medicinal use (67 per cent) and maintenance of ecological balance, soil and water conservation (50 per cent), ergonomics (33 per cent), habitat for other living organisms (31 per cent), non-timber forest products (30 per cent) and multiple uses (28 per cent) emerged as the factors that offer good prospects for maintaining tree diversity in coffee plantations.

Table 4.10: Technology information required by planters

Sl. No	Pariculars	Per cent
1	Appropriate combination	63
2	Fast growing	48
3	Good for coffee and pepper	48
4	Latest species	31
5	Timber yielding trees	24
6	Density of trees	17
7	Mechanical pruning	17
8	Multiple use	14
9	Canopy cover	11

**Table 4.11 :Problems and prospects of mainntaining tree diversity
in coffee plantations**

Sl. No	Prospects	Per cent
1	Religious value	76
2	Medicinal value	67
3	Ecological balance	63
4	Soil and water conservation	50
5	Ergonomics	33
6	Habitat	31
7	Non-timber forest product	30
8	Multiple use	28
9	Additional income	13
10	Good shade	4
	Problems	
1	Slow growth	87
2	Competition with coffee	87
3	Non-profitability	54
4	Increases pests	54
5	Bad for pepper	54
6	Bad canopy	37
7	Attracts animals	37
8	Restriction on felling	35
9	Larger space	28
10	Excess shade	15
11	Hinders sprinklers	13
12	Small holding	13
13	Problem in pruning	13
14	More labour cost	7.4

DISCUSSION

CHAPTER V

DISCUSSION

This chapter deals with the discussion of the results that is presented in the previous chapter under the following headings:

5.1 General characteristics of the sample

The sample selected for the survey consisted of equal number (27) of planters drawn from small and large growers. Besides, adequate care was taken to cover the plantations under different tenure systems. Equal number (18) of planters were drawn from the three selected villages, one each from the three taluks in Kodagu district. This was done to have a better comparison between the plantations coming under different groups, tenure system, locality and at different altitudes respectively.

5.2 Tree density in coffee plantation

Density of trees in coffee plantation is an important factor since the study provided by the trees affects the yield of coffee. Density of trees was found to vary from one plantation to the other depending on the variety of coffee grown along with other factors. The number of trees per acre varied with a minimum of

120 trees in robusta plantation and to a maximum of 288 trees in arabica plantation while, the average density was 281 and 180 trees per acre in arabica and robusta plantations respectively. This is attributed to the fact that arabica plantations require more shade when compared to robusta plantations. It is interesting to note planters were maintaining higher density than that is recommended by the Central Coffee Research Institute (CCRI), Chickmangalore district. The CCRI recommendation is to maintain 100 trees per acre in robusta and 200 trees per acre in arabica plantations. Higher tree density than recommended is observed because of the fact that planters derive good revenue from pepper that are supported by the trees in the coffee plantations. This has induced the coffee growers to have high density of trees in coffee plantations.

Of the trees in the coffee plantations seventy-eight per cent were identified as commercial tree species, twelve per cent as traditional trees and the remaining ten per cent of the trees as both commercial and traditional tree species. Majority of the trees are commercial type because of their timber value and also they are good for both coffee and pepper crops.

Silver oak was found to be the most predominant tree species constituting about thirty two per cent of the total trees identified in the coffee plantations. Ponwal was found to be the next dominant species followed by balanji. Silver oak is the most preferred species because of its fast growing nature and suitability as a standard for growing pepper. In addition, it has also good timber value.

In small plantations the density was found to be low with 215 trees per acre when compared to 247 trees per acre in large plantation. This may be attributed to the extraction of timber by the small planters as influenced by the need for additional income by felling the trees.

Tree density was found to be higher in plantations coming under unredeem land tenure system when compared to the plantations under jamma and redeem land tenure systems. This difference is explained by the very nature of the tenure system wherein permit for felling of trees is not granted legally. While in the other two systems of land tenure felling of trees is permitted after obtaining prior permission from the forest department. Obviously, plantations under unredeem land tenure had relatively more number of traditional trees when compared to the plantations under redeem and jamma tenures (Table 4.2). Thus, non-granting of felling rights has helped in maintaining tree diversity that too with more of traditional trees. In addition to traditional trees, planting of commercial trees that were most preferred by the planters has been done in unredeem lands because of its compatibility with coffee and pepper crops.

Different varieties of coffee require different levels of tree density. This was reiterated from the results obtained which indicated that arabica plantation had more density of trees with 281 trees per acre when compared to robusta plantation with an average tree density of 180 trees per acre.

Regarding density in coffee plantation, majority of the planters opined that it is desirable to have optimal density since it would seriously affect the coffee yield. This is understandable since too much shade hinders light and thereby photosynthetic activity, which has a bearing on coffee yield. Planters were convinced that arabica plantations required higher tree density than robusta plantations (Appendix IV). It was interesting to note that all the respondents preferred to grow more trees since they can derive additional income by training pepper on such trees. There are instances where planters had derived more income from pepper trained on shade trees *vis a vis* main crop of coffee.

5.3 Tree species diversity in coffee plantation

Trees being a basic necessity in coffee plantations tree diversity was found to be relatively higher in all the estates. In general, large plantations had higher tree species diversity when compared to small plantations due to the reason mentioned earlier that the small growers for want of additional income resort to higher exploitation of trees. Tree species diversity was higher in plantations under unredeem land tenure because of the reason indicated earlier that the tenure system does not permit felling of trees. This has encouraged species diversity since the traditional trees were not destroyed as a compliance to law while taking up coffee cultivation. It was observed that the planters derived indirect benefits other than timber by maintaining species diversity. Plantations in Nellihudikeri

village coming under Somwarpet taluk had higher tree species diversity when compared to the other two villages (Table 4.3).

Post stratification of the data into plantations of different age groups showed that majority (56%) of the plantations belonged to the age group of 15-40 years. The plantations in the older age group (40-60 years) showed relatively higher tree species diversity compared to younger plantations (Table 4.3). The reason for this may be attributed to the fact that as the age of the plantation advances there will be more natural growth of plants contributing to species diversity.

Altitude is a factor that determines the type of vegetation in a locality. The results showed high TDI values at lower altitudes and lower TDI values at higher altitude (Table 4.3). This comparison was made after post stratifying the data into plantations at different altitudes groups viz., low (850-870m), medium (871-890m) and high (891-910m). This is but expected since at the higher altitudes there will be more of soil erosion and runoff of rain water. In the lower altitudes the soil conditions are good because of movement of soil from upper to lower regions. The water holding capacity of such soils is also high which encourages vegetative growth of all types of plants resulting in higher species diversity.

The results of the regression of TDI reiterated the earlier observation that altitude and tenure system being the most important factors in influencing tree

diversity. It is interesting to note that altitude contributed negatively to tree diversity. i.e., tree diversity decreased with increase in altitude (Table 4.4).

5.4 Stumpage value of standing stock of trees.

Trees in coffee plantation provide huge revenue if properly managed and harvested at the right age. The average volume of standing tree stocks and their stumpage value in coffee plantation were estimated at 31 cubic meter and Rs 6.4 lakh per acre respectively. This denotes that the trees in the coffee plantations have enormous timber value in addition to the other direct and indirect benefits that these trees provide to the planter, the plantation and to the surrounding environment.

As mentioned in the previous section, the land tenure system under which the coffee plantations exist plays a major role in determining the composition of the trees which in turn determines the value of the trees in coffee plantations. Accordingly, plantations under unredeem land tenure where there is no felling right had high timber volume and consequently high value at an average of 44 cubic meter and Rs 8 lakh per acre respectively as compared to the plantations under jamma and redeem land tenure systems. In large plantations, the volume and value of trees was found to be high with the average volume of 39 cubic meter per acre and the stumpage value averaging at about Rs 7.7 lakh per acre (Table 4.6). This difference in the volume and value of trees in coffee plantation

may be attributed to lower tree density and species diversity as small growers resort to timber extraction more often to realise additional income.

Altitude is an important factor determining the type of vegetation and accordingly the volume and value of trees varied in plantation at different altitudes. The average volume was low (28 cubic meter) but in contrast the stumpage value (Rs 6.8 lakh per acre) was high at low altitude when compared to medium and high altitude (Table 4.6).

The volume and stumpage value of trees per acre was higher in arabica plantations at 38 cubic meter and Rs 7.6 lakh per acre respectively when compared to the robusta plantations with an average volume of 26 cubic meter. In robusta plantation, the average stumpage value was low at Rs 5.6 lakh per acre (Table 4.6). This is explained by the fact that arabica coffee needs more shade and hence the density per acre was higher thereby resulting in higher stumpage value.

Variety of coffee, tenure system and size of the plantation were found to be significant when these independent variables were considered for regression with stumpage value of standing stock of trees as the dependent variable (Table 4.7).

5.5 Benefits from trees

Benefits from trees are always under-estimated and some of them either go unnoticed or unaccounted for because of the wide range of benefits that trees provide, ranging from timber as direct benefit to ergonomics as indirect benefit. Providing shade for coffee and support for pepper were viewed as the major direct

benefits derived from trees as expressed by the respondents along with other direct benefits (Table 4.8). Other direct benefits identified related to timber value, fuel wood and food in the form of fruits. Soil and water conservation was indicated as the major indirect benefit derived from trees by the planters. Besides, most respondents agreed with the fact that trees act as windbreakers. Religious value attached to trees, medicinal value and maintenance of ecological balance were expressed as the other indirect benefits by the respondents. All these subscribe to the fact that the value or the benefit from trees cannot be valued by considering only the timber value or other tangible value of trees but other intangible benefits also have to be evaluated if we have to arrive at the true value of the trees. Overall, the results of the study justifies the indirect contribution of coffee plantations in maintaining ecological balance by housing large number and variety of tree species, although maintenance of ecological balance is not the main objective of the coffee plantation. It is very important to note that planter himself is not the only beneficiary but also the entire neighborhood in particular and the globe as a whole in general is benefited one way or other by the trees that are grown and maintained in the coffee plantations.

5.6 Opinion survey

5.6.1 Tree type grown

Almost all the planters undertook planting of commercial trees (98 per cent) because these species were highly profitable and provide support for pepper in addition to providing the required shade for coffee. The commercial trees are

fast growing type and yield good timber. Non-profitability of traditional species was the main reason for preferring commercial type of trees (Table 4.9).

5.6.2 Help received from the forest department

Large growers received more help from the forest department than the small growers. This clearly emerged from the survey wherein 92 % of the large growers expressed that they received help from the forest department by way of obtaining tree seedlings at discounted prices. In contrast, only eighteen per cent of the small growers indicated that they received similar help from the forest department.

5.6.3 Technology information required by the planters

Planters look forward for technological information that is required to upgrade their coffee plantations. Majority of the respondents sought information on the appropriate combination of tree species in coffee plantation. They were keen to get the information on fast growing species that are good for both coffee and pepper, mechanical devices for pruning since labour charges for tree pruning were quite high and on the density of trees to be maintained in coffee plantations (Table 4.10).

5.6.4 Problems and prospects of maintaining trees in coffee plantations

The problems revealed by the planters related to planting, maintaining and felling of trees in coffee plantations. The legal hurdles faced to secure permission for selective felling of trees was found to be the major concern of the planters. Majority of the planter respondents opined that the restriction on felling of trees should be minimised or removed partially so that they can grow trees and sell them as and when required. The planters are also aware of the fact that tree felling destroys coffee plantations which reduces their income. They strongly felt that all rights on the land should be given to the owner of the land so that they can raise variety of plants that contribute to tree diversity. However, forest department is concerned with the shift that occurs from multiple species to less number of tree species in the process of felling and replacement. In addition to the legal problems, competition offered by some of the tree species with coffee plants, non profitability of some of the tree species, higher incidence of pests and diseases, non-suitability of some species as support for pepper and poor canopy offered by some species were expressed as other problems in maintaining tree density and species diversity (Table 4.11).

In the opinion of the planters maintenance of tree species has good prospects both in terms of timber and non-timber values. The non-timber values relate to religious, medicinal and environmental value of the trees and the presence of pleasant environment for the labourers for working in coffee

plantations. Besides, trees provide a habitat for other living organisms and non-timber forest products in addition to several other minor prospects (Table 4.11).

CONCLUSION

CHAPTER VI

SUMMARY AND CONCLUSION

The significance of trees in coffee plantations and its positive impact on the surrounding environment needs no justification. The benefits derived from trees are immense. The tangible benefits from trees in coffee plantations are in the form of: timber, fruits, and fuel wood, whereas, the intangible benefits are: soil and water conservation, shade for the coffee plants, support for pepper, wind break, religious and medicinal value. Several tree species are grown and maintained in the coffee plantations for different purposes by the planters and they derive several benefits from them. The coffee plantations in a way contributes to the conservation of trees species though there are instances of loss of few species due to the extension of coffee plantations in the Western Ghats.

The present study was taken up with the main objectives of analysis of tree species diversity in different land tenure systems and assessment of stumpage value, direct and indirect benefits of forest trees in coffee plantations.

The study was conducted in Kodagu district in the Western Ghats region of Karnataka. The sample consisted of 54 coffee growers, eighteen planters each drawn from three land tenure systems, viz., Jamma, Redeem and Unredeem. Simple tabular analysis was employed to analyse the general characteristics of the sample planters, number, proportion and density of tree species in coffee plantation, direct and indirect benefits of trees in coffee plantation. Besides, problems and prospects of maintaining

tree species diversity in coffee plantation were elicited. Simpson's index was employed to analyse the tree species diversity in coffee plantations. Regression analysis was employed to know the influence of various factors on tree species diversity and stumpage value of trees in coffee plantations.

The area under coffee plantation ranged between six and eighty acres with an average area of 41 acres. The yield recorded in sample plantations ranged from 1250 to 1800 kg of raw coffee per acre with the average yield of 1483 kg per acre.

Density of trees per acre ranged between 120 to 288 in coffee plantations. The average number of trees (247 trees per acre) was higher in large plantations compared to the smaller plantations (215 trees per acre).

The plantations under redeem and jamma land tenure had relatively higher tree density with 242 and 232 trees per acre respectively compared to plantations under unredeem land tenure with an average of 219 trees per acre.

Considering plantations in terms of variety, arabica plantations had higher tree density (281 trees per acre) compared to robusta plantations with an average of 180 trees per acre.

Sixty-five tree species were identified in coffee plantations of which 78 per cent were traditional tree species, 12 per cent commercial tree species and 10 per cent belonged to both traditional and commercial type of tree species.

Silver oak was found to be the most predominant tree species accounting for 32 per cent of the total trees followed by ponwal (14 per cent) and balanji (12 per cent).

Tree diversity was higher in large plantations with an average TDI value of 0.8586 while the tree diversity was relatively lower in small plantations with average TDI value of 0.8221. Tree diversity in plantations under unredeem land tenure was the highest with TDI averaging of 0.8916. The TDI value in plantations under redeem and jamma land tenure was 0.8227 and 0.8068 respectively. Tree diversity was higher at lower altitude with an average TDI value of 0.8521. The TDI at higher altitude was low with an average figure of 0.7983. The old plantations had relatively higher tree diversity with an average TDI of 0.8431 compared to young plantations, which had an average TDI of 0.8392. Regression results confirmed that land tenure system and altitude significantly influenced tree diversity.

The average stumpage value of trees for the entire sample worked out to Rs 6.4 lakh per acre. Plantations under unredeem land tenure had very high stumpage value of trees averaging at Rs 8 lakh per acre. Stumpage value of trees in plantations under jamma and redeem land tenure was relatively lower with estimated values Rs 5.9 lakh and Rs 5.2 lakh per acre respectively. Large plantations had higher stumpage value at Rs 7.7 lakh per acre, compared to smaller plantations with an average of Rs 5.1 lakh per acre. Plantations at low altitude had higher stumpage value with Rs 6.8 lakh per acre while those at higher altitude had relatively lower stumpage value at Rs 5.8 lakh per acre. Arabica plantation had higher stumpage value of trees at Rs 7.6 lakh per acre as compared to Rs 5.6 lakh per acre in robusta plantation. Further, regression analysis

reinforced that variety of coffee, tenure system and size of the coffee plantation had a significant influence on the stumpage value of trees in coffee plantations.

All the respondents equivocally expressed that the shade provided by trees for coffee and support for pepper vine were the major direct benefits from trees in coffee plantations in addition to timber and fuel wood. Most respondents expressed that soil and water conservation, medicinal and religious value and trees acting as wind breaks as being the indirect benefit derived of them.

Ninety-eight per cent of the respondents preferred to grow commercial tree species under existing circumstances because of their profitability. Other factors favouring commercial species related to non-profitability of traditional tree species, support for pepper, shade for coffee, multiple use, fast growth and timber yielding ability of commercial species.

Large growers expressed that they received help from the forest department in the form of supply of seedlings at discounted price.

Majority of the planter expressed that it is less desirable to have more trees in coffee plantations than the recommended density of 100 trees per acre in robusta and 200 trees per acre in arabica plantations respectively. However, they expressed that higher tree density is good for arabica plantations.

Technology information relating to appropriate combination of trees in coffee plantation, fast growing tree species that provide shade for coffee and support for pepper were sought by the planter respondents.

Coffee growers expressed that they face several legal problems while harvesting the trees in their plantations. They were of the view that restriction on felling of trees should be minimal and the legal procedure of availing permission to fell trees should be less time consuming.

Competition of certain tree species with coffee and slow growth of species were expressed as the major problems in maintaining tree diversity in coffee plantations. Non-profitability, facilitating incidence of pests and diseases and non-compatibility of some of the tree species with pepper emerged as the other problems as expressed by majority of the respondents.

Religious, medicinal and environmental values were expressed as the major factors contributing to good prospects of maintaining tree species diversity in coffee plantations. Other prospects as indicated by the respondents related to habitat for living organisms, non-timber forest products and multiple use of trees.

Conclusions from the study:

Both tree density and tree diversity is high in all types of coffee plantations particularly in plantations under unredeem land tenure system where there is legal restriction on tree felling. Thus continuance of unredeem land tenure systems is better

off in terms of conserving tree species diversity and density as compared to jamma and redeem systems of land tenure. However, unredeem land tenure system has its own drawbacks. It deprives the planter the right on the trees in his own land. Thus there is a need for change in policy permitting selective felling rights in lands under unredeem land tenure in order to develop coffee plantation.

There is need to provide proper extension service to the coffee growers and their relative densities in coffee plantations. Besides information on tree species that are suited for pepper cultivation as well as that yield non-timber forest products need to be provided which will enhance their income levels and also provide incentive in maintaining tree diversity.

Coffee estates that house wide variety of trees should strive to avail the “Green box” provisions in WTO Agreement on Agriculture. For instance, Brazil has already initiated the debate on the ‘multifunctionality’ role such as positive externality and environmental functions from agriculture in the World Trade Committee on “Trade and Environment”.

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CHAPTER VII

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APPENDICES

Appendix I: Green box provisions

As per item 12, Annex two, Article 21(Final provisions) of Agreement on Agriculture, the payments under environmental programmes are as below:

- a) Eligibility for such payments shall be determined as part of a clearly-defined government environmental or conservation programme and be dependent on the fulfillment of specific conditions under the government programme, including conditions related to production methods or inputs.
- b) The amount of payment shall be limited to the extra costs of loss of income involved in complying with the government programme.

Appendix II: Constitution of individual species to the total number of trees per acre (per cent)

Sl No	local name	Scientific name	Per cent (%)
1	jack	<i>Artocarpus integrifolia</i>	3.00
2	Ponwal	<i>Erythrina indica</i>	14.83
3	Athi	<i>Ficus glomerata</i>	3.55
4	Neeli	<i>Indigofera aspalathoids</i>	1.02
5	Silver oak	<i>Grevillia robusta</i>	31.85
6	Hebbalasu	<i>Artocarpus hirsutus</i>	0.02
7	Ajini	<i>Artocarpus species</i>	2.37
8	Bilwara	<i>Albizia odoratissima</i>	0.70
9	Goli	<i>Ficus amplissima</i>	1.25
10	Kare	<i>Randia uliginosa</i>	0.06
11	Antola	<i>Sapindus emarginatus</i>	0.23
12	Thari	<i>Terminalia bellirica</i>	1.22
13	Cher	NA	0.08
14	Teak	<i>Tectona grandis</i>	0.89
15	Balanji	<i>Acrocarpus fraxinifolius</i>	12.88
16	Bollandi	<i>Lagerstroemia parviflora</i>	0.78
17	Kakke	<i>Cassia fistula</i>	0.11
18	Rosewood	<i>Dalbergia latifolia</i>	2.88
19	Kulurmau	<i>Machilus macrantha</i>	0.43
20	Alandi	NA	0.43
21	Kachpuli	<i>Garcinia sp</i>	0.21
22	Byri	<i>Antiaris toxicaria</i>	0.43
23	Mathi	<i>Terminalia alata</i>	1.06
24	Kumbli	NA	0.65
25	Guava	<i>Psidium guajava</i>	1.08
26	Nerale	<i>Syzygium cumini</i>	0.35

Appendix II continued			
SI No	local name	Scientific name	%
27	Chakote		0.65
28	Palm	<i>Caryota urens</i>	0.33
29	Mango	<i>Mangifera indica</i>	2.15
30	Maesopsis	<i>Maesopsis emini</i>	1.05
31	Subabul	<i>Leucaena leucocephala</i>	0.07
32	Coconut	<i>Cocus nucifera</i>	1.05
33	Paramara	<i>Ficus hispida</i>	0.03
34	Kabbamara	<i>Careya arborea</i>	0.06
35	Hedle		0.02
36	Gaglaganti	<i>Diospyros montana</i>	0.02
37	Bage	<i>Albizia amara</i>	0.12
38	Oranges	<i>Citrus reticulata</i>	1.81
39	Kad Patte	<i>Cinnomomum malabadrurn</i>	0.02
40	Honne	<i>Pterocarpus marsupium</i>	0.28
41	Butterfruit		0.20
42	Sampige	<i>Michelia champaka</i>	0.01
43	Doopa	<i>Canarium strictum</i>	0.12
44	Byange	<i>Pterocarpus species</i>	0.82
45	Noga	<i>Toona ciliata</i>	1.32
46	Gher	<i>Anacardium occidentale</i>	0.05
47	Wild neem	<i>Melia composita</i>	0.03
48	Sapota	<i>Achros sapota</i>	1.05
49	Chappe	<i>Memecylon adule</i>	0.01
50	Thandi	<i>Terminalia species</i>	0.76
51	Muthurchi	<i>Butea monosperma</i>	0.66
52	Eucalyptus	<i>Eucalyptus grandis</i>	2.66
53	Aal	<i>Ficus bengalensis</i>	0.10
54	Nellige	<i>Phyllanthus emblica</i>	0.14
55	Mangium	<i>Acacia mangium</i>	0.72
56	Ambate	<i>Spondias acuminata</i>	0.03
57	Pulanje	<i>Tamarindus indica</i>	0.34
58	Chand	<i>Santalum album</i>	0.13
59	Basari	<i>Ficus religiosa</i>	0.09
60	Karadi	<i>Chukrassia tabularis</i>	0.31
61	NeerANJI	<i>Salix tetrasperma</i>	0.06
62	Tadale	<i>Olea diocia</i>	0.09
63	Kallathi	<i>Solanum erianthum</i>	0.06
64	Narumara	<i>Polyalthia fragrance</i>	0.05
65	Cotton	<i>Ceiba pentandra</i>	0.17

Appendix III: Trees as per timber value under different classes of plantation

Traditional	Per cent	Commercial	Per cent	Both	Per cent
Jack	3.00	ponwal	14.83	teak	0.89
Athi	3.55	silver oak	31.85	rosewood	2.88
neeli	1.02	mysopsis	1.05	subabul	0.07
hebbalasu	0.02	orange	1.81	butterfruit	0.2
ajini	2.37	noga	1.32	byange	0.82
bilwara	0.07	eucalyptus	2.68	sapota	1.05
goli	1.25	mangium	0.72	sandalwood	0.13
kare	0.06	balangi	12.68		
antwala	0.23				
thani	1.22				
cher	0.08				
bollandi	0.78				
kakke	0.11				
kulurmau	0.43				
alandi	0.43				
kachpuli	0.21				
byrie	0.43				
mathi	1.06				
kumbli	0.65				
guava	1.08				
nerale	0.35				
chakote	0.65				
palm	0.33				
mango	2.15				
coconut	1.05				
paramara	0.03				
kabbamara	0.06				
hadle	0.02				
gaglaganti	0.02				
bage	0.12				
kad patte	0.02				
honne	0.28				
sampige	0.01				
doopa	0.12				
gher	0.05				
wildneem	0.03				
chappe	0.01				
thandi	0.76				
muthurchi	0.66				
aal	0.1				
nellige	0.14				
ambate	0.03				
pulanje	0.34				
basari	0.09				
karadi	0.31				
neerANJI	0.06				
tadali	0.09				
kalathi	0.06				
narumara	0.05				
cotton	0.17				

Appendix IV: Share of individual trees (per acre) under different classess of plantations (per cent)

Local name	Large		Small		Jamma		Redeem		Unredeem		Arabica		Robusta	
	%	avg/acre	%	avg/acre	%	Avg/acre	%	Avg/acre	%	Avg/acre	%	Avg/acre	%	Avg/acre
Jack	3.12	7.70	2.9	6.16	3	6	3	8	3	7	3	8	5	4
Ponwal	14.11	34.86	15.7	33.67	17	40	15	36	12	27	16	44	14	12
Athi	3.38	8.34	3.8	8.09	3	7	3	8	4	9	3	9	5	4
Neeli	1.12	2.77	0.9	1.94	1	3	1	2	1	2	1	3	0	0
Silver oak	29.18	72.08	34.9	75.10	36	84	34	82	25	54	34	94	31	26
Hebbalasu	0.03	0.08	0.0	0.00	0	0	0	0	0	0	0	0	0	0
Ajini	2.49	6.16	2.2	4.78	2	5	2	6	3	6	2	7	3	3
Bitwara	0.75	1.86	0.6	1.39	1	2	1	1	1	2	1	2	1	1
Goli	1.40	3.45	1.1	2.31	1	2	1	2	2	4	1	4	1	1
Kare	0.08	0.20	0.0	0.09	0	0	0	0	0	0	0	0	0	0
Antola	0.31	0.76	0.1	0.29	0	0	0	0	0	1	0	1	0	0
Thani	1.18	2.91	1.3	2.71	1	2	1	3	1	3	1	4	1	1
Cher	0.11	0.27	0.1	0.12	0	0	0	0	0	0	0	0	0	0
Teak	1.23	3.04	0.5	1.07	1	1	1	2	1	3	1	3	1	1
Balanji	12.77	31.53	13.0	27.97	14	32	14	34	11	23	13	36	12	10
Bollandi	0.95	2.35	0.6	1.24	1	1	1	1	1	3	1	2	1	1
Kakke	0.19	0.47	0.0	0.06	0	0	0	0	0	1	0	0	0	0
Rosewood	2.98	7.37	2.8	5.94	2	4	3	7	4	9	3	8	5	4
Kulurmau	0.41	1.01	0.4	0.96	0	1	0	1	1	2	0	1	1	0
Alandi	0.55	1.36	0.3	0.64	0	0	0	1	1	2	0	1	1	1
Kachpuli	0.31	0.76	0.1	0.20	0	0	0	0	0	1	0	1	0	0
Byri	0.58	1.42	0.3	0.58	0	0	0	1	1	2	0	1	1	0
Mathi	1.30	3.21	0.8	1.70	1	2	1	2	1	3	1	4	1	1
Kumbli	0.74	1.82	0.5	1.17	1	1	1	1	1	2	0	1	1	1
Guava	0.92	2.28	1.3	2.73	1	2	1	3	1	2	1	3	2	2
Nerale	0.42	1.03	0.3	0.59	0	0	0	1	1	1	0	1	1	0
Chakote	0.67	1.66	0.6	1.33	1	1	1	1	1	2	1	2	1	1

Appendix IV continued:

Palm	0.40	0.99	0.2	0.53	0	0	0	1	1	1	0	0	1	1	0	0	1	1	1
Mango	2.15	5.31	2.1	4.61	2	4	2	6	2	5	2	6	4	4	2	6	4	3	3
Mysopsis	1.14	2.81	1.0	2.05	1	3	1	2	1	2	1	3	1	1	1	3	1	1	1
Subabul	0.05	0.13	0.1	0.21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coconut	1.17	2.88	0.9	1.96	1	2	1	3	1	3	1	2	2	2	1	2	2	2	2
Paramara	0.04	0.10	0.0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kabbamara	0.05	0.11	0.1	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hedle	0.03	0.08	0.0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gaglaganti	0.03	0.07	0.0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bage	0.17	0.43	0.1	0.12	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Oranges	2.09	5.17	1.5	3.19	1	3	3	6	2	3	2	5	2	2	2	5	2	2	2
Kad Patte	0.05	0.11	0.0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Honne	0.39	0.96	0.2	0.34	0	0	0	0	1	2	0	1	1	1	0	1	1	0	0
Butterfruit	0.10	0.25	0.3	0.66	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
Sam pige	0.02	0.04	0.0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Doopa	0.16	0.39	0.1	0.15	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Byange	0.97	2.39	0.6	1.38	1	1	0	1	1	3	1	2	2	1	1	2	2	1	1
Noga	1.56	3.86	1.0	2.25	1	3	1	2	2	4	1	4	2	1	1	4	2	1	1
Gher	0.10	0.24	0.0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wild neem	0.04	0.10	0.0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sapota	1.09	2.69	1.0	2.15	1	2	1	3	1	3	1	2	2	1	1	2	2	2	2
Chappe	0.02	0.06	0.0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thandi	0.89	2.19	0.6	1.32	1	1	1	2	1	2	1	2	2	1	1	2	2	1	1
Muthurchi	0.79	1.95	0.5	1.10	1	1	1	1	1	2	1	2	1	1	1	2	1	1	1
Eucalyptus	2.66	6.57	2.7	5.74	3	6	3	7	3	6	2	7	5	4	2	7	5	4	4
Aal	0.18	0.44	0.0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nellige	0.17	0.42	0.1	0.22	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Mangium	0.56	1.37	0.9	1.95	1	1	1	1	1	2	1	2	2	1	1	2	2	1	1
Ambate	0.05	0.12	0.0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pulanje	0.31	0.77	0.4	0.82	0	0	0	1	1	1	0	1	1	1	0	1	1	1	1
Chand	0.23	0.56	0.0	0.06	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Basari	0.11	0.27	0.1	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Karadi	0.38	0.94	0.2	0.50	0	0	0	1	0	1	0	1	1	0	0	1	1	0	0
Neeranji	0.08	0.19	0.0	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tadale	0.10	0.26	0.1	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kallathi	0.08	0.20	0.0	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Narumara	0.08	0.19	0.0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cotton	0.22	0.55	0.1	0.26	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
TOTAL	100	247	100.0	215	100	232	100	242	100	219	100	281	180	180	100	281	180	100	100