Chapter 2

LITERATURE REVIEW AND METHODOLOGY

This chapter contains a review of literature on teak plantations and the methodology used for analysing the productivity and profitability of teak plantations. A brief outline of the activities in teak plantation management and the forestry terms relevant for this study is included here.

2.1 Review of literature

Although there is a profusion of literature on teak and several bibliographies on teak are available there is very little available on the productivity aspects and even less on the economic aspects. In a literature search spanning ten years from 1985 to 1994 in Foresty Abstracts, Indian Forester, Forest Ecology and Management, Indian Journal of Forestry, Myforest and in the Monograph on Teak (Tewari, 1992) it was reported that only 1.4% of the publications were related to economics and around 1.4% in the area ‘production’ (Chacko, 1995).

A recent compilation of annotated references of teak (White, 1993) does not even have a section on economics and reports no publication on economics of teak. Another publication by FAO titled ‘Teak in Asia’ (FAO, 1993) gives country wise status reports on teak management. Yet except for Bangladesh, which reports that most plantations of teak in that country
belonged to site class III with an average yield of 105.9 m³/ha at 50 years (Banik, 1993), no other country, including India (Kumaravelu, 1993), gives the productivity or profitability figures for teak plantations.

A monograph on teak (Tewari 1992) gives a comprehensive compilation of the different aspects of teak management, statistics and research. In this volume it is reported that the teak plantations in Nilambur belong to site quality class I and that of Wynad belongs to site quality II based on the standard procedure of site quality determination based on top height of the crop. Although according to the top height measurements Wynad has only site quality II, according to basal area density of the crop it was equivalent to that of site quality I. This is an indication that site quality determination based on top height alone need not give an accurate picture of the growing stock or potential yields.

The monograph also reproduces two cost-benefit studies in teak done by the Madhya Pradesh Forest Department in 1974 showing that the Internal Rate of Return (IRR) for teak plantations of site quality II/III was 13.9% for a rotation of 60 years in Eastern Maharashtra and that in Bastar District of Madhya Pradesh in site quality II the IRR was 12 to 13% for the same rotation. The Benefit-Cost (BC) ratio in each case was 2.95 and 1.8 respectively.
In a pioneering work, Bourne (1922) prepared the first volume and money yield tables for Nilambur teak which show not only the volume of the growing stock at different ages and the yield it also give the value of such yields net of the extraction costs. The money yield tables are based on current (average of 1916-19) rates which can be used for finding the Net Present Value with an appropriate discount rate. Although the procedure for making the money yield tables are simple when the actual volume and yield tables are available, no other money yield tables for teak in Kerala have since been published. Perhaps with teak prices changing on a monthly basis, money yield tables will lose their relevance quickly.

In the teak bibliography by Mathur (1973) 40 references are given in a group 'forest management, business economics of forestry, administration and organisation of forest enterprises'. Most of them refer to the articles in the journal *Tectona*, published from Indonesia in Dutch language. The remaining few are from Burma and general articles on forests or Working Plans from India.

Another bibliography on teak by Krishnamurthy (1975) shows nine references under the subject head, 'Economics and economic products from forest' which again are mostly from Indonesian sources.

However, several studies on the various factors influencing growth and productivity of teak plantations are available. They are mostly centred around
site deterioration, fire, pest infestation and management issues. A brief review of relevant studies is given below.

The effect of continuous teak plantation on the soil properties and the capacity of the site to sustain the level of productivity was a serious issue discussed among foresters. Browne (1929) ascribed poor growth in some second rotation teak plantations in Nilambur to soil deterioration under the first rotation plantation. The need to maintain site productivity in the context of teak plantations in Nilambur was stressed in the third Silvicultural Conference in 1929 (FRI and C, 1929). Champion, the central Silviculturist carried out an extensive study of the problem and brought out a forest bulletin on ‘the problem of pure teak plantations’ (Champion, 1932). He found the soil to be comparatively much harder in plantations apparently due to exposure to the sun and wind in the hot season and to the effect of drip in the rains. The hardening of the surface soil under pure teak without any undergrowth promoted rapid erosion which resulted in excessive washing away of the fertile top soil. The adverse effect of erosion was aggravated in plantations affected by fire. He mentioned that although adequate experimental evidence of soil deterioration under pure teak was lacking it was advisable to maintain a natural undergrowth and to provide strict fire protection to protect the soil against soil deterioration. This view was endorsed by the Fourth Silvicultural Conference in 1934 (FRI & C, 1934) and the Fifth Silvicultural Conference 1939 (FRI & C, 1941).
The Fourth Silvicultural Conference maintained that evidence of soil deterioration in Nilambur teak plantations was lacking while Gupta (1946) was of the opinion that there was site deterioration after clearfelling and planting of teak in Nilambur Divisions. Davis (1940) reported that there was no site deterioration in alluvial soils near the river banks. He, however, mentioned that the teak plantations tend to stagnate after a time or even to be invaded by more shade tolerant species resulting in the replacement of teak. There is a view that growth of teak alternates between faster and slower growth. The reasons for slower growth are damage by insects, overcrowding, over shadowing by faster growing trees and fire (Anon 1897).

Griffith (1937-38) was sceptical of the benefits of a cover crop in teak plantations. Laurie and Griffith (1942) reported that if secondary influences such as erosion, fire and heavy grazing are excluded, proof of soil deterioration under pure teak was lacking although theoretical considerations indicate that it is likely. Temporary adverse conditions may hinder regeneration, but these can be overcome by soil working and other measures.

Davis (1940) believed that conversion of natural forests to teak plantation led to laterization of the soil leading to lowering the moisture retaining capacity of the soil and shortening the effective teak growing season itself. In his opinion degradation of pure teak plantation is either due to the
exposure of the underlying laterite rock or due to the formation of laterite from very complex weathering of the soil itself.

Griffith and Gupta (1947) contested the opinion of Davis after a detailed study of the soils in natural forests and teak plantations. They reported that the chemical composition of the soils were not affected and that only the physical condition was degraded by becoming more hard. They concluded that it is not the actual formation of laterite but the hardening of the already existing laterite soil or laterite rock on exposure and insolation under teak plantation that was responsible for the deterioration of teak quality in Nilambur. They attributed past failures in Nilambur to faulty site selection.

Reports from other parts also highlighted the adverse effects of pure teak plantations on the soil, particularly on plantations on steep slopes and fire prone areas. Ghani (1951) reported that soils under teak plantations, affected by severe erosion and lack of undergrowth, behaved like laterite. Chowdhury (1951) also adhered to the same view and reported that the process of laterization was accelerated by pure teak plantations due to the absence of soil cover.

Kadambi (1945) did not find any soil deterioration in Mysore and ascribed this to the favourable effect of the appearance of natural undergrowth under teak plantations. Blanford (1922) stated that in Burma (now Myanmar) there was no soil deterioration under pure teak except by soil
erosion. Annual erosion losses up to 152 tonnes per ha has been reported from teak plantations in Trinidad while it was only 17 tonnes per ha in the adjoining natural forests (Evans, 1982). Blanford (1933) reported that pure teak led to serious erosion in Burma but no other deterioration in soil could be postulated. He had noticed earlier that teak plantations in Burma grew exceedingly well in the earlier years but the growth deteriorated considerably after about 20 years (Blanford, 1922).

Seth and Yadav (1959) confirmed that the problem was acute where sufficient undergrowth was absent and where fire protection was neglected. The performance of teak deteriorated when the plantations were extended up the slope and in lateritic areas. Jose and Koshy (1972), analysing soil characteristics under teak plantations in Nilambur, found that organic matter content decreased and soil deterioration occurred up to the age of 30 years in newly formed plantations and thereafter it was built up. They also found that considerable compaction of soil had taken place in the second rotation areas.

The problem of site deterioration in plantations cannot be ignored as second and subsequent crops under the management regime involving no active soil amelioration measures will result in a progressive deterioration of physical and chemical conditions of soil (Lundgren 1980). Alexander et al. (1980) found that taungya cultivation with tapioca in young teak plantations accelerated soil erosion in Kerala.
Occurrence of fire is very frequent in almost all teak plantations in Kerala. The deleterious effects of fire on teak plantation growth and wood quality is well known. It could wipe out a very young plantation (Ansep, 1925). In older plantations it could eliminate the undergrowth, burn up the organic matter in the soil and reduce the number of soil organisms. Blanford (1933) reported that epicormic shoots develop in teak trees following fire.

The importance of maintaining a natural undergrowth with protection from fire and grazing to maintain the productivity of plantations was stressed by Champion (1933). He added that in Europe, the main object of underplanting was maintenance and improvement of the soil. Studies in Indonesia showed that teak is very susceptible to root competition especially of grass and *Imperata cylindrica*. With heavy weed growth, the teak plants stagnate and the leaves become yellow and in severe cases the tops of trees may die off. To prevent the grass growth, alternate rows of green manure crops are raised in Indonesia (Coster, 1939).

Eidemann (1932) of Indonesia reported no benefit of cover crops in teak plantations. Griffith (1937-38), a senior Indian forester, was of the opinion that a cover crop could not benefit teak plantations. However, Alexander *et al.* (1982) recommended that intercrops which provide cover namely *Leucaena leucocephala*, *Calliandra calothyrsus* and *Acacia auriculiformis* may be tried to mitigate deliterious effect of soil erosion.
Pest problems are reported to be serious in Nilambur. Defoliating insect attack in plantations can seriously reduce the annual volume of increment (Nair et al. 1985). Beeson (1931) studied the impact of defoliating pests in Nilambur teak plantations and found that severe defoliation occurred in the pre-monsoon period (April-June). Champion (1935) justified expenditure to prevent severe defoliation as considerable loss of increment was reported. Hole (1901) mentioned that defoliating insects did mild damage to teak in Rangoon division and added that there was nothing extra-ordinary or serious about it. The large scale expansion of teak plantation in Nilambur without maintaining a buffer of natural forest around each plantation and failing to maintain adequate undergrowth could be the reason for the severity of the defoliation problem in Nilambur. Innovative research efforts to control the defoliating pests using biological control measures are ongoing in KFRI.

Water blister is another problem reported from teak plantations along water courses. Bakshi and Boyce (1959) advised to avoid planting teak in very moist sites where water blister usually develops. Kallarakkal et al. (1992) reported that the prevalence of the problem of water blister in teak trees is limited to within 50m of river banks or water sources. As one moves away, the frequency of affected trees gets reduced and beyond 350m the problem is absent. Water blister is not fatal to the trees but the quality of timber is affected.
The manual of Indian silviculture places the greatest importance to timely silvicultural operations in plantations (Champion and Trevor, 1938). The authors stated that many plantations failed although the work was excellently done, simply because some operations were done after the optimum time for them. They added that a late start is peculiarly fatal as casualties and weed troubles are greatly increased even to the extent of making the plantations more or less a failure. Carrying out of thinning operations at the right time and in the right intensity is very important and the economic return from the plantation will be greatly affected if these are ignored (Sagreiya, 1947).

Alexander et al. (1987) made a study of the soil properties in different site qualities of teak plantations and observed that variation in site quality of teak plantations is influenced by soil parameters such as gravel, sand, pH and exchange acidity.

Kjaer and Foster (1996) have done a study of the economics of tree improvement of teak based on a projected gain in Mean Annual Increment (MAI) from using genetically superior seedlings. A high present value is estimated for tree improvement programmes even if teak prices remain unchanged. This is so notwithstanding the fact that research and development costs for screening and mass producing genetically superior planting materials are quite high.
In another report on teak research and development, White (1991) mentioned that international provenance trials with teak seeds of different origins showed that the best all round performance with respect to health, growth and quality on a variety of sites was recorded by seeds of Konni (Kerala) origin and Bangsri (Indonesia). He adds that the Bangsri provenance is possibly a distributive descendent of the Indian provenance. Trials in Australia also showed that teak provenance of Kerala origin showed the highest diameter and basal area growth among a range of international sources.

On the problem of pure teak plantation, White (1991) comments that the old problems are still current. Among them soil deterioration, soil erosion, volume decline in later generations, defoliation etc. are still debated.

In spite of a detailed search no previous studies on analysing the productivity of teak plantation using data collected from a large region covering all age groups could be located. The problem is compounded by the high variability in the productivity and the wide price spread in the price of poles and logs.
There are different operations in the management of a teak plantation. The operations are clearance, slash burning, land preparation, nursery raising, preparation of stumps, planting, maintenance, weeding, loranthus cutting, periodic thinnings and final felling. The initial planting is done with a spacing of 2 m x 2 m to reduce weed growth and to obtain a straight bole. As the canopy develops, some trees are removed to provide sunlight. There are two types of thinnings - mechanical and silvicultural. The first two thinnings at 4th and 8th years are called mechanical thinnings where trees in the alternate diagonals are removed. The subsequent four thinnings are called silvicultural thinnings where stunted and poorly grown trees are removed retaining a healthy crop. Yield obtained during thinning operations are termed as thinning yield.

The trees that remain after the different thinnings are felled at the rotation age in an operation called final felling. This is a clearfelling. The rotation age is the age of the plantation when it is finally felled. The total yield is the sum of all the yields from thinnings and the final felling yield. The mean annual increment (MAI) is an important measure of productivity used in forestry. MAI is obtained by dividing the total yield by the rotation age.

Yield tables for teak plantations have been published by the Forest Research Institute, Dehra Dun (FRI and C, 1970). Yield tables give the
expected yields in thinning and final felling at a particular age. Five year age intervals are used in the yield tables. It also shows the various crop parameters such as crop diameter and top height for different ages.

Site quality indicates the potential of a site to grow a particular crop. It is based on the age and top height of the crop. Usually site quality determination is done only once in a rotation. When Divisional Working Plans are revised at 10 to 15 year intervals, new plantations above 10 year which were not site quality mapped during the previous plan is taken up for site quality mapping. In the case of Nilambur, the latest Working Plan is for the period 1982-83 to 1991-93. Due to reorganisation of forest divisions, currently there are Nilambur North and Nilambur South Divisions. In this study both are considered together and referred to as Nilambur Divisions.

2.2.1. Productivity analysis

For the productivity analysis, the parameters used are mean yield, MAI and expected yield in different site qualities. Teak plantations in Kerala are managed on a rotation of 60 or more years except in Nilambur Forest Divisions which follows a 50 year rotation. Productivity analysis has been done separately for Nilambur Divisions and together for the 14 other divisions. The results are presented separately for Nilambur Divisions, Other Divisions and Kerala. Due to the long tradition of teak growing in Nilambur,
detailed analysis for Nilambur North and Nilambur South Forest Divisions were carried out.

The procedure for the calculation of mean yield is as follows: The yield data collected was grouped operation wise. Within each operation, weighted average yield per ha was worked out considering the area of each plantation as the weight. These weighted average yields were added together to arrive at the total yields per hectare. Due to great variability in yield within an operation, the minimum, maximum and coefficient of variation are also shown.

Teak plantations in Nilambur were managed on a rotation of 60 years prior to early 1980s. Later it was reduced to 50 years as per the Working Plan of Ranganathan (1981). The yield data collected were therefore classified for two periods 1967-81 and 1982-94. Mean yields were computed as mentioned earlier for each of the two periods. Both periods were combined and the mean yield of the entire period was computed.

Apart from showing the minimum and maximum yield obtained in different periods, low and high yields were also calculated. The low yield represent the mean yield corresponding to the lowest decile of area under plantation when the yields are arranged in the ascending order. Likewise, the high yield represents the mean yield for the highest decile.
For evaluating the performance of teak plantations, the actual mean yields were compared with the expected yields for different site quality classes available in the All India Yield Tables for teak. Based on the yields realised, the average site quality attained was also assessed. The same analysis was done for the rest of Kerala.

The mean yields obtained per hectare for each set of operation were calculated. For calculating the mean yields, weighted average was taken using the area of plantation as the weight. For examining the variability, the coefficient of variation was worked out for each operation.

Conventionally, the site quality of a plantation is a good indicator of the productivity or yield levels that can be expected. An attempt has been made to compare the actual timber yield/production in Nilambur with the site quality which is the potential productivity.

The question whether there is any perceptible change in the productivity of teak plantations over time has also been looked into by examining the yields obtained in different operations based on the period in which the plantations were raised.
2.2.2 Profitability analysis

Profitability analysis requires data on the stream of costs and returns from the time of raising nursery to the final felling of the plantation. The data on costs include nursery raising, slash burning of plantation site and land preparation, aligning and staking to mark the position for planting, planting of stumps in crowbar holes, maintenance, cultural operations, weeding, tending, climber cutting, epiphyte (loranthus) cutting, periodic thinning operations and final felling. The returns include yields in the form of timber, poles and firewood billets obtained in different thinning operations such as first and second mechanical thinning (1M, 2M), first to fourth silvicultural thinnings (1S, 2S, 3S and 4S) and final felling.

The average cost for each operation was obtained from the working costs actually incurred in different ranges in 1995. This method was adopted because it is the best way to arrive at the real prices necessary for cost benefit analysis.

If past prices are used, it is necessary to use some price indices to obtain the real prices. If All India wholesale price indices or that of wood and wood products are used, it may have a different trend than that of the trend in the local costs and prices. In the indices of wood and wood products major components such as pulpwood, plywood, furniture etc. are included and it is not specific to log prices in Kerala.
The average cost per ha for different operations (from nursery raising to final felling) was compiled from the 1995 cost data from all the Forest Ranges in Nilambur. There is an approved schedule of rate for the different operations in plantation management. A provision for slightly higher rates is also made to take care of the difficulties encountered in some areas due to inaccessible type of terrain etc. Accordingly, Ranges have been classified as ordinary, difficult and very difficult based on accessibility. The cost figures used in this study are based on the average expenditure per ha actually incurred in different operations during 1995. These figures have been collected from range records. For thinning and final felling the expenditure per ha is related to the actual yield obtained. Therefore the costs per m³ of yield obtained was found out and this was used to calculate the per ha costs.

The method adopted for valuing the stream of returns is as follows. In each thinning and final felling operation, different classes of poles and logs are obtained. For example the yield in the 3rd silvicultural thinning includes poles of different size classes and logs of different girth and quality classes. The prices of different categories of poles and timber vary greatly. For the valuation of yield from different operations, the break-up of yield into different size and quality classes are eventually required. The break up of yield obtained from the plantation journals, files and other records were converted into per ha terms for each operation. The mean distribution was then worked out for each operation.
The percentage distribution was used for distributing the mean yields into different items of poles and timber in different operations is needed. The weighed average prices of each item needed for estimating the financial returns were worked out taking quantity sold of that item as weight using the auction prices of timber sold in government depots in 1995. The average prices of poles were obtained from data collected from the Range offices in Nilambur. The value of each item of yield in an operation was worked out by multiplying the average quantity per ha of the item with its average price. The total financial returns for each operation were obtained by aggregating the values of all items for each operation. The financial returns were estimated for the low and high yields also.

The maximum and minimum yields represent extreme values. Thus they cannot be used for economic analysis and therefore, the mean yields corresponding to the highest and lowest deciles based on the total area of plantations for each operation were calculated. These have been represented as high and low yields respectively.

The profitability analysis was carried out following the procedure given in Gregersen and Contreras (1992). From the stream of costs and returns, cash flow tables were prepared for mean, low and high yields. Net present value (NPV) was computed using the formula
\[ NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+i)^t} \]

where NPV = Net present value (Rs.)

\( B_t = \) Benefit (Rs.) in the year \( t \)

\( C_t = \) Cost (Rs.) in the year \( t \)

\( n = \) Rotation age in years

\( i = \) Discount rate

Internal Rate of Return (IRR) is that discount rate for which NPV=0

i.e. \( IRR = i \) such that

\[ \sum_{t=0}^{n} \frac{B_t - C_t}{(1+i)^t} = 0 \]

For a project to be profitable, the NPV should be greater than zero. The criterion for finding a project to be profitable on the basis of IRR is that IRR should exceed the consumption rate of interest (World Bank, 1976). However, a discount rate is usually selected arbitrarily taking into account time preference and inflation. Price (1989) suggests that the real discount rate can be calculated on the basis of money interest rate and inflation rate. To account for fluctuations in both the rates, in this study, four discount rates from 6 to 18% were considered for the financial analysis so that the sensitivity of the results to different rates can be observed.

As government teak plantations are raised in reserved forest land, no land rent is payable. As the forest policy of Government of India do not
permit the conversion of forest land to other uses, other land use options do not exist. There is certainly an opportunity cost of converting natural forest into teak plantations as bio-diversity, wilderness and aesthetic values are reduced when natural mixed forest are converted to monoculture teak plantations. Conversion of natural forests to teak plantations are not permitted under the current forest policy. Only the existing plantations continue to be managed as plantations. Therefore in this study the opportunity cost is not considered as no conversions take place now.

Forest land leased out to public sector corporations such as Plantation Corporation of Kerala, State Farming Corporation of Kerala etc. are charged a lease rent of Rs.1300 ha\(^{-1}\). This rate has been fixed a few years back and it may shortly be revised. Therefore, in the profitability analysis three options of land rent are considered, 1) without land rent, 2) with a land rent of Rs.1300 ha\(^{-1}\) and 3) with a land rent of Rs.2500 ha\(^{-1}\) to examine the effect on profitability. Besides these, the maximum surplus that can be generated was calculated and shown as the maximum land rent possible.

Apart from NPV and IRR, benefit cost ratio (B/C ratio) was also computed. B/C ratio is the ratio of the discounted total benefits to discounted total costs. The B/C ratio should exceed 1 for considering a project as profitable. The NPV and B/C ratio were calculated for different discount rates and profitability analysis was done. Using discount rates of 6,
9, 12 and 18% the NPV and B/C ratio was calculated to find the profitability of teak plantations.

2.2.3 Data base

The data required for this study were the yields from teak plantations, cost of different operations, price of teakwood and poles, information on site quality of plantations etc. Data were collected from unpublished records such as the files, documents and publications such as Working Plans and Annual Administration Reports of the Kerala Forest Department.

The Forest Department maintains plantation records at the Range Offices. The plantation journal is an important record to be maintained for each plantation and all details of each plantation such as year of planting, species, area, different operations carried out, costs and revenue are to be recorded. Every work which involves an expenditure or revenue will also have their respective files. The Divisional Forest Offices also have files on the approval of estimates of work carried out. Data on yield, cost, etc. used in the study are collected from the above sources.

The maintenance of plantation records at the Range Offices is not given a very high priority which has been observed in a state wide survey by KFRI, (1997). It revealed that plantation journals are available only for 51 percent of teak plantations. Even when these journals are available, the yield
data may not be entered in it as these are rarely inspected by senior officers. Due to heavy work load in the Forest Range Offices, perusal of all the files for collecting yield statistics was not easy. The strategy, therefore, was to collect the entire yield data that was available. In Nilambur, yield data was obtained for 251 plantations worked during the period 1967-81 and 117 plantations worked during 1982-94. Together they covered 12,536 ha. This area is much more than the existing teak plantations in Nilambur. Many older plantations included here have been felled and the area replanted. The data on yield were collected and compiled (see Appendix-1 for data). After sorting, those operations that were beyond a reasonable age limit were eliminated. Extremely delayed thinning operations distort the mean yields and do not permit to keep exclusive age limits for each thinning operation.

The yield data for teak plantations in Other Divisions was collected from 14 Forest Divisions viz. Thenmala, Konni, Ranni, Punalur, Kottayam, Munnar, Kothamangalam, Chalakkudy, Vazhachal, Thrissur, Parambikulam, Wynad South, Wynad Wild Life and Wynad North. The number of operations in different thinning and final felling was 363 with an area of 17,131 ha. (see Appendix 2 for division wise distribution and Appendix 1 for yield data.)

Teak timber from plantations are transported to different timber depots maintained by the Forest Department. At the depot logs are classified and arranged on the basis of length, girth and quality. The criteria of
classification of logs are given in Appendix 4. Logs of the same size and quality classes are grouped into lots of not more than 5 m³. These lots are sold in monthly open competitive auction. Each depot has separate files for each monthly auction. Price data for different girth and quality classes for the year 1995 were collected from Chaliyam, Nedumkayam and Aruvakode Government depots. Poles from young plantations are usually sold at the plantation site by the Range Officer by auction. Prices of poles were collected from the files maintained at the Range Offices.

Ten to fifteen year Working Plans are prepared for each Forest Division. Working Plans are documents giving management prescriptions, thinning schedule, rotation age etc. Site quality information on plantations is compiled from these Working Plans. Publications from the forest headquarters such as Annual Administration Reports and Forest Statistics are the other sources of information and data.