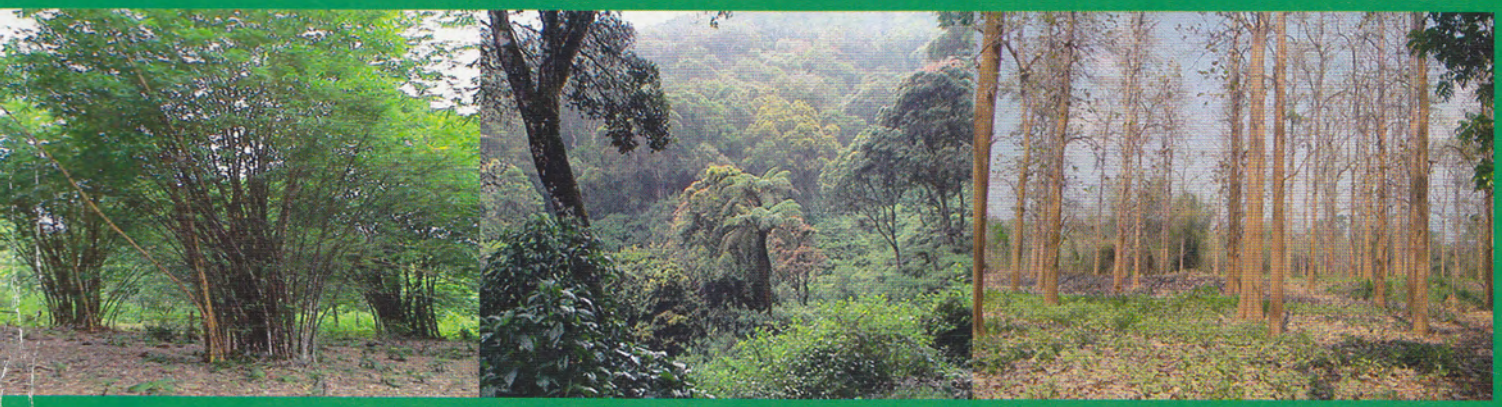
KFRI Research Report No.320

ISSN 0970-8103



COMPUTERIZED DATABASE ON KERALA FOREST RESOURCES AND DATA RETRIEVAL SYSTEM

M.Sivaram

Kerala Forest Research Institute
(An Institution of Kerala State Council for Science, Technology and Environment)
Peechi - 680653 Kerala, India

2008

KFRI Research Report No. 320

COMPUTERIZED DATABASE ON KERALA FOREST RESOURCES AND DATA RETRIEVAL SYSTEM

(Final Report of Project KFRI 429/2004)

M. Sivaram
Statistics Discipline
Division of Forest Information Management System

Kerala Forest Research Institute
(An Institution of Kerala State Council for Science, Technology and Environment)
Peechi – 680 653, Kerala, India

August 2008

ABSTRACT OF THE PROJECT PROPOSAL

1. Project number	: KFRI 429/2004
2. Title of the Project	: Computerized Database on Kerala Forest Resources and Data Retrieval System
3. Objectives	: (1) To modify and revise an existing computerized database and retrieval system on forest resources of Kerala (2) To develop prediction models useful for forest resource management in the state based on statistical analysis of data (3) To host the database on a website so that specific data are made available to the real users
4. Date of commencement	: April 2004
5. Scheduled date of completion	: September 2007
6. Funding agency	: Western Ghats Cell, Planning and Economic Affairs Department, Govt. of Kerala
7. Investigator	: M. Sivaram

CONTENTS

Acknowledgement

The author is thankful to

Dr.K.V. Sankaran, Director, Kerala Forest Research Institute for his support and encouragement,

Dr.R. Gnanaharan and Dr.J.K. Sharma former Directors for their constant support and encouragement,

Dr.K. Jayaraman, Programme Coordinator for encouraging the author to take up this project and providing useful suggestions at various time points and for his useful comments as editorial committee member,

Dr.C.N. Krishnankutty and Dr.P. Vijayakumaran Nair for the useful editorial comments and suggestions on the report,

Dr.K.V.Bhat for the final editing of the report,

Mr. Joalex Kollannur for understanding my intentions and writing program codes for the retrieval system,

Mr.M.A. Sajeev Krishnan, Mr.B. Syam and Ms. Jaisymol Thomas for gathering data from different agencies and update the database from time to time,

Mr.Anish Vijayan, Programmer for his help in preparing the installable version of the database,

Various Government Departments especially the Kerala Forest Department for providing required data to develop the database and

The Planning and Economics Affairs Department, Govt. of Kerala, for the financial support.

ABSTRACT

A computerized database and data retrieval system on forest resources of Kerala State, India was developed. The database contains the spatial-temporal data covering themes such as forest area, forest plantations, production, supply, demand and prices of forest products. The data in the database are stored in popular file formats such as Excel (xls), Word (doc) or Acrobat (pdf). The database has an interface developed using 'Microsoft Visual Basic'. It helps to retrieve the required data in a few clicks. The graphical representation of the data, data source and glossary are also integrated in the system.

The highlights of the important statistical data and the following two major applications of the database are also presented.

i. Projection of future availability of teak wood from forest plantations was undertaken under different scenarios, taking into account the factors such as species-mix, age structure, rotation age, productivity and planting rates. The projections indicated that the promotion of teak outside the forests such as home gardens and farmlands would help to bridge the gap between future demand and supply.

ii. The long-term trends in the real prices (deflated current prices) of teak wood in different girth classes for the period 1956 to 2005 were analysed by fitting different spline models. The analysis indicated that there was a declining trend in real prices since 1995 probably due to increased availability of substitute materials in the market. However, of late, the prices of teak wood have been increasing. The short-term price forecasts of teak wood were made using artificial neural network and auto-regressive integrated moving average models. The forecasts indicated that the quality teak wood would fetch high returns. Therefore, efforts should be made to produce quality teak wood.

1. INTRODUCTION

1.1 IMPORTANCE OF FORESTRY STATISTICAL DATABASE

In recent years, forests and forestry have attracted greater attention all over the world in view of their complex role in the environment amelioration besides the social and economic benefits they provide to the population. It is this fact that led to the development of sustainable forest management based on scientific principles and reliable data. There has been a wider use of forest statistics in resource estimation, making crucial management decisions, developing criteria and indicators for the assessment of sustainability, economic computations and making policy decisions.

Statistical modeling and prediction tools, databases and other newer techniques have gained greater applicability in forestry science. In a number of instances, statistical data or databases are very handy tools facilitating reliable analysis, resource accounting, making spatial and temporal comparisons, developing decisions support systems (DSS), yield prediction are but a few applications. In this 'knowledge era' decisions are guided by statistical data (evidence-based) and not by intuition. Statistical databases also improve the data quality, reduce duplication and encourage information dissemination.

Considering the importance of forestry statistics and database the Forest Policy 1988, Section 4.14 on Forest Survey and Data Base states 'Inadequacy of data regarding forest resources is a matter of concern because this creates a false sense of complacency'. Priority needs to be accorded to completing the survey of forest resources in the country on scientific lines and to updating information. For this purpose, periodical collection, collation and publication of reliable data on relevant aspects of forest management needs to be improved with recourse to modern technology and equipment.

1.2 DATA REQUIREMENTS

Most of the forest statistics that we have in the State/ Country are collected to meet the routine administrative needs of the Forest Department and is largely a bye-product of the administrative reports and records of the State Forest Departments such as reserve register, stock register, plantation journal and revenue register. But today's changed perspective of forest management from timber production to environmentally-oriented forest management (which has to take into consideration Clean Development Mechanism (CDM), Climate

Change Mitigation Strategies) requires a variety of data from a number of different sources and their analyses.

Forest planning requires data from forest environment and environment external to forests. Examples for the former case include data on forest area, growing stock, growth rates, rotation, etc. Examples for the latter case include demand and supply of forest products and complementary and competing products such as steel, fiber products and their prices.

Forestry activities were hitherto primarily carried out in land under the control of the Forest Department. The introduction of programmes such as Social Forestry, Agro forestry and Joint Forest Management and afforestation programmes demand great amount of additional data such as landuse pattern and socio-economic background of farmers.

It is clear that forestry statistics produced in Forest Statistics/Annual Reports are not sufficient to meet the present day data needs. The scope of the forestry statistics should be broadened to meet the demand of the different stakeholders in the changed circumstances.

1.3 OBJECTIVES

A number of agencies such as State Forest Departments, Forest Survey of India, Ministry of Environment and Forests etc. have been publishing data on various aspects of forest from time to time. However, there have not been efforts to integrate these data and produce as computerized database for easy data retrieval and reference. It has often been recommended that forestry statistics should be brought together in a centralized system covering all aspects. Many experts have compared it to a river system, which is fed by tributaries drawing water sources of glaciers, surface run off and underground resources. This system eventually feeds the ocean.

As far as Kerala is concerned, there have been some efforts in this line by Jayaraman and Krishnankutty (1990), 15 years before. Recently, Sivaram (2004) developed an integrated computerized database and retrieval software on selected aspects of forest resources of Kerala utilizing the data collected from several secondary sources and the data on certain aspects were analyzed. The objective of this project was to update the existing statistical database and add data on new themes and carry out statistical analysis to bring out useful information for forest management.

2. COMPUTERIZED DATABASE AND DATA RETRIEVAL SYSTEM

2.1. SOURCES OF DATA

The database was developed by collecting data from several secondary sources and by communicating with various agencies. The sources include the publications of the Kerala Forest Department, Ministry of Environment and Forests, Food and Agriculture Organization (FAO), Department of Statistics and Economics, Directorate of Census and the Kerala Forest Research Institute and the articles published in journals.

2.2. THEMATIC ELEMENTS OF THE DATABASE

The database was developed keeping in mind mainly the general data requirements of the personnel involved in forestry and related disciplines. It may be noted that the data on certain themes are provided at the national level depending upon the availability. The data on many of the aspects are of time-series type covering the period from 1980 to 2005.

The database was developed on the following themes.

i) **A Statistical Glance at Kerala and its Forests**
Summary statistics on important features of Kerala such as geographical area, latitude and longitude, population, forest area under different vegetation types, species-wise area under forest plantations, growing stock estimates and information on revenue and expenditure, Gross domestic product due to forestry sector, etc.

ii) **Land and Population**
Trends in landuse pattern, population by sex and literacy status, scheduled tribe population.

iii) **Forest Policies**
Documents on selected national forest polices and forest policies of the Kerala State.

iv) **Forest Administration**
Forest administrative units, forest stations, forest check posts and forest timber depots.

v) **Forest Economy**
Trends in gross and net state domestic products from forestry sector, revenue from forest products, revenue and expenditure, Plan and non-plan expenditure in the Kerala forestry sector.

vi) **Forest Area**
Trends in forest area with respect to legal status, vegetation type and land use pattern, Forest area and forest cover according to administrative units such as forest range, forest division and administrative district, tree cover estimates outside forests.

vii) Forest Plantations

Data bank containing list of individual plantations indicating the details such as location, name of the plantation and year of planting, trends in area under forest plantation by species and Forest Division, productivity of forest plantations for selected species.

viii) Growing Stock

Important species in forests, growing stock of forests, growing stock of teak, eucalyptus and bamboo.

ix) Production of Forest Products

Trends in the production of timber by species, production of non-wood forest products (NWFP), details on tribal societies and NWFPs collected.

x) Prices of Forest Products

Prices of timber species at State level and in various timber sales Divisions, quantity sold, prices of pulpwood species such as bamboo and eucalyptus and prices of NWFPs.

xi) Supply and Demand

Sector-wise demand and supply of timber, fuel wood, charcoal, etc., export and import of timber.

xii) Biodiversity

Protected area, Biosphere Reserves, plant and animal biodiversity, wetlands, list of algae, amphibians, bryophytes, birds, fishes, lichens, reptiles.

xiii) Mangroves and Sacred groves

Distribution of mangroves and sacred groves.

xiv) Forest Degradation

Annual deforestation rate, trends in forest offences and forest fire.

xv) Wildlife Census

Population estimates of major mammals including elephant and tiger estimated from different censuses.

xvi) Ecotourism

Trends in foreign and domestic tourists to Kerala, profile of the visitors to different sanctuaries and national parks, trends in budgetary allocation to tourism sector

xvii) Forest Weather

Weather data from selected districts, Forest Divisions and wildlife sanctuaries.

xviii) Maps

Kerala administrative boundary map, map showing boundaries of Forest Range and Divisions, maps of the individual Forest Division and Range, map showing Elephant Reserves and elephant density.

xix) Other Useful Statistics

Global level land area and forest area statistics, global statistics on production, trade and consumption of round wood and sawn wood.

2.3. DEVELOPMENT OF DATABASE AND RETRIEVAL SYSTEM

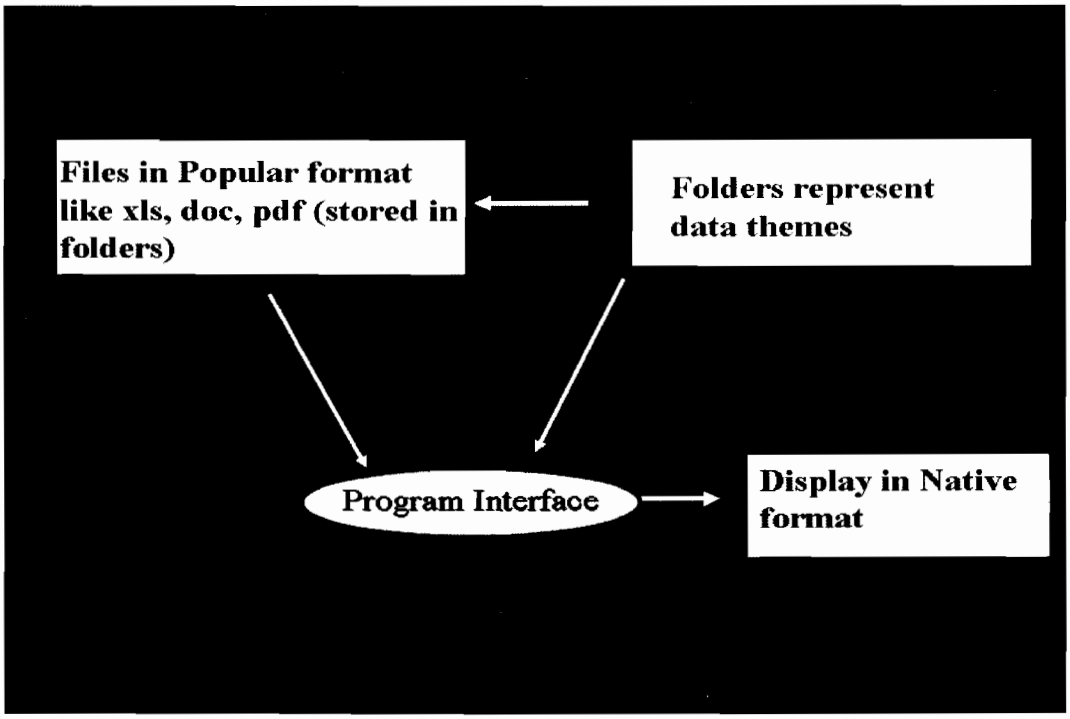


Fig. 2.1. Diagram showing the database system for storage and retrieval of data files

In an earlier project on database on forest resources of Kerala, a database and retrieval system was developed using the software Visual Fox Pro 6.0 (Sivaram, 2004). Because the data for the database are essentially collected from secondary sources at different levels in different formats, it is difficult to put these data tables in database such as Visual Fox Pro, MS Access and SQL Server and writing program codes for retrieval system. The updating of database from time to time is also difficult. So, an attempt was made to develop a simple interface using Microsoft Visual Basic so that data addition, updation and retrieval become easy. In this system, there are different data folders named after the major themes and prefixed by a three digit code (like 001, 002 etc.) stored in the root directory C:\database_forest. In each folder, files named after the title of the data table and prefixed by a three digit code are stored. The order of appearance of the themes and files under the each theme is based on decreasing order of the three digit code. The data files may be in Excel (xls), Word (doc) or in Acrobat (pdf) format. The Excel and Word files used are of 2003 version.

The program interface helps to retrieve the information available in these files in a few clicks. The first click on the theme of our interest (presented in the left panel of the main menu) will provide the details of the data files available under the theme (in the upper portion of the right panel). When a click on the data file of interest is done, its content is displayed in the bottom portion of the right panel in its native format. This file can be zoomed to full screen and content can be read. If needed, copying and printing can also be performed. For example, a click on the theme Forest Plantations (highlighted) in the left panel provides the list of data files available under it in the upper portion of the right panel. Further click on 'Trends in species-wise area under forest plantations' displays the data available in it in the bottom portion of the screen (Fig. 2.2). By clicking the 'Maximize' button the file is zoomed to full screen and data displayed. By clicking the 'Restore' button the main menu is retrieved (Fig. 2.3). The graphs are also made available for the data wherever possible. For example, Fig. 2.4 depicts the data on district-wise forest cover of the Kerala State.

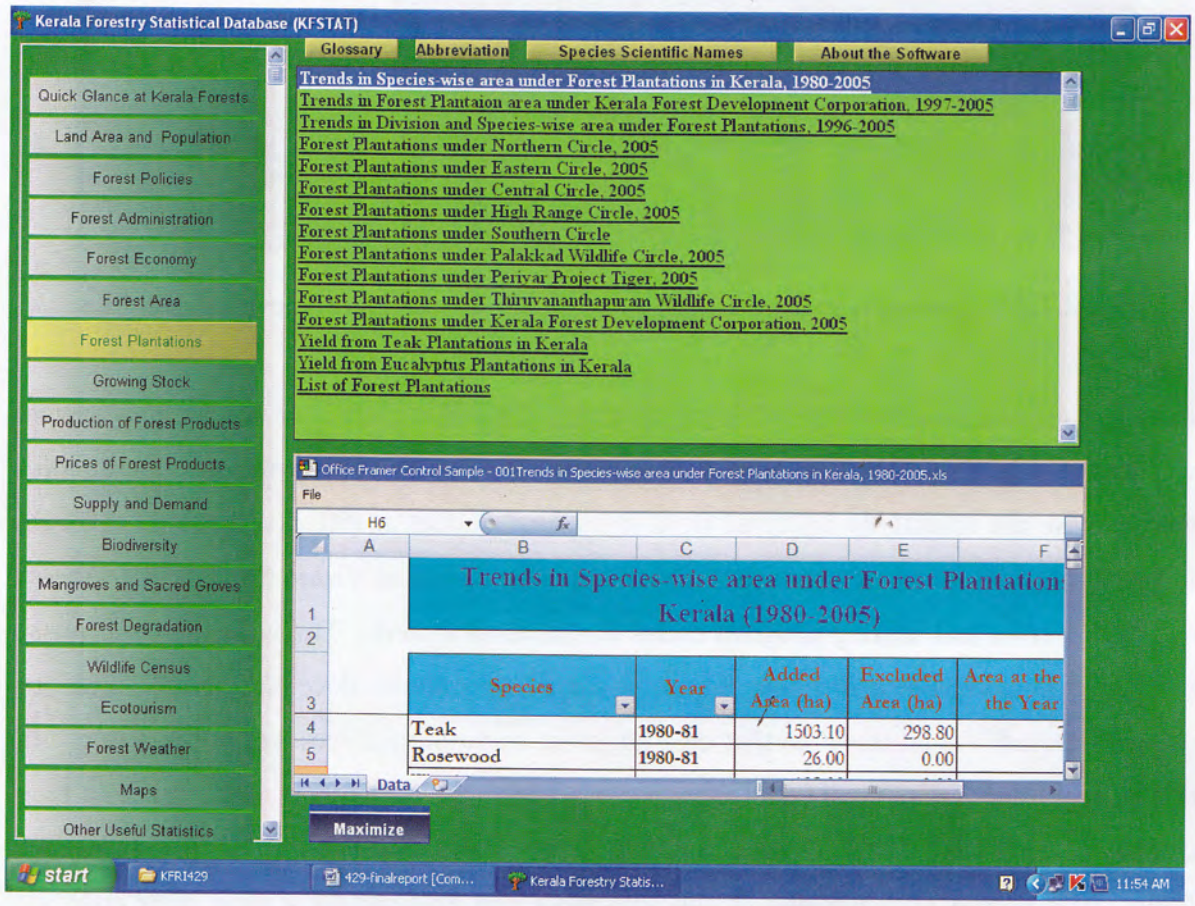
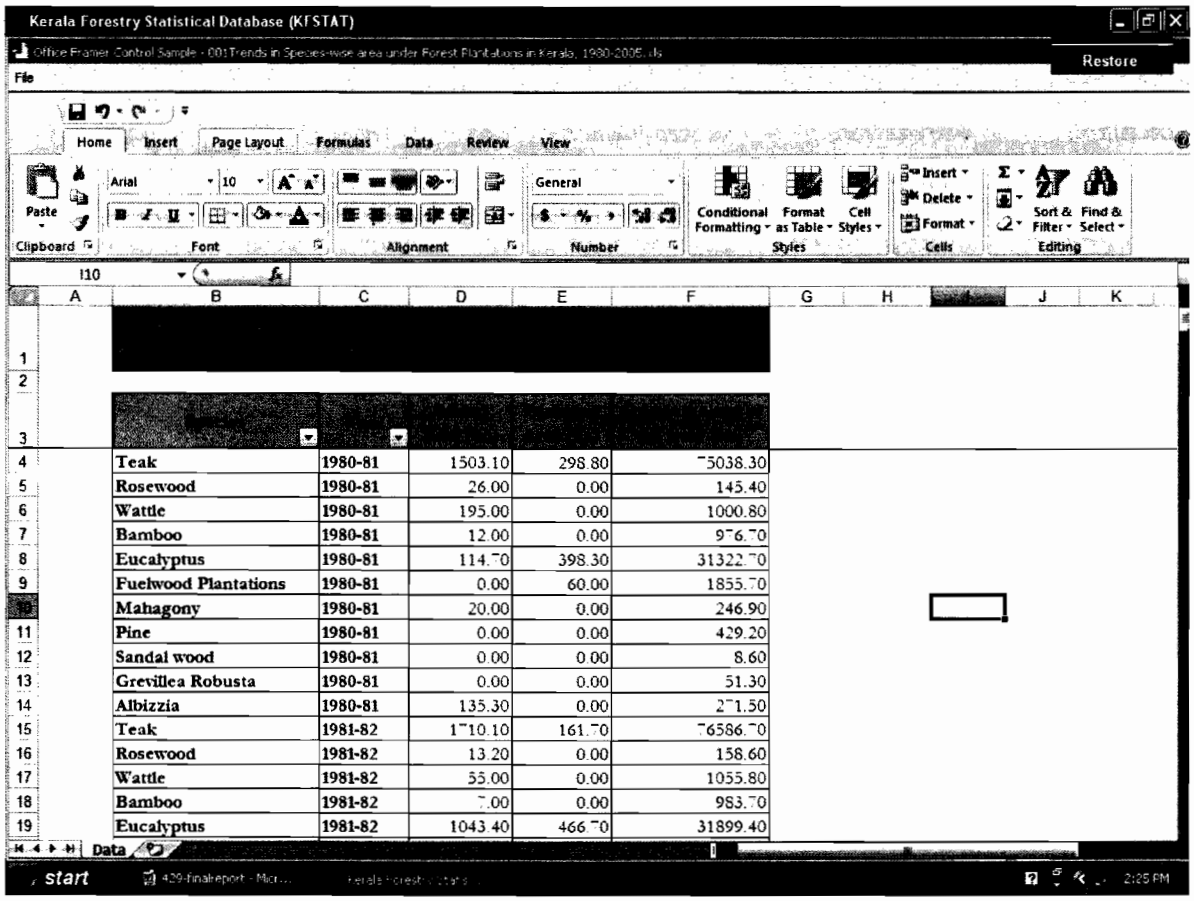


Fig. 2.2. Main menu of the database and retrieval system



Teak	1980-81	1503.10	298.80	75038.30
Rosewood	1980-81	26.00	0.00	145.40
Wattle	1980-81	195.00	0.00	1000.80
Bamboo	1980-81	12.00	0.00	976.70
Eucalyptus	1980-81	114.70	398.30	31322.70
Fuelwood Plantations	1980-81	0.00	60.00	1855.70
Mahagony	1980-81	20.00	0.00	246.90
Pine	1980-81	0.00	0.00	429.20
Sandal wood	1980-81	0.00	0.00	8.60
Grevillea Robusta	1980-81	0.00	0.00	51.30
Albizzia	1980-81	135.30	0.00	271.50
Teak	1981-82	1710.10	161.70	76586.70
Rosewood	1981-82	13.20	0.00	158.60
Wattle	1981-82	55.00	0.00	1055.80
Bamboo	1981-82	7.00	0.00	983.70
Eucalyptus	1981-82	1043.40	466.70	31899.40

Fig. 2.3. Maximized view of the left-bottom of the menu in Fig. 2.2. showing the details of the trends in species-wise area under forest plantations

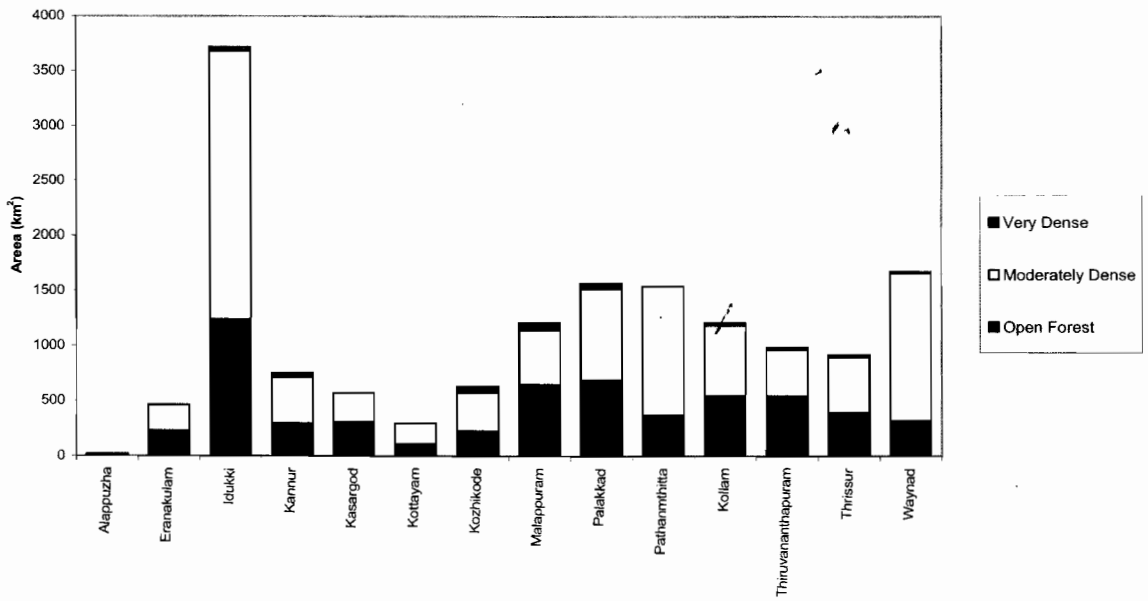


Fig. 2.4. District-wise forest cover shown above is the diagram presented in the database

The source for each data set is indicated in the software appropriately for authenticity. The system also contains a glossary. The software is best viewed under the screen area 1024 by 768 pixels.

This was an attempt to provide the database and retrieval system in an integrated manner after consulting a number of secondary sources. Therefore, there could be some errors and scope for improvement in presentation. The users of this package are welcome to send their valuable suggestions. As it is intended for refinement and updation periodically, it would be able to incorporate the modifications suggested.

2.4. INSTALLATION OF SOFTWARE AND STARTING UP FOR WINDOWS USERS

Installation

1. Place the CD-ROM "Kerala Forestry Statistical Database (KFSTAT)" in the CD-ROM drive of the computer.
2. Open the CD-ROM. Double click on the 'Kerala Forestry Statistical Database (KFSTAT).msi'.
3. Sub-window 'Welcome to Kerala Forestry Statistical Database (KFSTAT) Setup Wizard' will appear. Go on clicking 'Next' button.
4. Sub-window 'Ready to install' will appear. Click 'Install' button for the installation of the software.

How to start the program

1. Click on the 'Start' button in the menu bar
2. Select 'Programs' from the list now shown.
3. Select 'Kerala Forestry Statistical Database (KFSTAT)' from the subsequent list shown to start the program.
4. Alternatively just click the icon depicting a tree with KFSTAT.exe placed on the desktop.

Deleting the program

1. Click on the 'Start' button in the menu bar.
2. Select settings from the list now shown.
3. Select 'Control Panel' from the list of 'Settings' and click once on this item.
4. Select and open 'Add/Remove Programs' in the 'Control Panel'.
5. Select 'database_forest' from the list of installed programs and click on the 'Add/Remove' button.

3. APPLICATIONS OF DATABASE IN FOREST MANAGEMENT

The spatial-temporal data presented in the database is expected to generate useful information to appraise on various aspects of the forestry sector. The major forestry statistical data of Kerala are briefly highlighted below.

3.1. GENERAL FEATURES OF KERALA STATE AND ITS FORESTS

The State of Kerala is located in the south-west corner of the Indian Peninsula between 8° 18' and 12° 48' North latitudes and between 74° 52' and 77° 22' East longitudes, as a narrow strip of land. It encompasses an area of 38,863 km^2, which is 1.2 per cent of the total land area of India. The undulating topography ranges from below the MSL to 2,694 m above MSL. The land is panoramic with evergreen forests, picturesque landscapes and backwaters. The land of Kerala may be broadly classified into three geographical regions *viz*., lowland, midland and highland. The State has a coastline of nearly 550 km. There are 44 rivers in the State of which three are east-flowing and the remaining west-flowing. There are two distinct rainfall seasons in Kerala *viz*., the Southwest (June to August middle) and Northeast monsoon, which last from September to November end. During these two seasons, about 90 per cent of the annual rainfall is precipitated in the State. The Southwest monsoon accounts for two third of this precipitation. The average rainfall is about 3000 mm. Variation in temperature is from 23.9 to 37.7 °C in plains and from 10.0 to 32.2°C in hills.

As per the Census -2001, Kerala has a population of 3.2 crore which constitutes 3.4 per cent of the total population of the country. In terms of population density, Kerala has the high population density of 819 persons per km^2. It is the first State to achieve the highest literacy (91 per cent). The State has made significant achievements in health and these are reflected in the attainment of low infant mortality rate, low maternal mortality rate, low birth rate, low death rate and high life expectancy rate.

The State has 14 administrative districts. The provisional estimate of per capita of the State for the period 2004-05 at current prices was Rs.29,693/-. The main occupation of the people is agriculture. Kerala's climate permits cultivation of high value perennial crops. Kerala is the major Indian producer of several commodities notably pepper, rubber, cashew, cardamom, ginger and coconut. The wide variety of Kerala's cropping pattern is reflected in most farms with farmers usually growing several crops. The landuse pattern according to Kerala State Land Use Board reveals that the land put to non-agricultural use has been

steadily increasing while the net area shown and total cropped areas have been declining (Table 3.1).

Table 3.1 Trends in Land use Pattern in Kerala (1980-2006)

Unit '000 ha

Year	Land use classification											
	Total geographical area	Forest Area	Land put to nonagriculture uses	Barren & uncultivable land	Permanent pastures and grazing land	Land under miscellaneous tree crops	Cultivable waste	Fallow other than current fallow	Current fallow	Net area sown	Total cropped area	Area sown more than once
1980-81	3885	1082	270	86	5	64	129	27	44	2180	2885	705
1985-86	3885	1082	279	83	4	50	126	28	43	2191	2867	676
1986-87	3885	1082	263	82	4	46	129	28	44	2207	2871	664
1987-88	3885	1082	285	72	3	41	115	29	47	2211	2900	689
1988-89	3885	1082	284	71	3	41	116	28	47	2213	2963	751
1989-90	3885	1082	285	66	3	38	107	26	46	2232	3019	787
1990-91	3885	1082	297	58	2	34	95	26	44	2247	3020	773
1991-92	3885	1082	301	55	2	34	93	26	44	2248	3021	773
1992-93	3885	1082	303	55	2	34	91	27	42	2249	3046	797
1993-94	3885	1082	308	51	2	37	90	29	49	2238	3043	805
1994-95	3885	1082	323	48	1	32	82	29	48	2240	3048	809
1995-96	3885	1082	313	43	1	27	74	29	51	2265	3067	802
1996-97	3885	1082	318	41	1	23	67	29	55	2269	3021	753
1997-98	3885	1082	320	39	1	22	65	28	58	2270	2969	698
1998-99	3885	1082	324	28	1	20	63	32	68	2258	2917	658
1999-00	3885	1082	354	29	0	19	58	32	72	2239	3002	762
2000-01	3885	1082	382	29	0	15	59	34	78	2206	3022	816
2001-02	3885	1082	392	30	0	14	64	34	79	2191	2992	802
2002-03	3885	1082	393	30	0	13	69	39	71	2189	2970	732
2003-04	3885	1082	388	30	0	12	71	39	71	2194	2976	783
2004-05	3885	1082	430	29	0	10	70	41	68	2155	2996	841
2005-06	3885	1082	370	26	0	10	66	45	70	2132	2986	853
2006-07*	3885	1082	439	26	0	9	90	47	82	2111	2918	806

* Provisional figures Source:

In India, most of the forest resources are under the custody of the Government. The State Government owned State Forest Departments (SFDs) are managing the forest resources. SFD follows the directions of the both State and Central Government. In Kerala, timber extraction from natural forests has been stopped since 1980. The contribution of forest sector to the Gross State Domestic Product (GSDP) is Rs.1,302.24 crore which is just 1.5 per cent. Though forests meet a variety of social and environmental needs of the State it is seldom accounted in the State/National income. The maximum contribution to GSDP is from Idukki district followed by Pathanamthitta and Wayanad (Fig. 3.1).

The contribution of forests to State income is mainly from sale of timber (Fig. 3.2) especially from the sale of teak from teak plantations (see chapter 4.0 for more details). The expenditure by the Kerala Forest Department is almost as that of its revenue. About 50 per cent of its expenditure is for Plan Schemes.

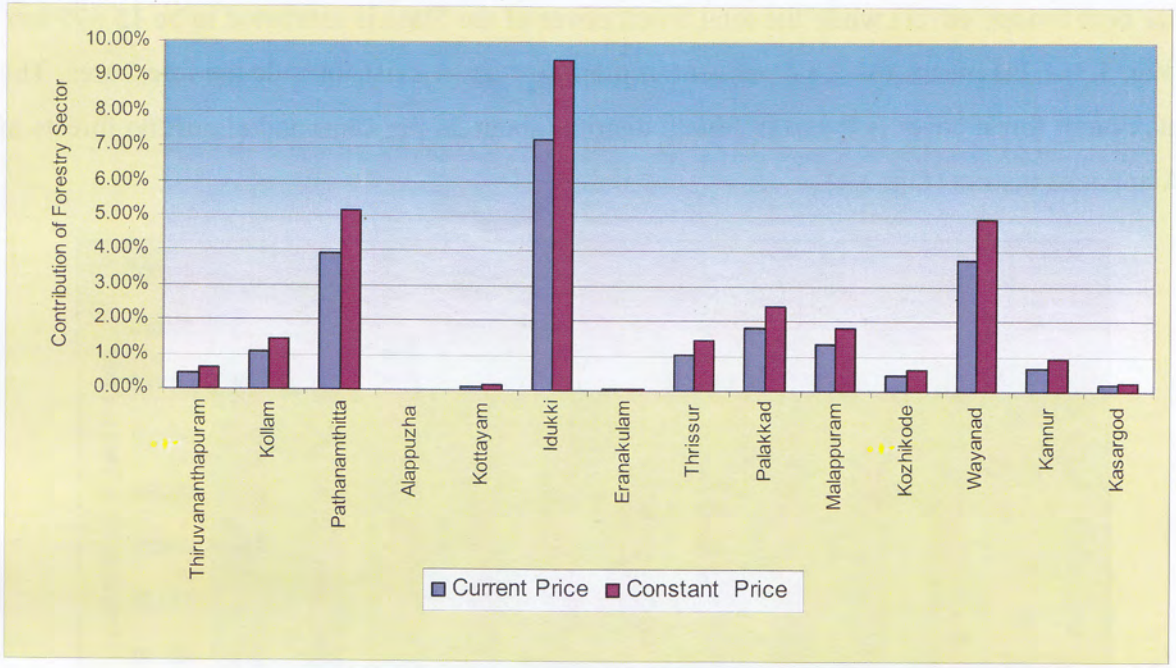


Fig. 3.1. District-wise percentage contribution of forestry sector to GSDP of Kerala State

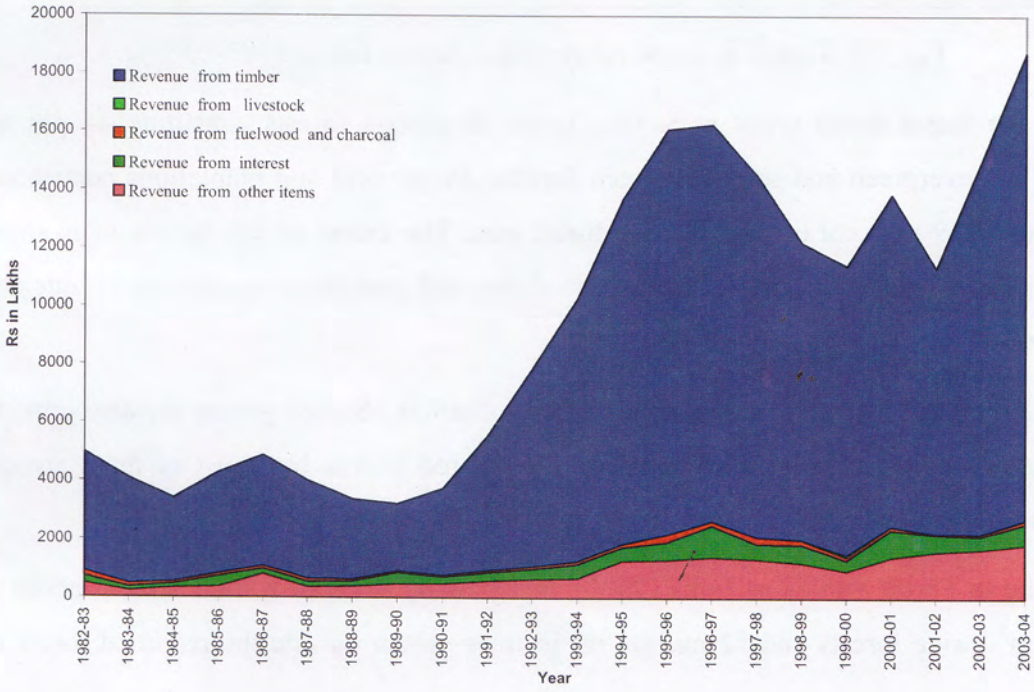


Fig 3.2. Revenue from the sale of forest products, 1983-2004

The total recorded forest area in India as per the government records is 7,65,200 km^2. Out of this, forests in Kerala constitute 1.5 per cent (11,265 km^2). However, according to Forest Survey of India (2005), only 85 per cent of the recorded forest area is under forest cover (>10

per cent canopy cover) while the total forest cover of the State is estimated to be 15,595 km^2 (Fig. 3.3). This means that 38.6 per cent of the forest cover exists outside the forest area. The maximum forest cover is found in Idukki district (about 24 per cent) and almost no forests in Alappuzha district (Fig. 2.4).

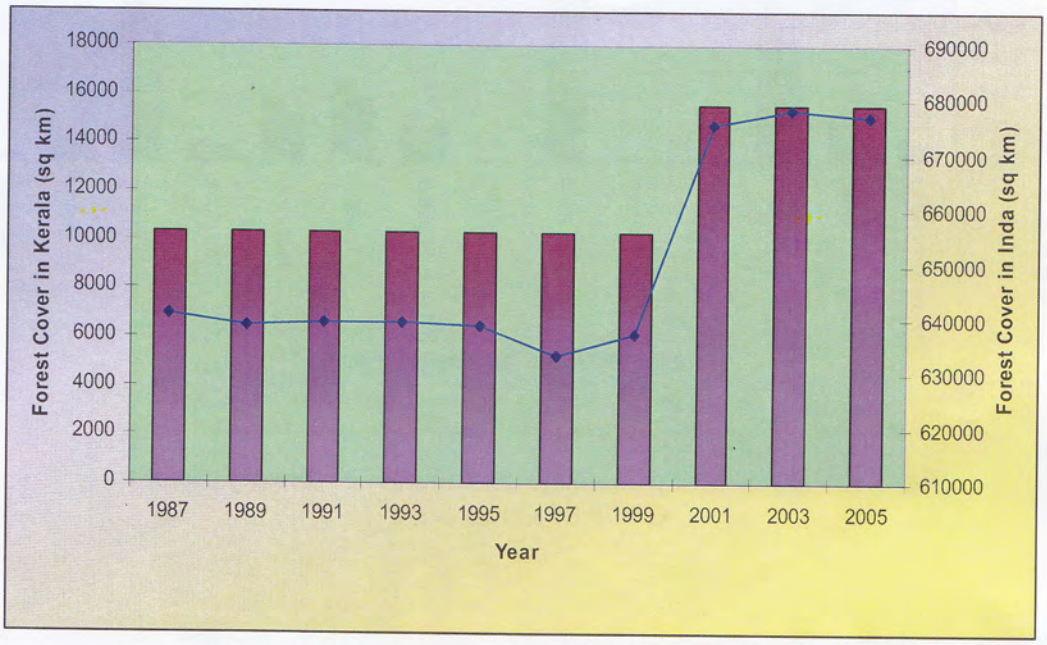


Fig. 3.3. Trends in forest cover of Kerala and India (1987-2005)

Among the major forest types in Kerala, moist deciduous forests constitute 44 per cent, tropical wet evergreen and semi-evergreen forests, 35 per cent and plantations contribute to the extent of 19 per cent of the effective forest area. The extent of dry deciduous is about 1 per cent. The montane sub-tropical temperate sholas and grasslands together contribute about 1 per cent.

About 4,000 ha of mangroves are spread across 9 districts. Sacred groves are also important in conserving forest ecosystem. Kerala has 761 sacred groves but most of them are quite small and fragmented. Only 361 groves exceed 200 m^2.

According to Forest Survey of India (2003), the growing stock of Kerala State is about 130 million m^3 inside forests and 52 million m^3 in trees grown outside the recorded forest area (ToF).

At present there are one Tiger Reserve, five National Parks and 12 Wildlife Sanctuaries including two Bird Sanctuaries and a Pea fowl Sanctuary, covering a total area of 2,382 km^2, which is 21 per cent of the recorded forest area. There are two biosphere reserves to the extent of 3,156 km^2 which is 28 per cent of the forest area.

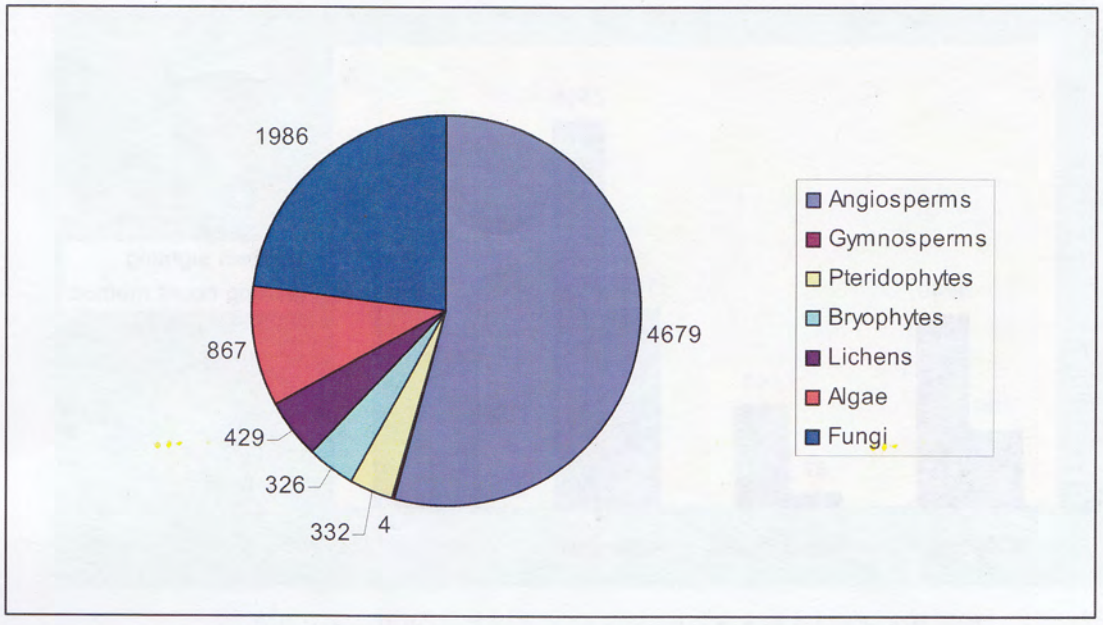


Fig. 3.4. Status of plant diversity in Kerala

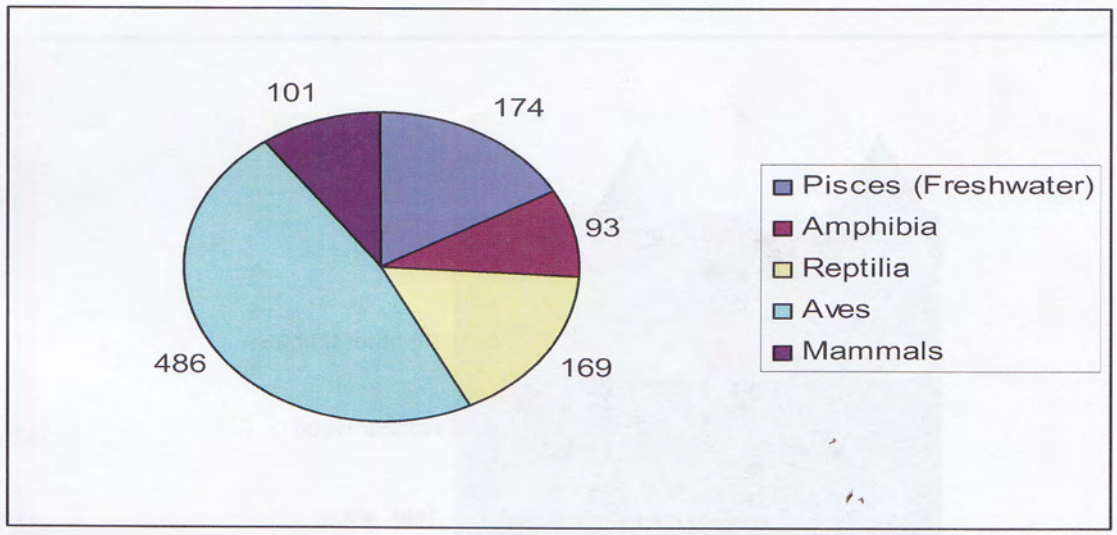


Fig. 3.5. Status of animal diversity in Kerala

According to State of Environment Report -2005 (KSCSTE, 2005) about 8,623 plant species and about 1,023 animal species have been recorded in the State. The distribution is presented in Figs. 3.4 and 3.5. The major animal species in Kerala include elephant, gaur, malabar giant squirrel, nilgiri langur, sambar deer, spotted deer, wild bear, lion-tailed macaque, nilgiri tahr and tiger. Recently, in 2007, wild elephant census was conducted. Based on the direct sightings the estimated wild elephant population was 3002. Based on the dung count method, the population was 6068 (Fig. 3.6).

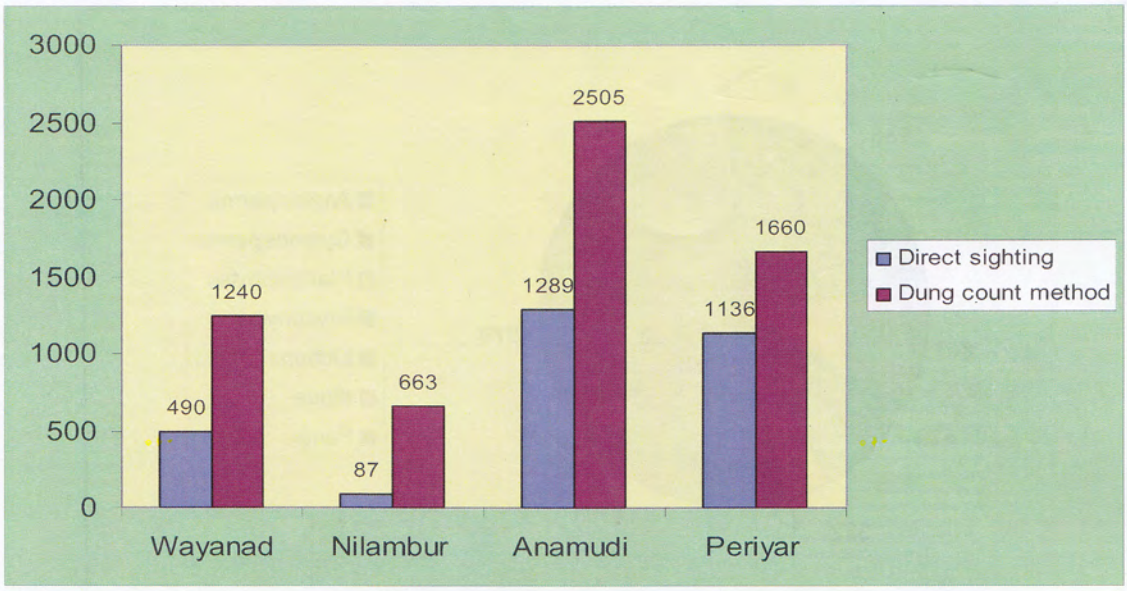
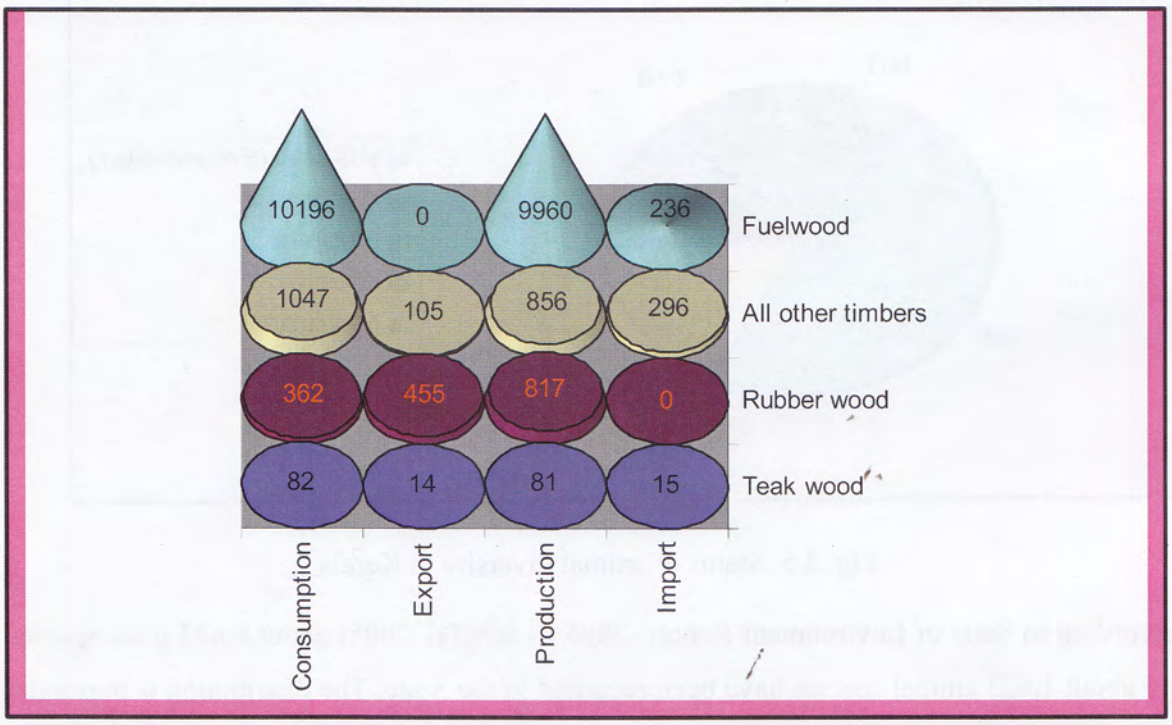


Fig. 3.6. Estimated elephant population based direct sightings and dung survey - 2007



Note : Numbers indicate wood quantity in m^3. Demand = Consumption+Export; Supply=Production+Import

Fig. 3.7. Demand and supply pattern of timber and fuelwood in Kerala (2000-01)

Krishnankutty *et al* (2005) studied the supply-demand situation of wood in Kerala. The wood consumption in the State is about 12 million m^3. There was a matching export to import of wood to about 5.5 lakh m^3. About 90 per cent of the total wood consumed is fuelwood

(Fig. 3.7.). Fig. 3.8 shows the distribution of demand over different sectors. The major demand for timber is from industries sector while the major demand for fuelwood is from household sector. Most of the wood requirement is met from home gardens and rubber estates (Fig. 3.9). Forests contribute only about 10 per cent of the total wood supply.

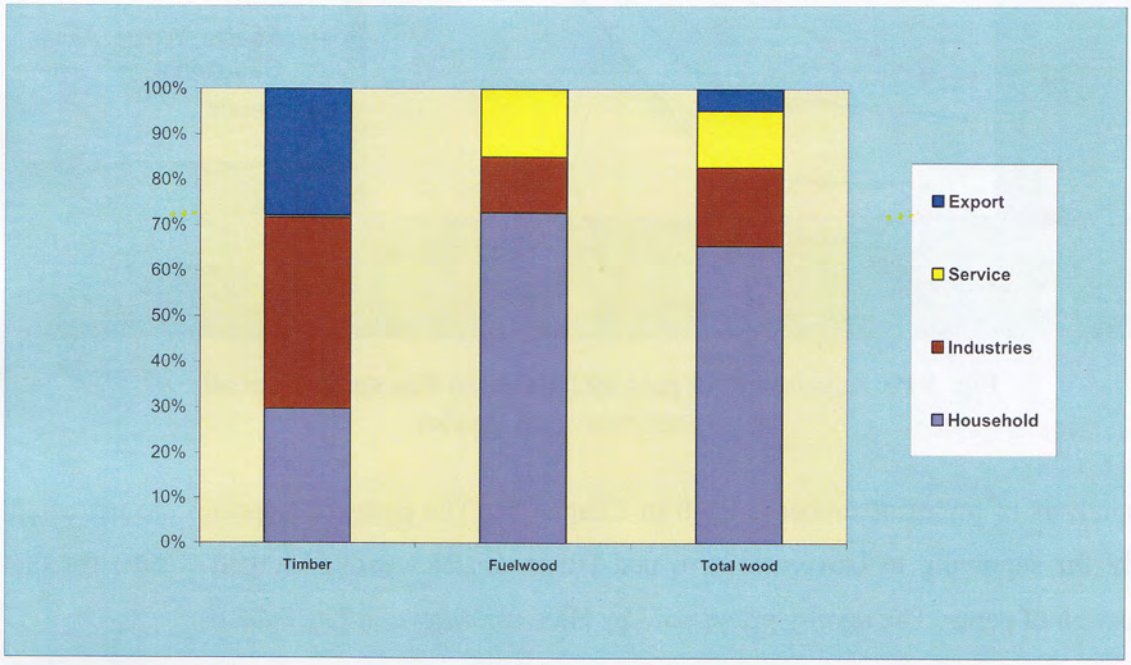


Fig. 3.8. Sector-wise demand for timber and fuelwood in Kerala (2000-01)

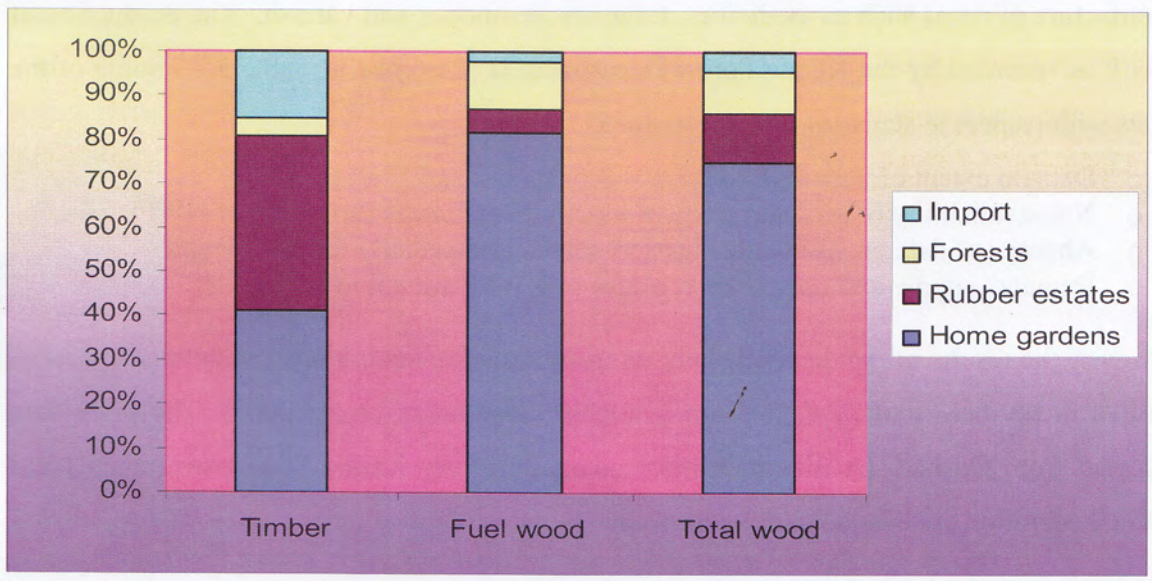


Fig. 3.9. Supply of timber and fuelwood from different sources in Kerala (2000-01)

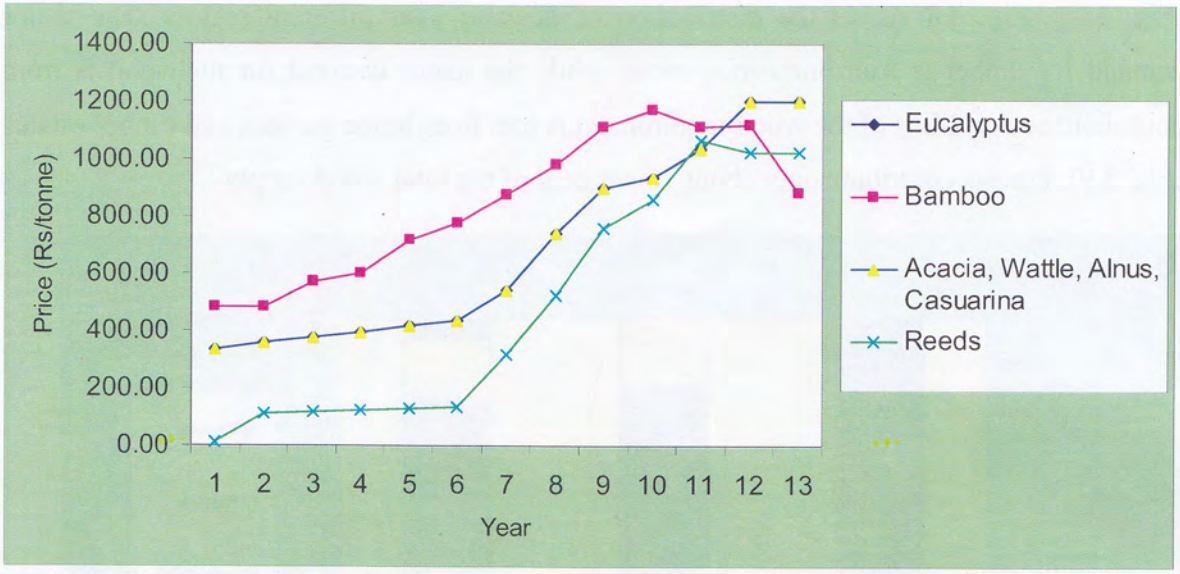


Fig. 3.10. Royalty prices paid by Hindustan Newsprint Limited for various pulpwood species

The analysis of prices of timber is dealt in Chapter 5. The pulpwood species are extracted mostly for supplying to Government owned Hindustan Newsprint Limited (HNL) for the production of paper. The royalty prices paid by HNL are shown in Fig. 3.10.

As far as the status of non-wood forest products (NWFPs) is concerned, there are over 500 species recorded in the State. Of these, 150 are exploited on commercial scale for the manufacture of items such as medicines, toiletries, cosmetics and varnish. The production of NWFP as recorded by the Kerala Forest Department is presented in Table 3.2. Some of the issues with respect to statistics of NWFPs are as follows

- Data on extent of unauthorized removal of timber and NWFP,
- Non-availability of growing stock/productivity estimates especially of NWFP,
- Absence of data on sustainable harvest schedule especially for NWFP and
- Demand, supply and open market prices of NWFP are not available.

However, the results of the detailed study on quantitative inventory and marketing aspects of NWFPs in northern part of Kerala are available (Sasidharan *et al.*, 2008). The price data collected from Oushadi (A pharmaceutical company of the Kerala State Government) and SC/ST Federation are available in the database.

Table 3.2 Production of Non Wood Forest Products in Kerala, 2005

Items	Quantity (kg)
Ayurvedic herbs	1060962
Spices	21278
Fibre	60310
Grass other than fodder	10046
Incensive plants	84292
Vegetable oil seeds	26266
Honey	59464
Bee's wax	1079
Medicinal Plants	78881

Joint Forest Management (JFM) scheme has been implemented since 1998. So far, a total of 327 JFM committees have been formed managing 1.7 lakh ha of forest area. The State has a lot of tourism potential, especially ecotourism, which Government of late, is promoting. Tourism sector also provides a lot of revenue to the Government. In 2003, about 1000 crore rupees was earned by the State. About 10 per cent of foreign tourists who come to India visit Kerala, mainly the Wildlife Sanctuaries/National Parks and backwaters. The distribution of number of foreign tourists to different tourist places is depicted in Fig. 3.11.

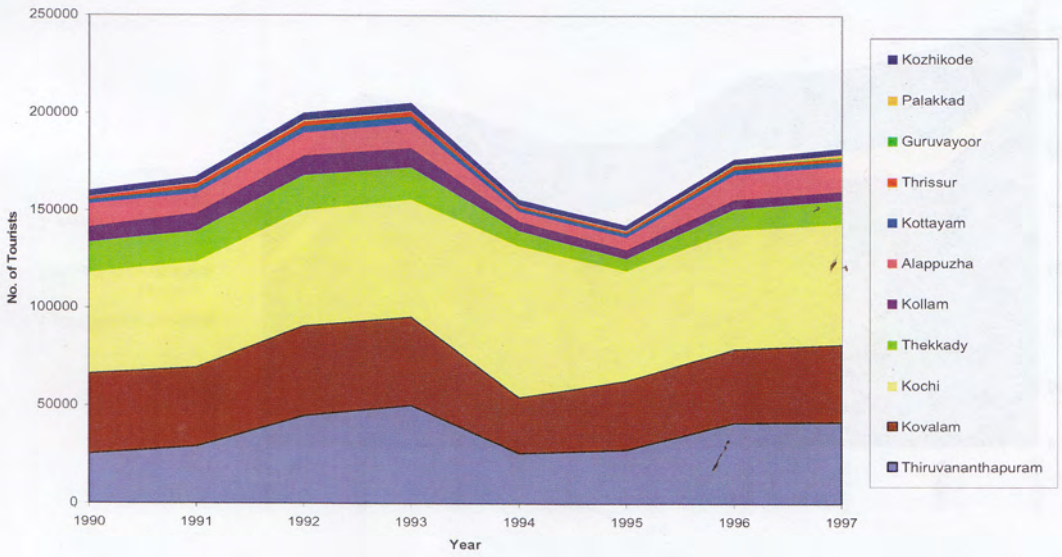


Fig. 3.11. Trends in foreign tourists arrival to different centers in Kerala

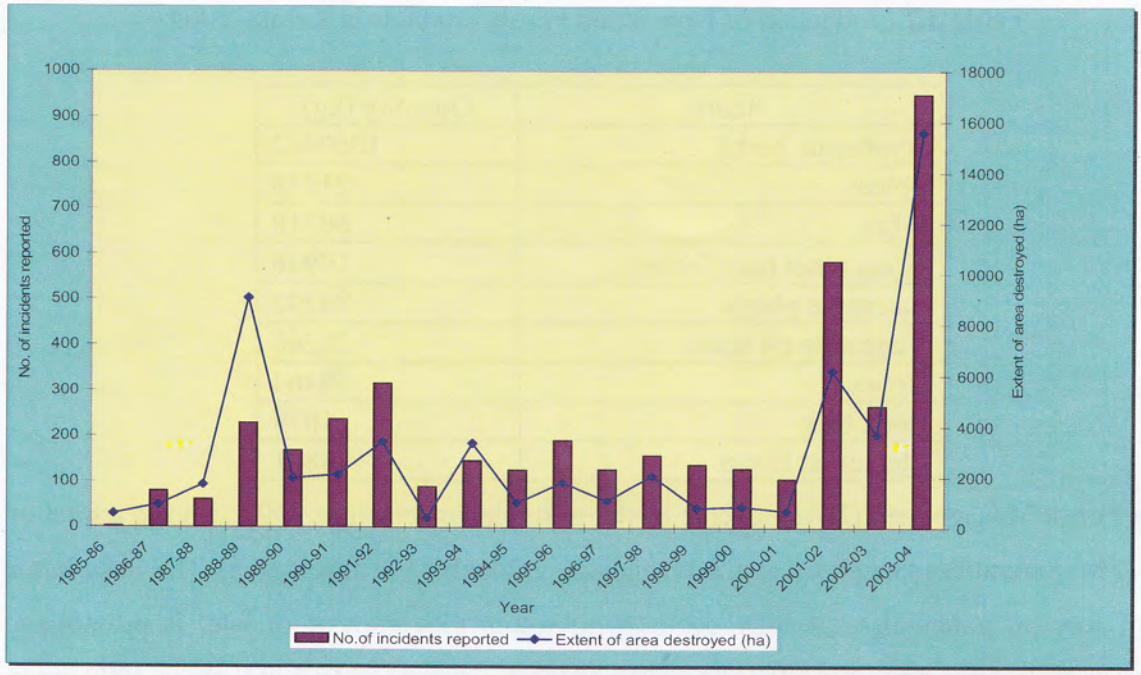


Fig. 3.12. Forest fire in Kerala forests (1985-2004)

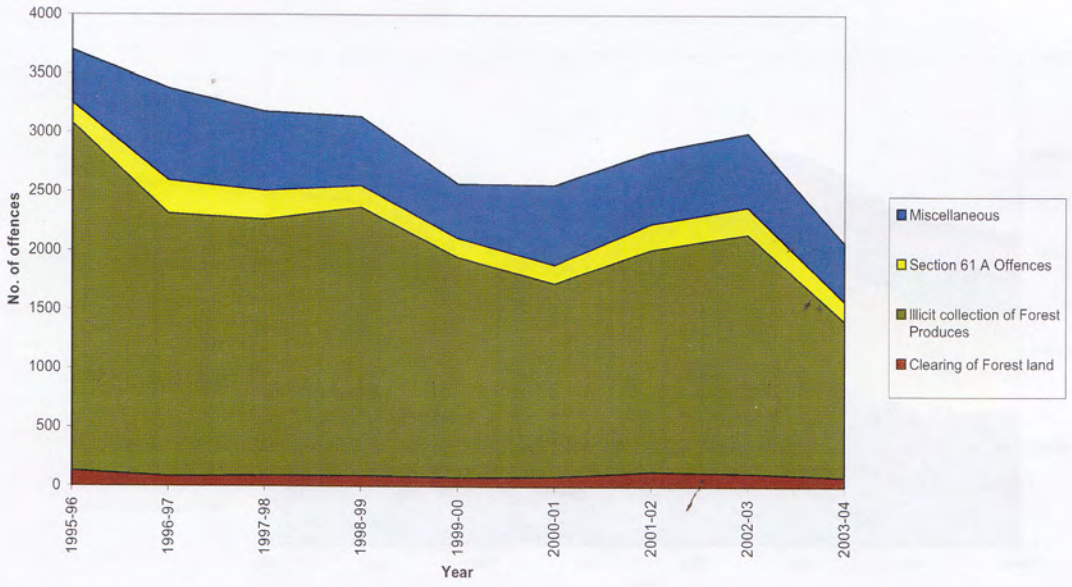


Fig. 3.13. Number of forest offences booked under Kerala Forest Act 1961 (1995-2004)

While there are several factors responsible for forest degradation, the Kerala Forest Department could record occurrences of forest fire, which is often considered to be underestimation. The cause for the forest fire is mostly anthropogenic. Fig 3.12 shows a large temporal variation with respect to number of fire incidents and area damaged. In 2003, there

were about 950 fire incidents damaging 15,580 ha of forest area. Illegal collection of forest produce and clearing of forest land are some of the other causes for forest degradation. The offences due to illegal collection of forest produces are the major offences as recorded by the Kerala Forest Department. On the whole, there is a declining tendency in the number of offences in the State over the years (Fig. 3.13).

3.2. DATA MINING ON SELECTED ASPECTS

Data mining is finding the hidden patterns that transform data into insight (*i.e.*, knowledge discovery) and applying discovered knowledge for business advantage (*i.e.* knowledge deployment). In this project, data mining was also carried out on selected data sets through mathematical/statistical models with respect to certain aspects so that new information could be obtained. It is in this regard, using the data available in the database collected from various sources, two in-depth studies were attempted to meet the following objectives.

i) to analyze the trends in the extent of teak plantations in Kerala

ii) to project the future trends in the availability of teak wood from forest plantations based on its age structure under different scenarios

iii) to analyze the trends in the real prices of teak wood and

iv) to make short-term forecasts of current prices of teak wood.

The first two objectives are met in Chapter 4 and the last two objectives are met in Chapter 5.

4. APPLICATIONS OF DATABASE IN FOREST MANAGEMENT

4.1. PRIMARY DATA SOURCE

The primary data source for the analysis in this chapter is as follows. The data on forest plantations were obtained through extensive communications with the Divisional Forest Officers of the Kerala Forest Department and Divisional Managers of the Kerala Forest Development Corporation. The officers were requested to provide the details of the individual plantations in their respective jurisdiction such as location, extent and year of planting. The data on volume estimates (productivity), thinning and rotation age, demand and supply of teak wood obtained from various research reports and All India Yield Table were also used for the analysis.

4.2. STATUS OF FOREST PLANTATIONS

4.2.1. Historical trends

Teak plantations form the major source of teak wood supply in Kerala. The history of teak plantations in Kerala has been discussed by Chundamannil (1993). The beginning for the establishment of teak plantations was first made at Nilambur, which dates back to 1842. Raising plantations later grew to become the genesis of network of teak plantations in India. A great majority of teak plantations in Kerala have been established under the government plantation programmes. With the introduction of Working Plans from 1895 to 1905 and 1906 to 1915, teak plantations were brought under systematic management for the scientific working. The period after the Second World War was marked by a sincere effort in afforestation in areas ravaged by excessive felling during the war period. Teak was the most preferred species for raising plantations during this period. During the early 1960's liberal approach was considered advisable in selecting areas for raising teak plantations as there was a demand for even poor quality teak. Consequent to this, teak plantations were raised extensively. Further, the initiation of planned development under Five Year Plans accelerated the plantation activity in Kerala. Plan funds were provided for the establishment of plantations. Even special teak plantation divisions were formed for intensive expansion and management of teak plantations. In the year 1922, 'taungya' system of raising teak plantation was introduced. However, it was discontinued in the early 1980's in view of its adverse effects on the soil and plant growth (Rao *et al.*, 1997). Mixed planting of teak with

softwood species from 1970 onwards and bamboo as underplanting in 1980's were other important management strategies adopted.

4.2.2. Current status and spatial distribution of forest plantations

At present, the total forest plantation area in Kerala is 1,91,000 ha. This is 17 per cent of the total forest area of 11,20,000 ha. Nearly, 95 per cent of the forest plantation area is managed by the Kerala Forest Department and 5 per cent by the Kerala Forest Development Corporation. About 12 per cent of the total forest plantation area is found in protected areas (National Parks/Wildlife Sanctuaries) which do not come under the purview of regular management of forest plantations. Therefore, the analysis is restricted to forest plantations under the territorial Forest Divisions which come under the regular management and available for exploitation. The species distribution of the forest plantations is presented in Fig. 4.1. Teak is the major species contributing 69,000 ha, which is 41 per cent of the total plantation area under territorial forest divisions. Fig. 4.2 shows the distribution of teak plantation area in different Forest circles. The Southern Circle has the maximum teak plantations, followed by Central and Northern Circle.

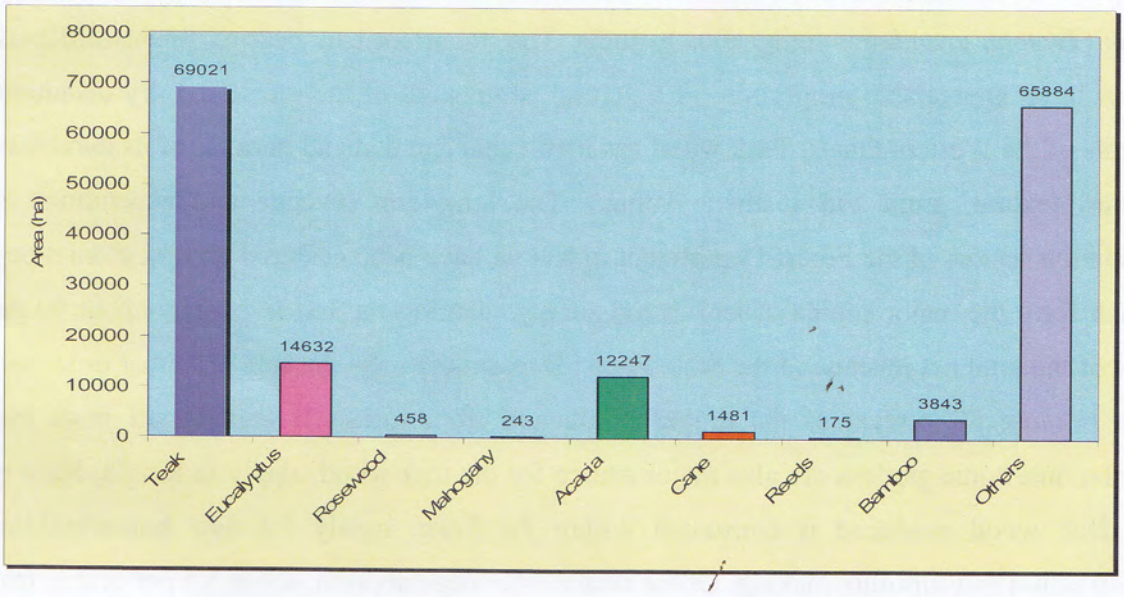


Fig. 4.1. Species wise distribution of forest plantations in Kerala- 2005

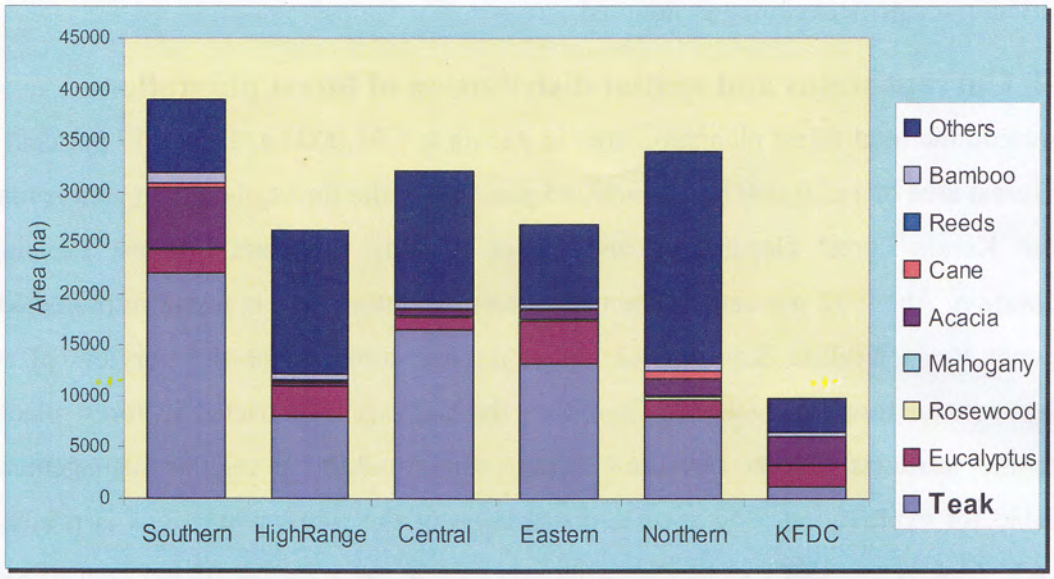


Fig. 4.2. Spatial distribution of forest plantations in Kerala- 2005

4.3. IMPORTANCE OF THE STUDY

Teak (*Tectona grandis*) is indigenous to India. The important teak bearing forests in Kerala occur in an appreciable proportion, as a natural component of the moist and dry deciduous forests of the Western Ghats. Teak wood has high value and demand because of its durability, colour, texture, grain and aesthetic value. The long-term revenue and expenditure in plantation sectors of the Forest Department in Kerala have been centered on teak plantations, which form the major source of teak wood supply. During the last five years about 90 per cent of the total net revenue of the State Forest Department is by the sale of timber especially teak because 80 percent of the timber production from forests is teak. Apart from teak plantations, home gardens are also major source for the teak wood supply in Kerala. Most of the teak wood produced is consumed within the State mainly for new house/building construction and furniture making. Of the total timber consumption, about 5.5 per cent is teak (Krishnankutty, 2005). Other important timber species consumed in the State are anjily, jack, mango, coconut and rose wood and imported timbers such as pynkado. The rubber wood has been used heavily in industries sector as Kerala has large tracts of rubber plantations which do not come under the purview of forest plantations.

Future projection of supply and demand and prices is an important activity in any business enterprise to plan the required activities ahead for addressing the future demand-surplus

situation and for optimal investment. Internationally, teak wood is a premium timber product. Therefore, it is important to understand the future availability of teak wood from forest plantations and how far it would meet the future demand of the society especially when there is no expansion of teak plantations and productivity is of major concern. Such exercise will aid in developing forest policies for the sustainable forest plantation management, especially of teak.

4.4. KEY FACTORS INVOLVED IN PROJECTIONS

4.4.1. Age structure of teak plantations

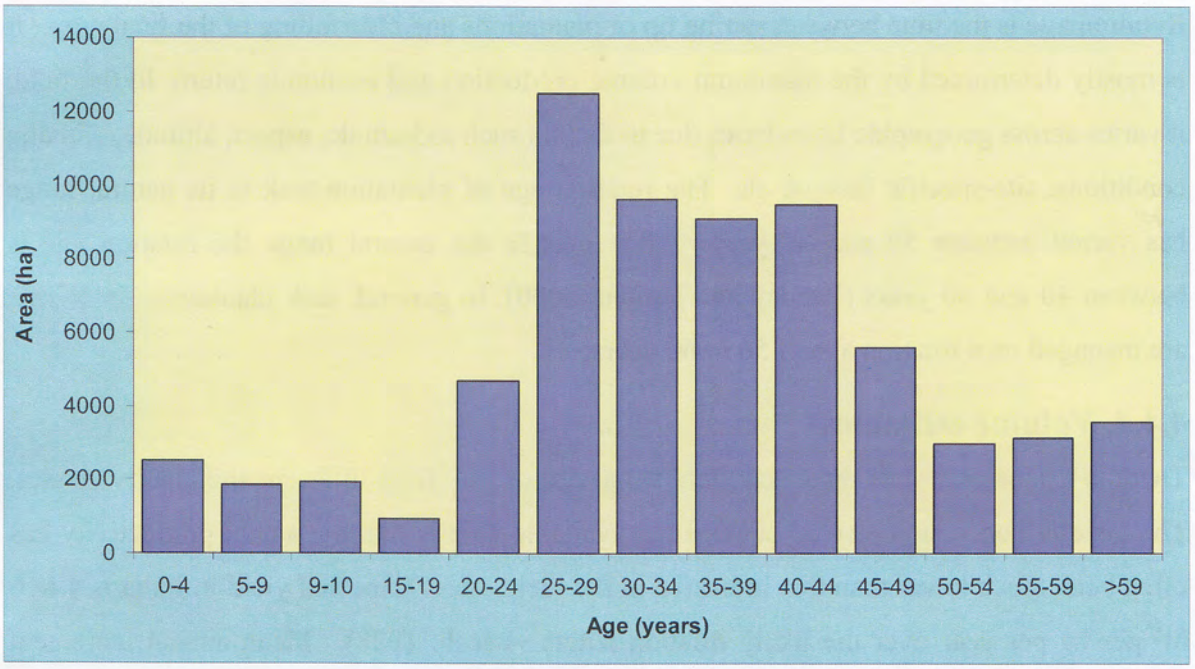


Fig. 4.3 Age structure of teak plantations under territorial forest divisions- 2005

The age structure of presently available plantations determines the future outturn of timber. The list of teak plantations as on year 2005 from all the Territorial Forest Divisions was classified according to different age groups and presented in Figure 4.3. Nearly 60 per cent of the plantations were found in the age group of 25-44 years.

4.4.2. Stocking and site quality

The productivity of teak depends on the stocking and site quality of the plantations apart from the quality of planting materials, the extent of pest and disease problems. An assessment made by Jayaraman and Chacko (1997) showed that only 5 per cent of the area under teak belonged to site quality class I. 86 per cent of the area belonged to moderate site quality

classes either II or III. In terms of stocking, the understocked and overstocked plantations were 74 per cent based on basal area per ha and 81 per cent based on number of trees per ha.

4.4.3. Thinning and rotation age

Thinning is an important operation to reduce competition between trees for producing commercially sizeable timber. The prescribed thinning years are 4, 8, 12, 18, 28 and 40 years. However, in practice, there is a variation in thinning years followed. The average thinning schedule worked out by Jayaraman and Chacko (1997) based on the data obtained from the records of the Forest Department are at 7, 10, 16, 24, 31 and 35 years.

Rotation age is the time between setting up of plantations and clearfelling of the final crop. It is mostly determined by the maximum volume production and economic return. In the field, it varies across geographic boundaries due to factors such as latitude, aspect, altitude, climatic conditions, site-specific factors, etc. The rotation age of plantation teak in its natural range has varied between 50 and 90 years, while outside the natural range the rotation age is between 40 and 60 years (Pandey and Brown, 2000). In general, teak plantations in Kerala are managed on a rotation age of 50 to 60 years.

4.4.4. Volume estimates

There is a paucity of data on actual yield at harvest of teak from different site quality classes. The general conclusion arrived at from the available data is that the actual productivity has often been much lower than that indicated in the yield table. Expected yield in India is 4 to 6 m^3 per ha per year over the likely rotation length (Leech, 1998). Mean annual increment (MAI) obtained from government owned plantations ranged from 2 to 5 m^3 per ha and is often below the potential yield of the site (Enters, 2000). The actual yield obtained from thinnings and final fellings in Konni forest was reported to be 2.5 m^3 per ha per year at 70 years (Pandey and Brown, 2000). Estimates of MAI of teak at 60 years including yield from thinning for different forest divisions were worked out by Jayaraman and Chacko (1997) based on the data collected from standing crop. The MAI varied from 4.0 m^3 per ha in Kozhikode Forest Division to 2.2 m^3 per ha in Kothamangalam Division at 60 years. The State level MAI was 3.1 m^3 per ha. Chundamannil (1998) reported actual yield realized from teak plantations in Nilambur Forest Division during the period 1967 to 1994 based on the data available in the files of the Forest Department. The MAI ranged from 0.97 to 5.64 m^3 per ha with the overall mean of 2.85 m^3 per ha at 53 years.

4.5. MODELING THE FUTURE AVAILABILITY OF TEAK WOOD FROM FOREST PLANTATIONS

The mathematical formulation of the idea of projection is as follows.

a_i be the area of the i^{th} individual plantation in ha (i=1,2, ...N). c_i be the year of planting of the ith plantation. The projected availability of teak wood or projected total yield (P_{tr}) in a given projection year t is a sum of the quantum of yield that is obtained from thinning (T_{tr}) and felling (F_{tr}) for the given rotation age r and thinning year j =1,2, ... k.

$$P_{tr} = T_{tr} + F_{tr}$$

$$T_{tr} = \sum_{j=1}^{k} A_{tj} \times t_j$$

$$F_{tr} = A_{tr} \times y_r$$

where

$$A_{tj} = \sum_{i=1}^{N} a_i \quad \text{for all } i \text{ satisfying the condition } c_i + j = t$$

$$A_{tr} = \sum_{i=1}^{N} a_i \quad \text{for all } i \text{ satisfying the condition } c_i + r = t$$

t_j - thinning yield (m^3 per ha) for the given thinning year.

y_r- felling yield (m^3 per ha) for the given rotation age.

4.6. FORMULA USED FOR PROJECTING THE FUTURE DEMAND

$$D_t = D_0 (1 + r)^n$$

where

D_t = teak wood demand in the projection year t

D_0 = teak wood demand in the beginning year (base year)

n = number of years between base year and intended projection year t

r = compound growth rate for teak wood

4.7. OPTIONS AND ASSUMPTIONS INVOLVED IN PROJECTIONS

4.7.1. Options

In Kerala, the rotation age for teak generally ranges from 50 to 60 years due to varying growth attainment. Therefore, it was decided to make different projections according to three rotation periods 50, 55 and 60 years.

With regard to felling yield used for projection, the yield as per the All India Yield Table (FRI, 1970) against site quality III was used because majority of the teak plantations in Kerala were of site quality II or site quality III (Jayaraman and Chacko, 1997). We could think of two possible variations with respect to yield due to thinning. The thinning years considered were 4, 8, 12, 18, 28 and 40 years and the thinning years of 7, 10, 16, 24, 31 and 35 years as worked out by Jayaraman and Chacko (1997) based on the records of the Kerala Forest Department. The sum of the thinning yield and felling yield as per the All India Yield Table was termed as potential yield. The sum of the thinning yield as per Jayaraman and Chacko (1997) and felling yield as per the All India Yield Table was termed as estimated yield.

With respect to projection of future demand for teak wood we relied on the studies conducted by Krishnankutty (1997, 2005). According to these studies the total demand for teak wood was 64,000 m^3 in 1987-88 and 96,000 m^3 in 2000-2001 showing the annual compound growth rate of nearly 3.2 per cent over the period of 13 years. On this basis, the future trend in the demand for teak wood was projected by considering differential annual growth rate with the demand estimated in 2000-01 as base. The different annual growth rates considered were 2 per cent, 3 per cent and 4 per cent respectively.

4.7.2. Assumptions

One of the important assumptions made in the projection of future availability of teak wood is that plantations that are felled during the year will be replanted in the subsequent year. It was also assumed that the addition of new teak plantations during the projection period would be negligible. This assumption seemed plausible because there was no land available for extending teak plantations as indicated earlier.

4.8. RESULTS AND DISCUSSIONS

For the projection purpose, only teak plantations that come under the Territorial Divisions were considered. The teak plantations belonging to Wildlife Divisions were not considered

for projection because there were no routine management practices such as thinning or felling adopted in those plantations.

When the projected demand is compared with the projected figures of availability of teak wood it appears that the extent of teak plantations in Kerala at the existing level are potential enough to meet the future demand at least up to the period 2030-2040 even at the maximum assumed annual growth rate of 4 per cent demand (Fig. 4.4 – 4.6). However, the past trends in the annual production of teak wood from forest plantations have been far less when compared with the projected demand scenario (Fig. 4.7). For example, the production of teak wood from forests during the last five years was only about half of the demand. Therefore, activities in promoting the productivity of teak plantations and teak planting outside the forests such as home gardens and farmlands should be continued. This would help fill-up the gap between future demand and supply from forest plantations.

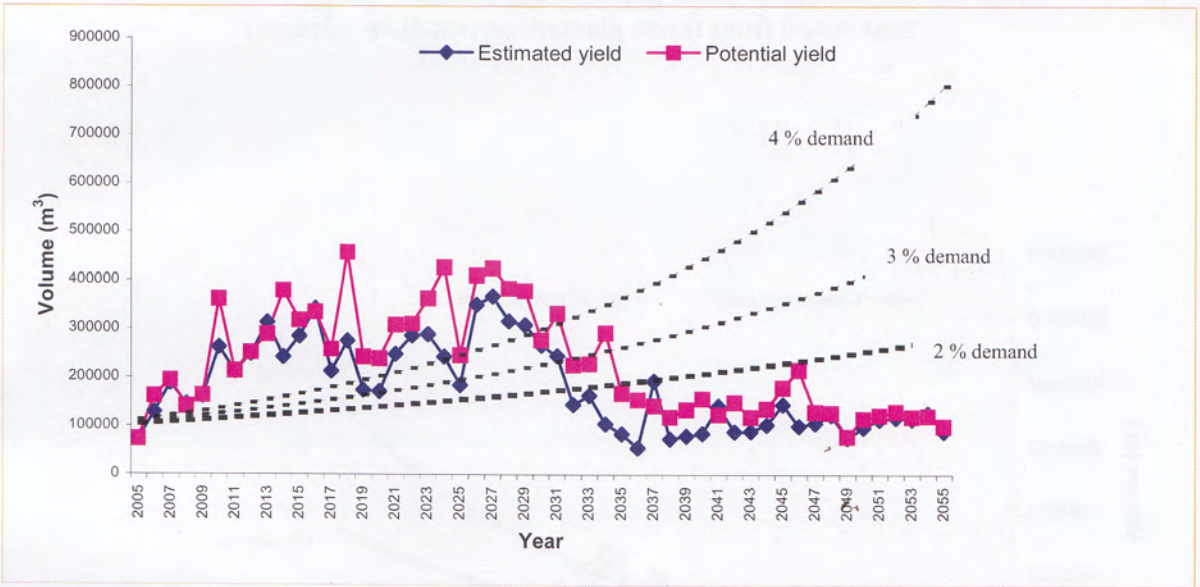


Fig. 4.4. Future trends in the gap between demand and availability of teak wood from forest plantations (rotation: 50 years)

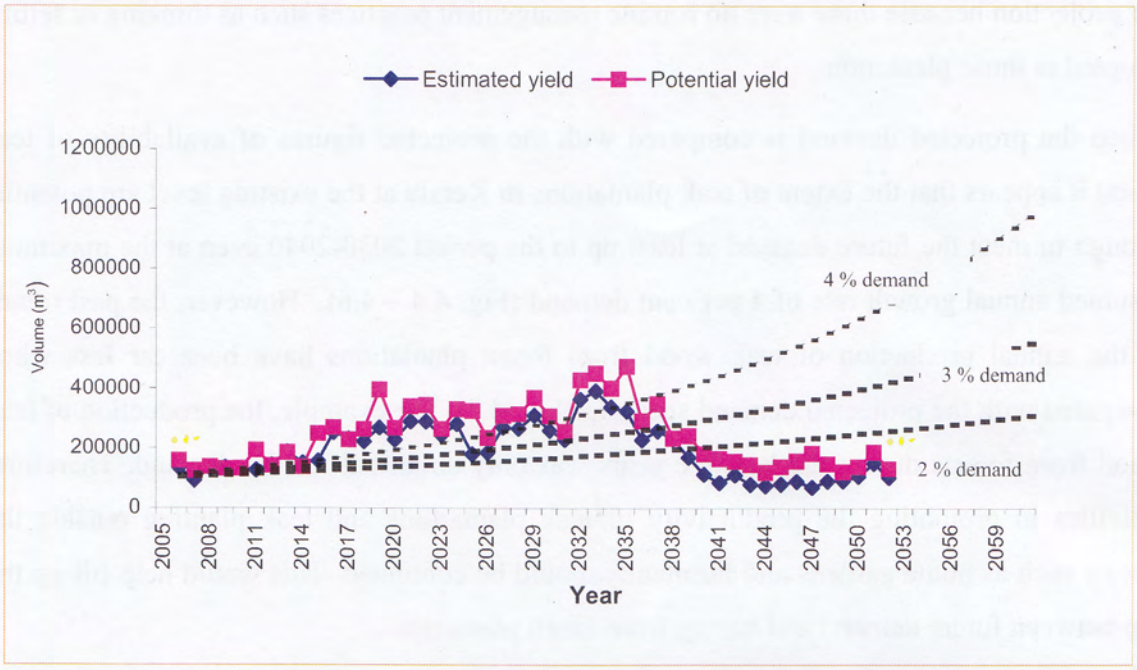


Fig. 4.5. Future trends in the gap between demand and availability of teak wood from forest plantations (rotation: 55years)

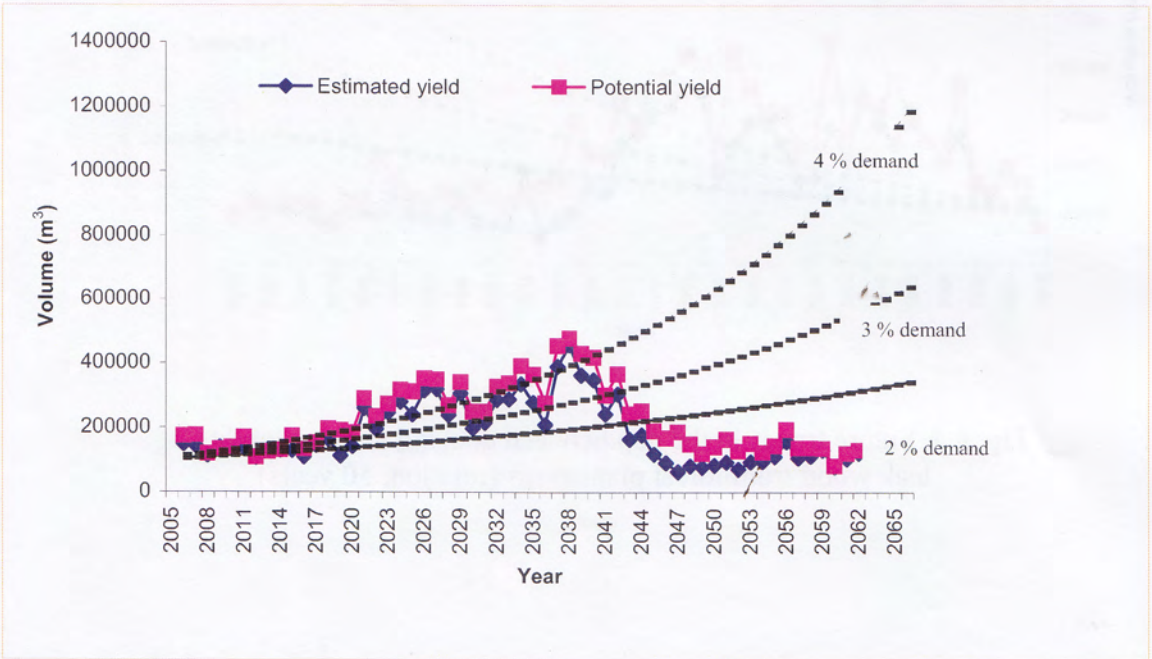


Fig. 4.6. Future trends in the gap between demand and availability of teak wood from forest plantations (rotation: 60years)

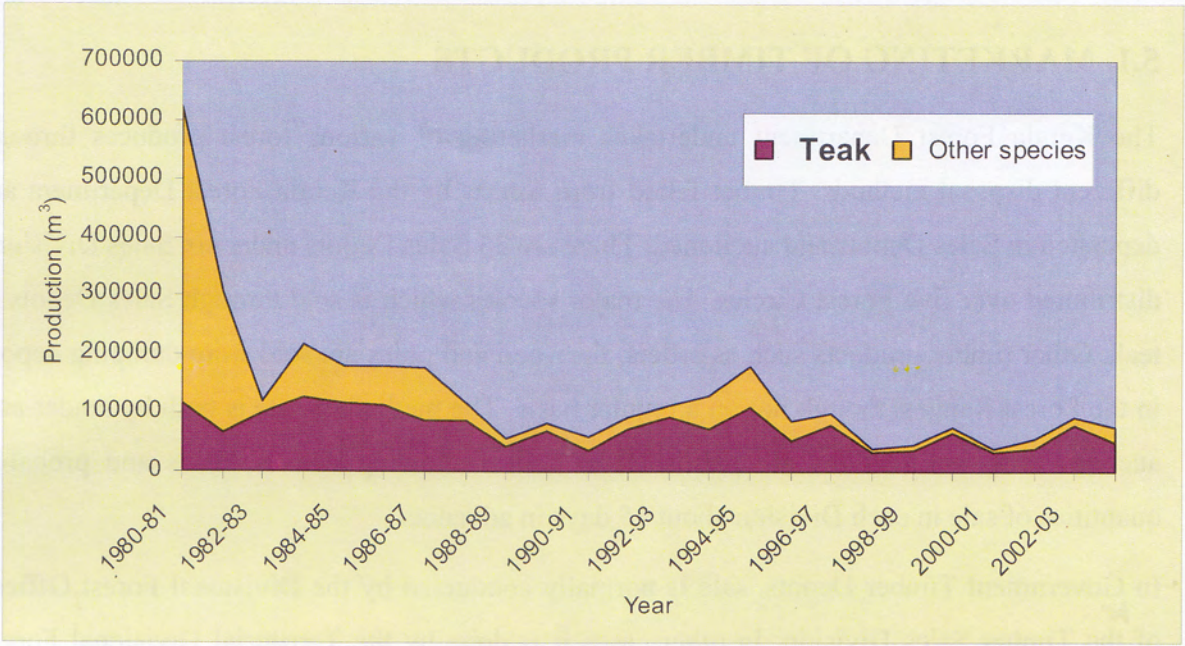


Fig. 4.7. Trends in the production of teak wood (round wood equivalent) and other species from the forests of Kerala. (1980 -2005)

5. ANALYSIS OF TIMBER PRICES

5.1. MARKETING OF TIMBER PRODUCTS

The Kerala Forest Department undertakes marketing of various forest produces through different disposal methods. Timber felled from forests by the Kerala Forest Department are deposited in Sales Depots and auctioned. There are 33 Sales Depots under six Sales Divisions distributed over five Forest Circles. The major species which is sold through Sales Depots is teak. Other timber products such as billets, firewood and poles are sold from dumping depots in the Forest Ranges, though not on a regular basis. The method of sale is both by tender and auction. Press-notifications are published in dailies showing venues, dates and probable quantities of sale in each Division about 15 days in advance.

In Government Timber Depots, sale is normally conducted by the Divisional Forest Officer of the Timber Sales Division. In other cases it is done by the Territorial Divisional Forest Officers concerned. Conservator of Forests of the Forest Circle having control over the Sales Divisions confirms the sale. Conservator of Forests himself conducts sale of Rosewood. Before announcing the auction, lots are formed comprising different girth classes according to the species. The prices quoted by the bidders are tabulated and sale is ratified in favour of the highest bidder.

Bonafide users for the purpose of house construction can directly purchase timber by paying fixed prices, up to a maximum quantity of 5 m^3. This facility is available with five Timber Depots.

5.2. PRICE ANALYSIS OF TEAK WOOD

Variation in prices of forest products is one of the main sources of uncertainty in forest planning. The prices of timber depend on its length, girth and quality. There were instances where teak fetched very high prices. In the year 2005, a teak log fetched a world-record high price at the rate of Rs.1.13 lakh per m^3 at the Central Depot, Aruvakkode, under the Timber Sales Division of Palakkad Circle. The TVS Group took 31 m^3 at a price of Rs.1,00,400 per m^3 for the reconstruction of Vadakkumnathan Temple, Thrissur. Earlier, Krishnankutty (1989,1998, 2001a, 2001b, 2002) made a significant contribution in the analysis of the past and future teak wood prices using spline and auto regressive integrated moving average (ARIMA) models. The details of the trend analysis of past prices and forecasting of future

prices of teak with the updated data and using latest forecasting techniques are presented in the following sections.

5.3. DATA ACQUISITION AND METHODS

5.3.1. Primary Data Source

The data on timber prices were obtained by extensive communications/visits to Timber Sales Divisions/Timber Depots of the Kerala Forest Department. The data collected so were compiled at Divisional level and at State level. The data relating to the period 1943-1994 was from Krishnankutty (1998) and data relating to 1994-1998 was from Krishnankutty *et al* (2003). Data for the period from 1998 to 2006 was collected and compiled during this project.

5.3.2. Trends in current and real prices of teak wood

Teak wood is classified into as many as 50 classes based on mid-girth, length and quality. In this study, for the purpose of analysis, 5 girth classes, *viz.*, Export class (185 cm and above) , Girth class I (150-184 cm), Girth class II (100-149 cm), Girth class III (75-99 cm) and Girth class IV (60-74 cm) were considered. The weighted average prices per m^3 were worked out using the following formula after duly accounting for the quantity of timber sold.

Weighted average price of the j^{th} girth class

$$WP_j = \frac{\sum_{i=1}^{n} q_{ij} p_{ij}}{\sum_{i=1}^{n} q_{ij}} \qquad (i = 1, 2, \ldots n)$$

where q_{ij} = quantity sold of the i^{th} lot belonging to the j^{th} girth class

p_{ij} = price of the i^{th} lot belonging to the j^{th} girth class

The changes in current prices may be due to inflation (general price increase) in the economy of the Country. Therefore, the average annual current prices were converted into average real prices by deflating of Wholesale Price Index (WPI) with the base year 1993-94. The formula used for deflating (Croxton *et al.*, 1973) is

$$\text{Real Price} = \frac{\text{Current Price}}{\text{Wholesale Price Index}}$$

The WPI values for the period 1956- 2006 are available with different base years (Office of the Economic Advisor, Ministry of Commerce and Industry). The latest WPI series is available for the period 1993-2006 with the base year 1993-94. Therefore, the WPI values for

the period 1956-1992 were recasted using the back shifting formula (Croxton *et al.*, 1973) with the base year 1993-94.

$$\text{Recasted WPI of the year} = \frac{\text{Old WPI of the year}}{\text{WPI of new base year}} \times 100$$

5.3.3. Modeling the prices of teak wood using spline model

Linear regression model is a general model for fitting any relationship between continuous dependent and independent variables. This includes the important class of polynomial regression models. Polynomials are used in situations where the response is curvilinear, because even complex nonlinear relationships can be adequately modeled by polynomials. But sometimes it is found that a low order polynomial provides a poor fit to the data, and increasing the order of the polynomial modestly does not substantially improve the situation. This problem occurs when the function behaves differently in different parts of the range of x (independent variable). The usual approach, however, is to divide the range of x into segments and fit an appropriate curve in each segment. Spline function offers a useful way to perform this type of piecewise polynomial fitting (Montgomery and Peck, 1982).

Splines are piecewise polynomials of order k. The boundary points of each segment are referred to as break points, interior knots or simply knots. Knots give the curve freedom to bend and more closely follow the data. Splines with few knots are generally smoother than splines with many knots, however, increasing the number of knots usually increase the fit of the spline function to the data.

A spline with h knots, $t_1 < t_2 < \ldots < t_h$, with continuous first $k-1$ derivatives, can be written as

$$E(y) = \sum_{j=0}^{k} \beta_{0j} x^j + \sum_{i=1}^{h} \beta_i (x - t_i)_+^k \qquad (1)$$

where

$$(x - t_i)_+ = \begin{cases} (x - t_i) & \text{if} \quad x > t_i \\ 0 & \text{if} \quad x \le t_i \end{cases}$$

This basic spline model can be easily modified to fit polynomials of different order in each segment, and to impose different continuity restrictions at the knots. If all $h+1$ polynomial pieces are of order k, then spline model with no continuity restriction is

$$E(y) = \sum_{j=0}^{k} \beta_{0j} x^j + \sum_{i=1}^{h} \sum_{j=0}^{k} \beta_{ij} (x - t_i)_+^j \qquad (2)$$

where $(x-t_i)_+^0 = 1$ if $x > t_i$ and 0 if $x \leq t_i$. Thus if the term $\beta_{ij}(x-t_i)_+^j$ is in the model, this forces a discontinuity at t_i in the j^{th} derivative of *E(y)*. If this term is absent, the j^{th} derivative of *E(y)* is continuous at t_i. The fewer continuity restrictions required, the better the fit because more parameters are in the model, while the more continuity restrictions require, worse the fit but smoother the final curve will be. The solution for the equations 1 and 2 can be found using the least square method.

5.3.4. Identification of best spline model

The price trends were analyzed by fitting different spline models. The knots for the model were identified by visual examination of trend graphs. The knots identified for export class are k_1=1977 and k_2=1989. The knots for girth class I, II and III are k_1=1967, k_2=1977 and k_3=1995. The knots for girth class IV are k_1=1977 and k_2=1998. Different spline models *viz.*, linear spline, linear spline with discontinuities at knots, quadratic spline, quadratic spline with discontinuities at knots on first and second derivatives and quadratic spline with discontinuities at knots were fitted. The least square method was used for estimating the parameters of the model. The PROC TRANSREG procedure in SAS was used to fit the models. The best model was selected based on Root Mean Square Error (RMSE), Adjusted R^2, Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) (Hair *et al.*, 2003).

Since the interpretation of quadratic spline is more complicated, linear spline with discontinuities is used to find the rate of changes of real prices of teak wood in different periods. The estimated linear spline model with discontinuity at the 2 knots k_1 and k_2 is given by

$$y = \beta_{00} + \beta_{01}x + \beta_{10}(x-k_1)_+^0 + \beta_{20}(x-k_2)_+^0 + \beta_{11}(x-k_1)_+^1 + \beta_{21}(x-k_2)_+$$

If $x \leq k_1$, the model is

$$y = \beta_{00} + \beta_{01}x$$

If $k_1 < x \leq k_2$,

$$y = \beta_{00} + \beta_{01}x + \beta_{10} + \beta_{11}(x-k_1)$$

$$= (\beta_{00} + \beta_{10} - \beta_{11}k_1) + (\beta_{01} + \beta_{11})x$$

and if $x > k_2$

$$y = \beta_{00} + \beta_{01}x + \beta_{10} + \beta_{20} + \beta_{11}(x - k_1) + \beta_{21}(x - k_2)$$
$$= (\beta_{00} + \beta_{10} + \beta_{20} - \beta_{11}k_1 - \beta_{21}k_2) + (\beta_{01} + \beta_{11} + \beta_{21})x$$

Thus the rate of change of real prices of teak wood with respect to the year x for the period $x \leq k_1$, $k_1 < x \leq k_2$ and $x > k_2$ are β_{01}, $\beta_{01} + \beta_{11}$ and $\beta_{01} + \beta_{11} + \beta_{21}$ respectively.

5.3.5. Forecasting of teak wood prices using ANN and ARIMA

A time series is a sequence of observations taken sequentially in time. The succession of values in a time series is usually influenced by some external factors. If the information on the influencing factors is not known, only the past values of the time series itself can be used to build a mathematical model for forecasting future values. In traditional statistical forecasting, several models emerged from time to time. The most popular forecasting model is Auto Regressive Integrated Moving Average (ARIMA) model due to Box and Jenkins (1994). These mathematical models, however, are linear and may fail to forecast the turning points because in many cases the data they model may be highly non-linear. Recently, there have been applications of artificial neural network (ANN) to time series forecasting problems in variety of fields ranging from forecasting of rainfall to stock market prices (Lin, 1995; Rech, 2002; Guhathakurta, 2006). This is because ANN is free from assumptions including linearity and robust to missing observations. In this section, an attempt has been made to compare the performance of ANN with ARIMA in forecasting prices of teak wood in different girth classes.

In this study, two different forecasting modeling approaches were used.

1. Artificial neural network (ANN) model, which is a non-traditional modeling technique.
2. ARIMA model which is a traditional statistical technique.

The elaborate details of the above two modeling approaches are given in Sivaram (2007).

5.4. RESULTS

5.4.1. Trends in current and real prices of teak wood

Tabe 5.1 provides the current prices of teak wood for the recent years. Among the five different spline models fitted for the real prices, linear spline with discontinuities at the two knots is the best model for export class and girth class IV. The quadratic spline with discontinuities at the three knots is the best model for girth classes I, II and III. The functional form of the chosen spline models for describing the real prices of teak wood in different girth

classes are given in table 5.2. The observed and predicted real prices are presented in Fig. 5.1. The rate of changes of real prices of teak worked out using linear spline model in different girth classes are given in Table 5.3.

Export class (1970-2006)

The trends in real prices of teak wood in export class based on linear spline model showed an increasing trend for the entire period. The rate of changes in different periods, $x \leq 1977$, $1977 < x \leq 1989$ and $x > 1989$ are given by 196, 562 and 243 respectively.

Girth class I, II and III (1956-2006)

With regard to girth class I, II and III, there was a decline in real prices during 1956-1967, then an increasing trend from 1968 to 1995 and then a decreasing trend in real prices during 1996-2006. All these three classes showed a rapid increase in prices for the period 1977-1995 and the rate of change is ranged from 467 to 943.

Girth class IV (1970-2006)

As in the case of export class, the real prices of girth class IV also showed an increasing trend for the period 1970 to 2006 and the rate of increase ranged from 56 in 1999-2006 to 328 in 1977-1998.

In general, there was no increase in real prices of teak wood since 1995; in fact there was a negative growth rate. However, of late, the prices of teak wood is picking up in the market. Most of the teak wood produced and sold in a year was in Girth Class II and Girth Class III and generated most of the revenue from teak wood. The trends in these classes indicated the impact of government polices and acts. The National Forest Conservation Act, 1980 banned clear felling from natural forests and therefore the reduced supply led to the price rise during 1980's. The accelerated positive growth in prices during the later part of 1980's and the first part of 1990's could be due to the Kerala Preservation of Trees Act, 1986 and the National Forest Policy, 1988 and stoppage of selection felling since 1987. The decline in real prices since the year 1995 could be due to globalization, increased wood import and availability of wood substitutes due to technology innovations. The increase in real prices of teak wood since 2005 could be due unprecedented growth in real estate sector.

Table 5.1 Current prices of teak wood in Kerala (1999 to 2006)

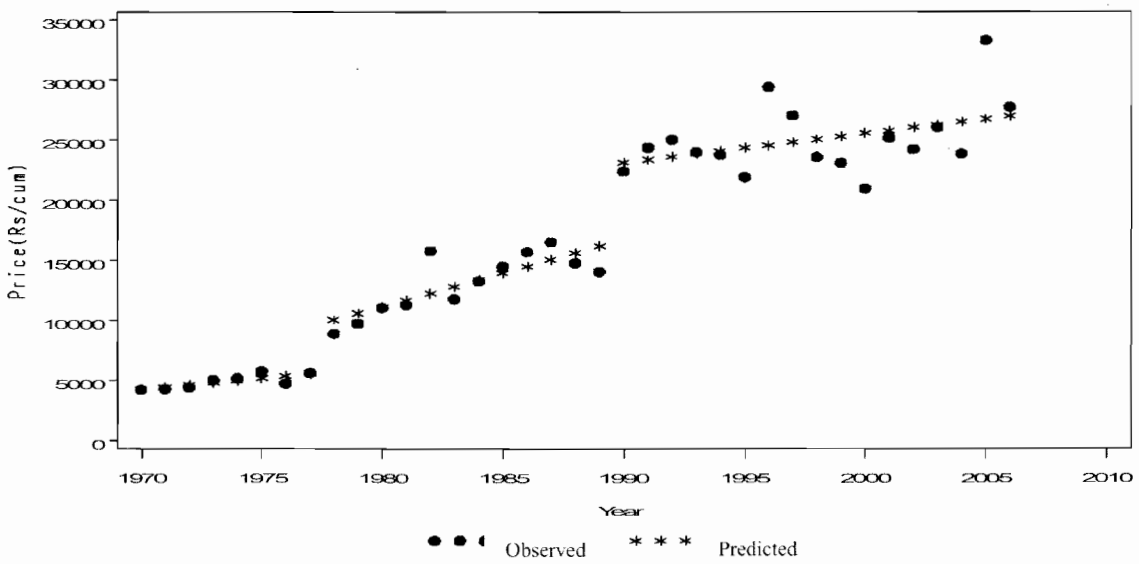
Unit: Rs./ m^3

Girth Class	1999	2000	2001	2002	2003	2004	2005	2006
Export	33602	32687	40680	40457	45896	44746	65263	57270
I	31185	33649	37643	38627	42349	42237	57533	48937
II	26220	27053	30270	30496	31261	30962	42636	44295
III	19732	21180	21735	22088	21598	21903	28998	33174
IV	15266	15972	15891	17129	15350	16480	19795	24638

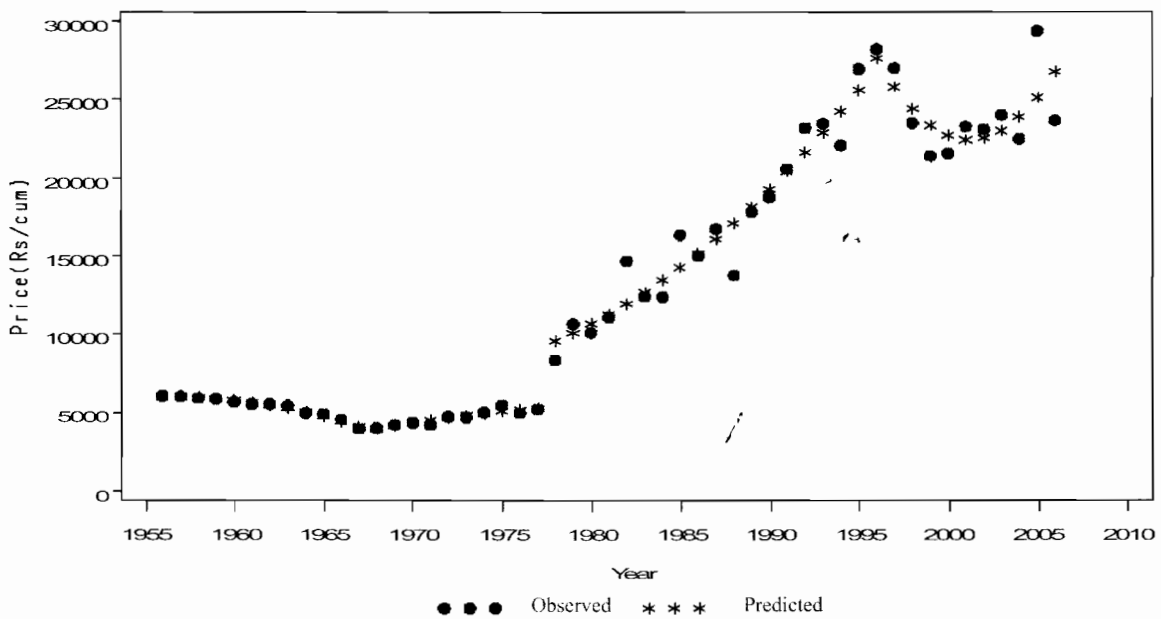
Table 5.2 The functional form of the chosen spline models for describing the real prices of teak wood in different girth classes for the period 1956 - 2006

Girth Class	Spline Model	Functional form
Export	Linear spline with discontinuity	$y = -381155 + 195.63x + 3903.48(x-1977)_-^0 + 6645.12(x-1989)_-^0 + 366.77(x-1977)_- - 319.29(x-1989)_-$
I	Linear spline with discontinuity	$y = 337281 - 169.19x - 544.42(x-1967)_+^0 + 2041.17(x-1977)_+^0 - 474.48(x-1995)_-^0 + 316.09(x-1967)_+ + 795.66(x-1977)_+ - 1026.75(x-1995)_-$
	Quadratic spline with discontinuity	$y = -62892247 + 64302x - 16.43x^2 - 368.15(x-1967)_-^0 + 3850.57(x-1977)_-^0 + 4157.39(x-1995)_-^0 + 559.38(x-1967)_- + 324.45(x-1977)_- - 3769.16(x-1995)_- + 10.75(x-1967)_-^2 - 33.18(x-1977)_-^2 + 162.09(x-1995)_-^2$
II	Linear spline with discontinuity	$y = 174115 - 86.51x - 915.09(x-1967)_+^0 + 2607.52(x-1977)_+^0 + 1333.84(x-1995)_-^0 + 243.72(x-1967)_+ + 560.12(x-1977)_+ - 991.69(x-1995)_+$
	Quadratic spline with discontinuity	$y = -61025858 + 62315x - 15.91x^2 - 750.14(x-1967)_+^0 + 2494.33(x-1977)_-^0 + 7238.31(x-1995)_-^0 + 482.02(x-1967)_- + 666.62(x-1977)_- - 3607.68(x-1995)_- + 10.15(x-1967)_-^2 + 2.88(x-1977)_-^2 + 224.95(x-1995)_-^2$
III	Linear spline with discontinuity	$y = 162666 - 81.23x - 423.11(x-1967)_-^0 + 2785.35(x-1977)_-^0 + 2649.81(x-1995)_-^0 + 210.28(x-1967)_- + 338.08(x-1977)_- - 921.53(x-1995)_-$
	Quadratic spline with discontinuity	$y = -18370964 + 18816x - 4.82x^2 - 454.24(x-1967)_+^0 + 958.11(x-1977)_+^0 + 9245.90(x-1995)_+^0 + 322.98(x-1967)_+ + 954.66(x-1977)_+ - 2832.74(x-1995)_+ - 0.61(x-1967)_+^2 - 24.45(x-1977)_+^2 + 231.48(x-1995)_+^2$
IV	Linear spline with discontinuity	$y = -378594 + 193.18x + 2019.01(x-1977)_-^0 - 2428.85(x-1998)_-^0 + 134.95(x-1977)_- - 272.18(x-1998)_-$

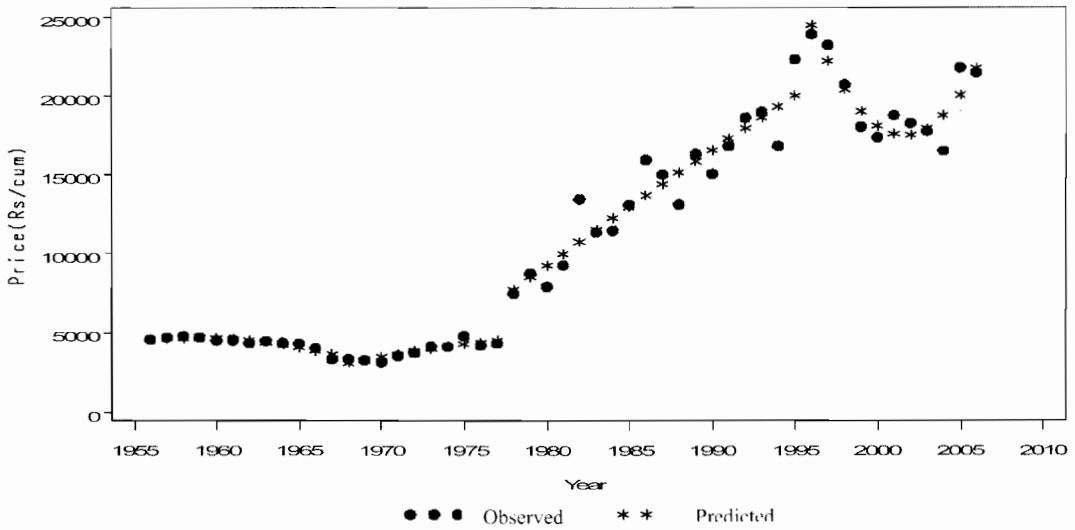
a) Export class (Linear spline with discontinuity)



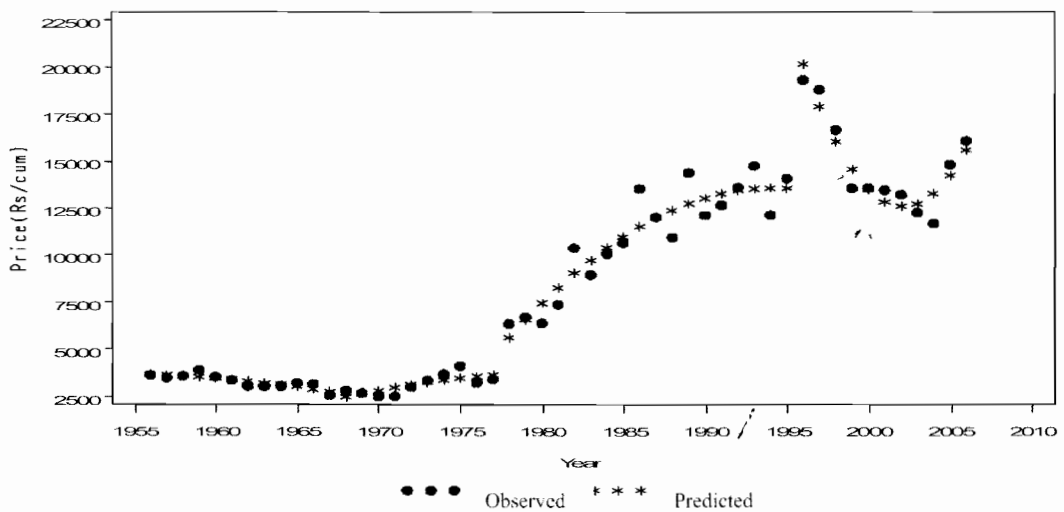
b) Girth class I (Quadratic spline with discontinuity)



c) Girth class II (Quadratic spline with discontinuity)



d) Girth class III (Quadratic spline with discontinuity)



e) Girth class IV (Linear spline with discontinuity)

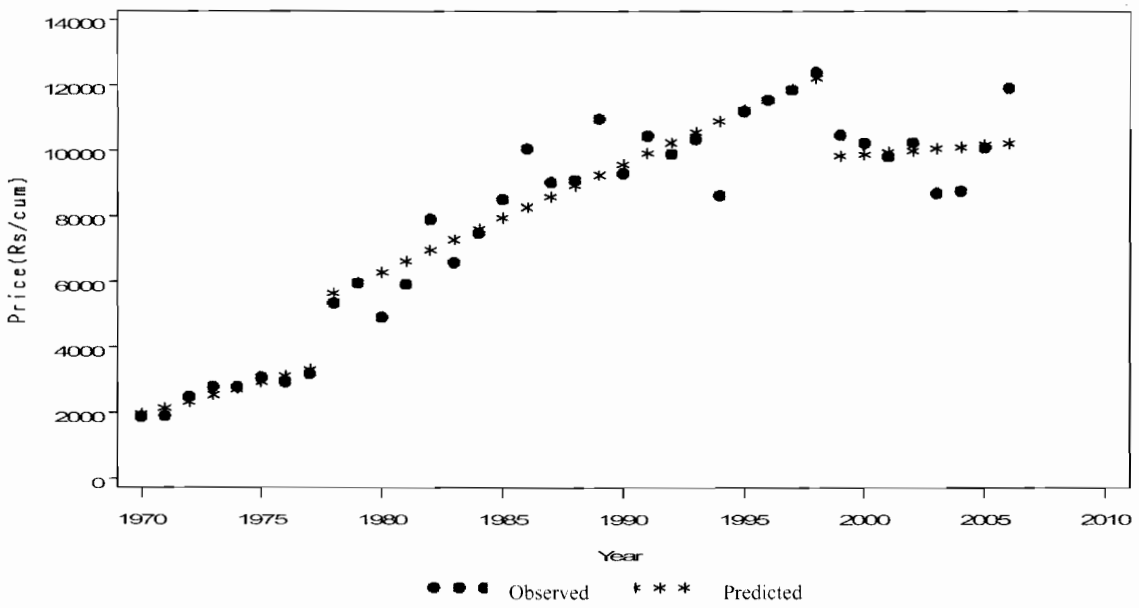


Fig 5.1 Predicted prices of teak wood using spline models for different girth classes
a) Export class b) Girth class I c) Girth class II d) Girth class III e) Girth class IV

Table 5.3 Rate of change of real prices of teak wood in different girth classes

Girth class	β_{01}	$\beta_{01}+\beta_{11}$	$\beta_{01}+\beta_{11}+\beta_{21}$	$\beta_{01}+\beta_{11}+\beta_{21}+\beta_{31}$
Export	$x \leq 1977$	$1977 < x \leq 1989$	$x > 1989$	
	196	562	243	
	$x \leq 1967$	$1967 < x \leq 1977$	$1977 < x \leq 1995$	$x > 1995$
I	-169	147	943	-84
II	-87	157	717	-274
III	-81	129	467	-454
IV	$x \leq 1977$	$1977 < x \leq 1998$	$x > 1998$	
	193	328	56	

5.4.2. Forecasting of teak wood prices

Among the ARIMA and ANN models, ARIMA model was chosen for forecasting because forecasting by ANN model was not sensible from the practical point of view despite ANN with log transformed prices showing lesser MAPE value than the ARIMA model. The exact forecasting of current prices for the year 2007 for five broad girth classes is given in Sivaram (2007). The forecasts indicated that the higher girth classes, *viz.*, Export class (185 cm and above), Girth class I (150-184 cm) would fetch high prices than the lower girth classes might be due to higher demand for quality teak wood (Table 5.4). This means that that the high quality teak wood would fetch high returns in the market. Therefore, efforts should be made to produce quality teak wood.

Table 5.4 Forecasted percentage increase in Teak wood prices using ARIMA model

Girth Class	Current Price (Rs/m^3) -2006	Forecasted Current Price (Rs/m^3) -2007	Percentage increase
Export	57,270 (1437)	69,830 (1753)	21.9
Girth Class I	48,937 (1228)	56,834 (1426)	16.1
Girth Class II	44,295 (1112)	46,231 (1160)	4.4
Girth Class III	33,174 (833)	34,783 (873)	4.9
Girth Class IV	24,638 (618)	25,949 (651)	5.3

US dollar equivalent is provided in parentheses (1 US $ = 39.845 INR)

5.5 PRICES OF OTHER TIMBER SPECIES

Tables 5.5 and 5.6 provide the current and real prices of selected timber species. Though there is an increasing trend in the current prices, the real prices remained more or less same except for mahogany. In general, there has not been much increase in the prices of timber. This indicates that the demand for timber has not been increasing, might be due to substitute materials available in the market.

Table 5.5 Current and real prices of selected timbers in Kerala (1999-00 to 2005-06)

Unit: Rs./ m^3

	Anjili		Irul		Maruthu		Chadachi	
Year	Current Prices	Real Prices	Current Prices	Real Prices	Current Prices	Real Prices	Current Prices	Real Prices
1999-00	4960	3414	5902	4062	5816	4003	5357	3687
2000-01	7215	4634	7404	4755	6493	4170	5014	3220
2001-02	12000	7440	8618	5343	6880	4265	6163	3821
2002-03	10766	6454	8632	5175	5900	3537	8201	4917
2003-04	12929	7350	8589	4883	5882	3344	9814	5579
2004-05	13396	7152	9585	5117	6967	3720	10038	5359
2005-06	13737	7023	10870	5557	8487	4339	11028	5638
	Thembavu		Venteak		Mahogany		Jack	
Year	Current Prices	Real Prices	Current Prices	Real Prices	Current Prices	Real Prices	Current Prices	Real Prices
1999-00	5807	3997	6012	4138	8508	5855		
2000-01	6148	3949	5810	3732				
2001-02	11370	7049	7454	4621	9251	5735		
2002-03	6741	4041	7433	4456	7207	4321		
2003-04	6865	3903	7688	4371	10304	5858	6721	3821
2004-05	9457	5049	8474	4524	15287	8162	5362	2863
2005-06	8655	4425	9823	5022	16495	8433	9356	4783

Table 5.6 Current and real prices of rosewood in Kerala (1999-00 to 2005-06)

Unit: Rs./ m^3

	Rosewood Exp		Rosewood I		Rosewood II		Rosewood III		Rosewood IV	
Year	Current Prices	Real Prices	Current Prices	Real Prices	Current Prices	Real Prices	Current Prices	Real Prices	Current Prices	Real Prices
1999-00			92638	63756	55044	37883	35359	24335	21081	14509
2000-01			123286	79182	26692	17143	34880	22402	14762	9481
2001-02			94662	58687	50051	31030	30672	19015	18505	11472
2002-03	240000	143885			48637	29159	19191	11505	12838	7697
2003-04	165500	94088	70867	40288	44811	25475	24230	13775	17048	9692
2004-05	67500	36038	63328	33811	38141	20364	30370	16215	15846	8460
2005-06			110286	56383	67866	34696	39256	20070	21228	10853

6. GENERAL OBSERVATIONS

A forestry statistical database at the State level is very important to know the trends in forestry sector in the State. This will in turn contribute to the development of national level database. Though the necessary action at the national level is happening, unless State Forest Departments are strengthened in creating and developing its own forest management information system and the database, the data will not flow for national level compilation.

There are certain problematic areas in the collection of forestry statistics which need to be addressed through policy decisions and managerial interventions. There are quite a lot of estimates which are underestimated with respect to fire occurrences and area affected and extent of grazing and unauthorized collection of non-wood forest products. These are often not fully covered and reported by the field personnel or are mostly incomplete.

There are also details which are not recorded at the ground level though they can be made available. For example, exact details of site quality, timber extracted through thinning and felling are not properly recorded in Plantation Journals.

The non-reporting and underreporting severely affects the interpretation of recorded figures and its further use. For example, in GDP estimation, the value of the unrecorded production of NWFPs is considered as 10 times the value recorded by the State Forest Departments (Kolli and Rajeswari, 2008).

The required data need to be made available to evaluate the programme implementation such as afforestation/reforestation/social forestry, etc. There is no data available in the public domain on survival status of the plants/ success rate of the new plantations raised.

There are also areas (*e.g.* wood industries, export and import of forest products) which do not directly come under the jurisdiction of the State Forest Department but data are required for planning purpose. This calls for the linkage between the departments to improve the existing official statistics.

Collection of data from different sources by any single individual/group of individuals from various departments is a herculean task. The research institutes should essentially be involved in the methodology development and productive analysis of data and draw conclusions for policy development. These institutes should also be encouraged to takeup subsidiary studies which would complement the official forestry statistics.

The other general issues often cited and also highlighted in an earlier report (Sivaram, 2004) include the following

- Lack of coordination between the agencies
- Non-availability of sufficient, usable and timely information
- Inadequate usage of forestry statistics
- Capacity building and
- Lack of feedback system

However, the immediate need is that the Ministry of Environment and Forests and State Forest Departments need to resolve the procedural difficulties and take necessary actions to promote genuine reporting of forestry data so as to improve its quality. Simultaneously, government should encourage development/strengthening of forest management information system and forestry database and data mining activities so that data become useful information for forest managers and policy makers.

REFERENCES

Box, G.E.P. and Genkins, G.M. (1994). *Time Series Analysis Forecasting and Control.* Pearson Education Inc. India. 574p.

Chundamannil, M. (1993). *History of Forest Management in Kerala.* Kerala Forest Research Institute, Peechi. 114p.

Chundamannil, M. (1998). *Teak Plantations in Nilambur – An Economic Review.* KFRI Research Report No. 144. KFRI, Peechi. 71p.

Chundamannil, M. (2001). *Economics of Forest Plantations in Kerala.* KFRI Research Report No. 210. KFRI, Peechi.

Croxton, F.E., Cowden, D.J. and Klein, S. (1973). *Applied General Statistics.* Prentice-Hall of India Private Limited, New Delhi. 754p.

Enters, P. (2000). Site technology and productivity of teak plantations in Southeast Asia. *Unasylva.* 51: 55-61.

FRI (1970). *Growth and Yield Statistics of Common Indian Timber Species* Vol.II. Forest Research Institute, DehraDun.

Guhathakurta, P. (2006). Long-range monsoon rainfall prediction of 2005 for the districts and sub-division Kerala with artificial neural network. *Current Science* 90(6): 773-779.

Hair, J.F., Anderson, R.E., Talham, R.L. and Black, W.C. (2003). *Multivariate Data Analysis.* Pearson Education Inc., Singapore. 730p.

Jayaraman, K. and Krishnankutty, C.N. (1990). *A Databank for Forestry Sector in Kerala.* Research Report No. 66. KFRI, Peechi. 27p.

Jayaraman, K. and Chacko, K.C. (1997). *Productivity of teak and eucalypt plantations in Kerala.* KFRI Consultancy Report, KFRI, Peechi.

Kolli, R and Rajeswari, T. (2008). Forestry Sector in GDP estimates. Lecture Notes for the Training Workshop on Collection, Compilation, Validation and Dissemination of Forestry Statistics, 21-25 April 2008. Kerala Forest Research Institute, Peechi.

Krishnankutty, C.N. (1989). Long term price trend of timber in Kerala. *Indian Journal of Forestry* 12(1): 7-22.

Krishnankutty, C.N. (1990). *Demand and supply of wood in Kerala and their future trends.* KFRI Research Report No. 67. Kerala Forest Research Institute, Peechi. 66p.

Krishnankutty, C.N. (1998). *Timber price trends in Kerala.* KFRI Research Report No. 160. Kerala Forest Research Institute, Peechi. 51p

Krishnankutty, C.N. (2001a). Teak price trends in Kerala State, India. *Indian Journal of Forestry* 24(1): 1-7.

Krishnankutty, C.N. (2001b). Forecasting of teak prices in Kerala State, India, using autoregressive integrated moving average models. *Indian Journal of Forestry* 24(2):119-122.

Krishnankutty, C.N. (2002). Factors influencing teak prices in Kerala. *Indian Journal of Forestry* 25(1): 25-29.

Krishnankutty, C.N., Chundamannil, M. and Sivaram M. 2003. Teak wood price projections for Kerala State. International Conference on Quality Timber Products of Teak from Sustainable Forest Mangement. 2-5 December 2003. KFRI, Peechi.

Krishnankutty, C.N., Thampi, B. and Chundamannil, M. 2005. *Wood Balance Study in Kerala and Market Survey*. KFRI Research Report No. 268. KFRI, Peechi. 54p.

KSCSTE (2005). *State of Environment Report Kerala 2005*. Kerala State Council for Science ,Technology and Environment, Thiruvananthapuram. 349p.

Leech, J.W. (1998). *Indicative estimates of hardwood volumes for the project "Hardwood Plantations in the Tropics and Subtropics"*. Report to the FAO Project GCP/INT/628/UK. Food and Agriculture Organization of the United Nations, Rome, Italy.

Lin, F., Yu, X.H., Gregor, S. and Iron, R. (1995).Time series forecasting with Neural Networks. *Complexity International Vol* 2.

Montgomery, C.C. and Peck, E.A. (1982). *Introduction to Linear Regression Analysis*. John Wiley and Sons, New York.

Office of the Economic Adviser to the Government of India, Ministry of Commerce and Industry. http: eaindustry.nic.in

Pandey, D. and Brown, C. (2000). Teak: a global overview. *Unasylva* 51 (201): 3-13.

Rao, D.S., Singh, M. and Shivaraju, B. (1997). Teak management in Kerala. In Chand Basha, S., Mohanan, C. and Sankar, S. (eds.). *Teak* – Proceedings of the International Teak Symposium, Thiruvananthapuram, Kerala, India, 2-4 December, 1991.

Rech, G. (2002). Forecasting with neural network models. *SSE/EFI Working paper series in Economics and Finance*. Department of Economics and Statistics, Stockholm School of Economics, Stockholm, Sweden.

Sasidharan, M., Sivaram, M. and Muraleedharan, P.K. (2008). Quantitative inventory of non-wood forest products in northern Kerala. KFRI Research Report No. 306. Kerala Forest Research Institute, Peechi. 435p.

Sivaram, M. (2004). *A Database on Forest Resources of Kerala*. KFRI Research Report No. 255. Kerala Forest Research Institute, Peechi. 66p.